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Nataša Manojlović

Improving Dwellers Participation in the Development of Flood Resilient Cities

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Improving Dwellers Participation in the Development of Flood Resilient Cities

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Vorwort

Liebe Leserinnen und Leser,

Wirtschaftlich, politisch und strategisch günstige Lagen an Flüssen und Meeren sind seit Jahrhunderten bevorzugte Siedlungsgebiete von Menschen. Weltweit leben derzeit rd. 3 Milliarden Menschen in der Nähe von Küsten. Von diesen 3 Milliarden Menschen leben mehr als 1 Milliarde in tief liegenden und potentiell überflutungsgefährdeten küstennahen Gebieten. Schwerpunkte sind in den Mega-Cities in Asien, aber auch in Australien, Europa und Amerika finden sich weite tiefliegende Küstengebiete. Zu diesen küstennah in überflutungsgefährdeten Gebieten lebenden Menschen kommen unzählige weitere, die in überflutungsgefährdeten Gebieten nahe größerer und kleinerer Flüsse leben.

Seit der Besiedlung von überflutungsgefährdeten Bereichen an Flüssen und Meeren nehmen die Hochwasser- und überflutungsbedingten Schäden weltweit teilweise dramatisch zu. Nach den Zahlen von Munich Re[1] dominierten beispielsweise in 2013 extrem hohe Überflutungsschäden aus Extremwettersituationen in Europa zum einen sowie hohe Schäden als Folge des Supertyphoons Haiyan mit mehr als 6000 Toten in Indonesien zum anderen die aus Naturkatastrophen resultierenden Schäden weltweit. Daneben gab es ebenfalls nach Angaben von Munich Re[1] im selben einige Sturmflutereignisse, die demonstriert haben, wie positiv rechtzeitige Warnungen und Schutz- sowie Schadensminimierungsmaßnahmen die Auswirkungen von Sturmfluten beeinflussen können. Hierbei haben sich insbesondere die nach den Sturmflutkatastrophen in 1962 sowie teilweise in 1976 deutlich angepassten Hochwasserschutzanlagen bewährt.

Im Zusammenhang mit der Bewertung erforderlicher Sicherheiten spielt die Betrachtung des Risikos als Produkt von Eintrittswahrscheinlichkeit eines Ereignisses mit den monetär oder nicht-monetär bewertbaren Konsequenzen sowie zudem auch die Möglichkeiten dieses Risiko im Sinne von Risiko-Minimierung oder der Verbesserung der Resilienz[2] von überflutungsgefährdeten Systemen zu beeinflussen eine wesentliche Rolle. Spätestens mit der Entwicklung und Umsetzung der EU-Hochwasserrisikomanagement-Richtlinie in nationale Gesetzgebungen hat hier ein Umdenken bei der Bewertung von Hochwassern und Überflutungen weg von einem traditionellen Schutzansatz hin zu einer mehr umfassenden Betrachtung von hochwassergefährdeten Systemen eingesetzt. Zudem sind demnach Formen der möglichst breiten und frühzeitigen Einbindung von (relevanten) Stakeholdern in die Entscheidungsfindungsprozesse mit dem Ziel resiliente Systeme zu entwickeln, die Akzeptanz bei der Umsetzung der erforderlichen Anlagen zu erhöhen sowie das zulässige verbleibende Risiko in überflutungsgefährdeten Gebieten festzulegen.

In diesem Zusammenhang hat Frau Dr. Manojlovic in ihrer Dissertation „Improving Dweller Participation in the Development of Flood Resilient Cities” einen wesentlichen und

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[1] http://www.munichre.com/en/media-relations/publications/press-releases/2014/2014-01-07-press-release/index.html

[2] Fähigkeit von Systemen bei einem Teilausfall nicht vollständig zu versagen.

umfassenden Beitrag zum verbesserten Verständnis der Funktion und der Bewertung (hochwasser-)resilienter Systeme (Städte) auf der Grundlage einer von ihr entwickelten holistischen Methodik und unter Einbeziehung der diversen Stakeholdergruppen geliefert. Daneben hat sie Wege zur praktischen Umsetzung ihrer Methode detailliert aufgezeigt und diese anhand von case studies aus Deutschland, der Schweiz und dem Vereinigten Königreich ansprechend verifiziert. Viele Ergebnisse ihrer Arbeiten wurden im Rahmen von nationalen und internationalen Projekten (insbesondere KLIMZUG-Nord, SMARTEST und SAWA) in Kooperation mit den jeweiligen Partnern erarbeitet. Bei der praktischen Anwendung der Methodik zeigt Frau Dr. Manojlovic eindrucksvoll, dass sie sowohl die technischen aber auch die didaktischen und eher sozialwissenschaftlichen Methoden nicht nur theoretisch tief durchdrungen hat sondern auch praktisch in einem Team umsetzen kann.

Es freut mich persönlich ganz besonders, dass Frau Dr. Manojlovic ihre vielfältigen Untersuchungen und Ergebnisse zu den Themen Resilienz, Risiko, Risikomanangement, und Stakeholder-Beteiligung in ihrer Dissertation umfassend dargestellt hat und die Arbeit an ihrer Dissertation zu einem sehr guten Abschluss gebracht hat. Diese Arbeit fasst die wesentlichen Grundlagen zu den angesprochenen und bereits oben erwähnten Schwerpunkten eindrucksvoll zusammen.

Abschließend ist es mir ein Anliegen, darauf zu verweisen, dass ich die Arbeit von Frau Manojlovic nach meinem Wechsel an das Institut für Wasserbau der TUHH in 2012 mit sehr viel Freude verfolgt und betreut habe, diese jedoch insbesondere auch das Ergebnis der langjährigen Zusammenarbeit von Frau Dr. Manojlovic mit meinem Vorgänger Prof. Pasche ist. Vieles trägt seine Handschrift und ich bin sicher, dass Prof. Pasche sehr glücklich über diesen umfassenden Beitrag gewesen wäre.

Peter Fröhle
Leiter des Instituts für Wasserbau

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I wish to thank the many people who in one way or another have contributed towards the completion of this thesis.

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I would like to express my very special gratitude to Prof. Dr. -Ing. Peter Fröhle, who gave me the final impetus and encouragement to finalise this work, by guiding me and acting as a trusted mentor in the last phase of the Thesis.
My gratitude goes to the dissertation committee- Prof. Dr-Ing. Peter Fröhle, Prof. Dr. Chris Zevenbergen, UNESCO-IHE and Prof. Dr.-Ing. Frank Schmidt-Döhl, TUHH for accepting this role and for their valuable support throughout the promotion process.
I extend my thanks to Dr.- Ing. Karl-Friedrich Daemrich and Prof. Dr.-Ing. Günter Rombach from TUHH for their encouragement and support during the rough times of this work.

I owe my deep gratitude to Prof. Richard Ashely from UNESCO-IHE and University of Sheffield who voluntarily accepted to support and guide me, generously sharing his knowledge and experience, whenever it was needed.

This journey would have been inconceivable without my colleagues from the Institute of River& Coastal Engineering at TUHH led by Prof. Dr.- Ing. Peter Fröhle and formerly lead by Prof. Dr.- Ing. Erik† Pasche. The tremendous continued professional and personal support I received over the years, especially from Dejan, Ilya, Vincent, Giovanni as well as from the technicians Jens, Katrin and Michael, contributed to the quality of this Thesis and kept me *resilient* during the tough times.
My gratitude also goes to my students David, Fenia, Frederic, James, Joana, Ulrich, Roberto and Saskia who I supervised during my PhD journey and who helped me in one way or another at different stages of this work. Further, I wish to thank my former colleagues Niloufar, Timm, Nataliya and Dagmar, for their unselfish support. Many thanks to Dr.- Ing. Peter Owotoki and the Institute of Embedded Systems atTUHH for the collaboration and evidence that transdisciplinary research can succeed and although challenging, can also be a great fun. I am thankful to the artist Mentor Ejupi for his unselfish committment and being a part of our experiment to combine engineering and arts, while desiging the flood animation studio.

I am heartily thankful to Prof. Dr. Chris Zevenbergen for being my supervisor and a trusted mentor, but also to his team from the Flood Resilience Group at UNESCO-IHE for accepting me as a member of their group and involving me in the inspiring and refreshing discussions, starting from our COST 22 times and throughout the preparation of this Thesis. Their professional but also personal support meant a lot to me all these years.

I am also very grateful to Dr Zoran Vojinovic from UNESCO-IHE for the inspiration, energy, discussions, advices, as well as for the editorial and technical support during the preparation of this Thesis.

This research heavily benefited from the financial support and the exchanges and discussions conducted in a number of EU projects and initiatives being COST C22, FP7 Projects SMARTeST, CORFU and PEARL, INTERREG IVb Project SAWA, CRUE Era Net Project SUCAs and the BMBF funded project KLIMZUG-Nord. The open research atmosphere created during the projects' lifetimes encouraged me to find my own path in the *forest* of the flood risk management research. Some parts of this Thesis have been published within the corresponding project reports.

I highly acknowledge the financial support provided by the German Federal Ministry of Education and Research (BMBF- IPSWaT) for awarding me a three-year doctoral scholarship.

This research could be grounded in reality thanks to a great support from the partners and stakeholders in the study areas in Germany (Hamburg and Lauenburg), the UK (Heywood) and Switzerland (Nidwalden).

I am blessed to have such friends, who were there with me and for me during all those years.

Finally, I have the opportunity to immortalise my deepest gratitude to my family in Germany and Serbia, especially to my daughter Mila who gave me the final and decisive kick to finalise this Thesis to welcome her as a 'PhD Mommy' in this world.

Thank you, Danke, Hvala!

Nataša Manojlović
Hamburg, March 2016

Abstract

Improving Dwellers Participation in the Development of Flood Resilient Cities

Following the requirements of the (urban) flood risk management-FRM (e.g. 2007/60/EC), the dwellers should become involved in the development of flood resilient cities, however they are in general case not empowered for this task. This calls for the development of methods and tools to improve their engagement. Within this work the methods and tools have been developed that address the decision making process on the resilient built environment and empower the dwellers to actively take their role in FRM and protect their homes. The obtained results indicate a strong need to analyse the dwellers and the built environment as the constitutive elements of a multiscale urban system and aim at the combined application the decision making and the capacity building methods.

Bezugnehmend auf die Anforderungen des Hochwasserrisikomanagements-HWRM (z.B. 2007/60/EC), sollten die Anwohner eine aktive Rolle übernehmen. Allerdings sind im Regelfall weder die Bereitschaft noch das Wissen vorhanden um diese Aufgabe zu leisten. Im Rahmen dieser Arbeit wurden die Methoden und Werkzeuge entwickelt und getestet, die einen Beitrag zum Kapazitätsaufbau von Anwohnern leisten und allgemein die Resilienz von Städten fördern. Die Ergebnisse deuten daraufhin, dass die Anwohner und die Bebauung als Bestandteile des multiskaligen urbanen Systems betrachtet werden sollten. Die Methoden zur Entscheidungsunterstützung und zum Kapazitätsaufbau von Anwohnern sollten holistisch entwickelt und umgesetzt werden.

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Abbreviations and Symbols

Abbreviations

2007/60/EC	Directive of the European Parliament and of the Council on the assessment and management of floods
4 As	Alleviation, Avoidance, Awareness and Assistance
AdaBoost	Adaptive Boosting
AHP	Analytic Hierarchy Process
AJAX	Asynchronous JavaScript and XML
ANN	Artificial neural networks
a.r.i	Average recurrence interval
CA	Classification accuracy
CAS	Complex Adaptive System
CBA	Cost Benefit Analysis
CI	Computational Intelligence
csv	Certified Server Validation
CV	Cross-Validation
DBMS	Database Management System
DM	Decision Making
DT	Decision tree
EC FD	EC Flood Directive 2007/60
ES	Expert system
FAC	Flood Animation Centre
FLORETO	Flood Resilience Tool
FPRM	Flood Probability Reduction Measures
FRC	Flood Resilient City
FReM	Flood Resilience Measures
FRM	Flood Risk Management
FRMP	Flood Risk Management Plan
GUI	Graphical User Interface
GIS	Geographic Information System
GW	Groundwater
ILGs	Interactive Learning Groups
IFM	Integrated Flood Management
ILP	Interactive Learning Program
KB	Knowledge Base
KD(D)	Knowledge Discovery
L(A)A	Learning (and Action) Alliance
LCA	Life Cycle Assessment

LMT	Logistic Model Tree
MCA	Multi Criteria Analysis
MLP	Multilayer Perceptron with Back Propagation Learning
NGE	Nested Generalised Exemplars
NNGE	Non-Nested Generalised Exemplars
NSM	Non Structural Measures
PART	Partial Decision Tree
RBE	Resilient Built Environment
RDBMS	Relational Database Management System
SH	Stakeholder
S-P-R-C	Source-Pathway-Receptor-Consequence
T	Tutorial
UFM	Urban Flood Management
VT	Virtual Trainer
WEKA	Waikato Environment for Knowledge Analysis

Symbols

A	cross section [m^2]
B	Benefit- difference between case without and with adaptation option
BCF	Benefit-cost factor
$BLL(F)$	Binomial Log-Likelihood / Linear Log Exponential loss Function
C_{oil}	oil content in the flood water
c_m	constants to be determined
D_{EH}	Euclidean distance variant of the Euclidean distance for classifying new instances(examples)
$D_{[i]}$	damage for flood event i[€]
$D(x)$	flood damage caused by flood depth x
$D_{without}$	case without adaptation option
D_{with}	case with adaptation option
E_i	i^{th} feature value on the example
EAD	Expected annual damage [€/a]
$ELF(F)$	Exponential Loss Function
f_m	basis (weak) functions
$F(x)$	additive function
H_i	i^{th} feature value on the exemplar
h	height of flood water/ flood depth [m]
h_{krit}	flood depth at which the inventory item can not perform its original function [m]
J	number of classes
$\text{KFAKR}\ (p,n)$	Annuity factor
M	mapping function ----Classification model (matching function)
$M_{optimal}$,	The function depicting the most optimal flood resilient system out of the pool of the systems delivered by the CI algorithm
n	discounting period [a]
$P(x)$	probability vector
p	interest rate [%]
$P(x)$	probability of flood level x
ΔP_i	probability of flood level x [-]

S_A	Overall ranking of option A
S	susceptibility of the inventory item
x	Attribute set (parameters)
y	Class labels (measures)
$x = (x_1, x_2 \ldots x_n)$	class of attributes set
X	input parameters
X^{∞}	complete set of all possible design criteria
$\lvert X \rvert$	Cardinality - the number of attributes of the input parameters
Y	categorical enumeration of all possible measures----Class labels (measures)
v	flood velocity [m/s]
V	volume [m3]
W_H	Exemplar weights
w_i	Feature weights

1 Introduction

1.1 Motivation

Recently the world has witnessed a growing severity of floods, posing a risk to health and well-being and causing considerable damage to properties and personal belongings (e.g. Europe 2002, 2006, 2013, New York, 2012, Australia and Asia, 2011). The available records since the 1980s indicate a rise in the number of reported flood disaster events and in the last decade this increase has been even more significant (Figure 1-1) (Munich Re, 2013).

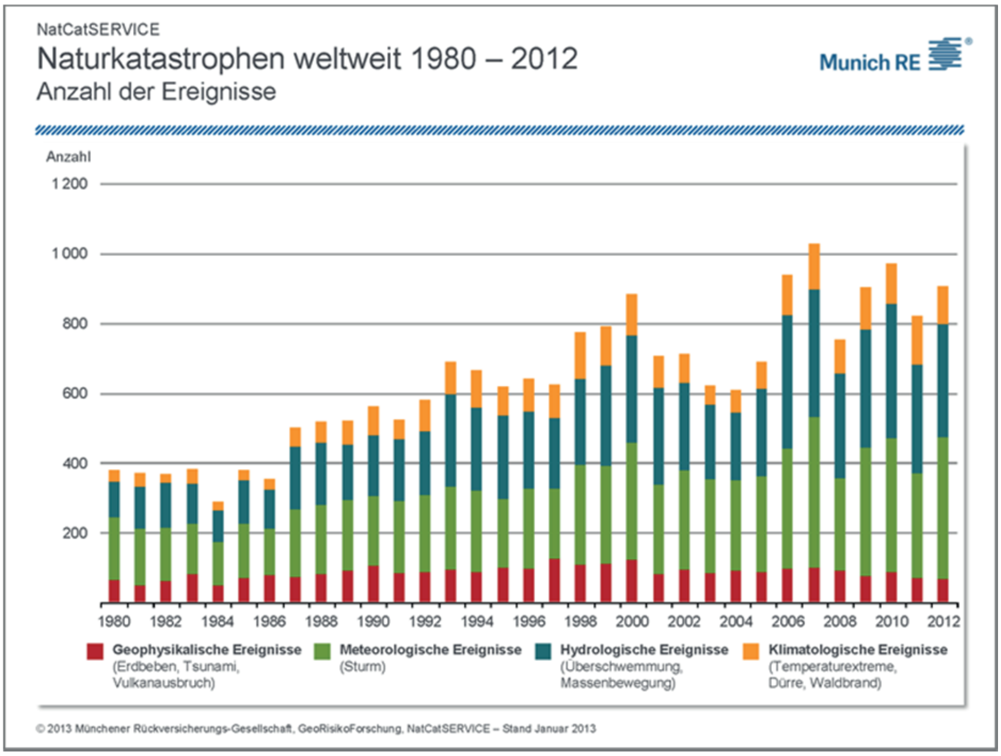

Figure 1-1 Number of flood disasters worldwide in the period 1980-2012 (red-geophysical events, green- meteorological events, blue-hydrologic events, orange-climatologic events, Munich Re, 2013)

In Europe, [an increase in the reported flood events from 31 in the period of 1973 – 1982 to 179 during the period of 1992-2002 has been observed, resulting in a total of 264 flood related disasters during the period 1973-2002] (EM-DAT[3]).

Not only have number of flood events increased in the most recent period, but the losses due to floods that contribute to the overall losses from natural disasters are also likely to increase. According to the International Disaster Database (EM-DAT[3]) [people reported to have been affected by flooding within the period from 1974-2003 worldwide has contributed to the overall numbers of victims of natural disasters, comprising some 51% of the total] (Figure 1-2 a). In Europe, an increase in flood losses (both insured and uninsured) can be observed in the period from 1950-2005 (Munich Re, 2007, Figure 1-2 b).

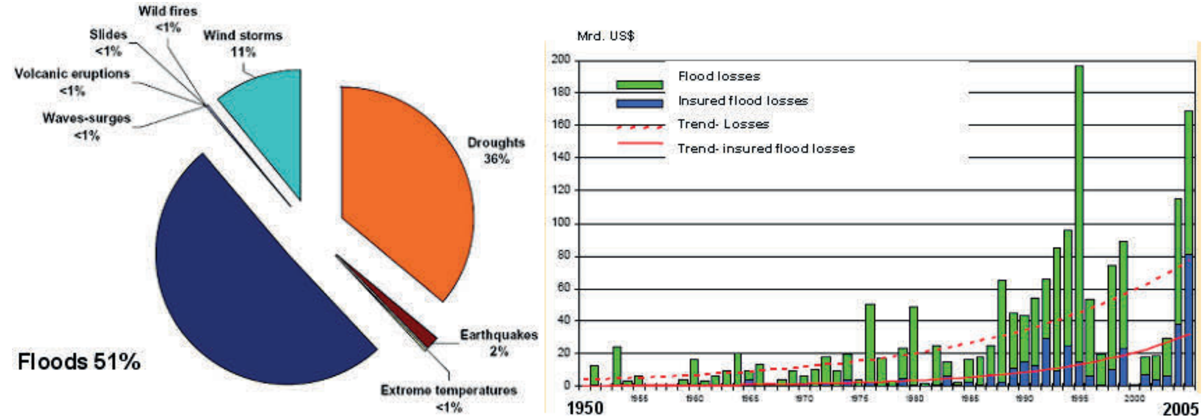

Figure 1-2 a) Distribution of people reportedly affected (injured+homeless+affected) by natural disasters in the world from 1974-2003 b) Flood losses in Europe 1950–2005; 10-year running mean (Munich Re, 2007)

Following the IPCC Report, 2007 and 2013 and the corresponding climate change projections, it is very likely that the extreme weather conditions will increase worldwide, also including the extreme precipitation events that can lead to flooding. In Europe, climate related hazards are likely to increase but are expected to vary geographically.

The flood problems require special attention in urban areas due to the sheer complexity of incorporating hydrological aspects as well as a host of social, economic, institutional and technical factors (Ashley et al., 2007). Floods have a direct impact on citizens and physical infrastructure including buildings, urban services and specific industries as well as indirect impact on economic sectors (Zevenbergen et al., 2008). The extent and severity of these impacts should be considered in terms of the scale of population and the extent of the land covered by urban areas. By assessing the current extent of urbanisation worldwide UN, 2001 referred to the "urban millennium" as when the global urban population exceeds the rural (cited in Rolf, 2006).

[3] http: //www.emdat.be (accessed May 2010)

[Currently, about half of the world's population lives in urban areas and urbanization rates, particularly in developing countries are expanding rapidly. The urban population increased from 220 million in 1900 to 732 million in 1950, and has reached 3.2 billion in 2005, thus more than quadrupling since 1950 (UN, 2005).] (Also Figure 1-3*).*

["The world has entered the urban millennium"] Kofi Annan, 2001 UN conference

Urbanisation is a complex, dynamic process playing out over multiple scales of space and time (Alberti et al., 2003). Urban systems are dynamic systems but the pace and ways they change from one state to another are not *a priori* known (Zevenbergen et al., 2008). Consequently, flood problems in urban areas need to be seen within a dynamic framework considering the main drivers shaping future development, such as climate change (IPCC, 2007, 2013) or rapid urbanisation (UN, 2005).

Also, future projections indicate that the urbanisation trend is likely to continue into the foreseeable future (Figure 1-3 and UNPD, 2004).

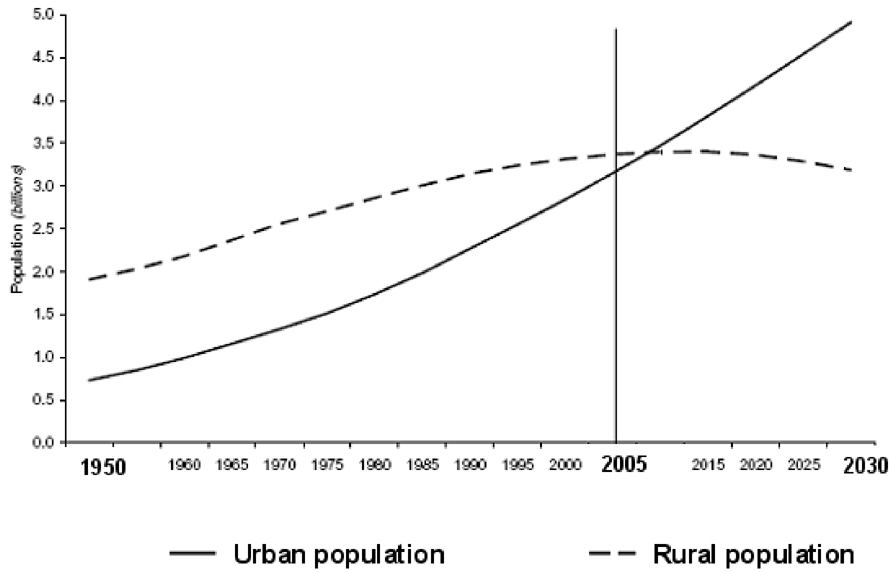

Figure 1-3 An increasing global population in the period of 1950-2030. around the year 2005 the urban population exceeded the rural for the first time (UN, 2005)

The trend of rapid urbanisation and the anticipated increase in the frequency of the extreme hydrometeorological events lead to a higher potential global risk to urban flooding as documented by the UN, 2012 and depicted in Figure 1-4.

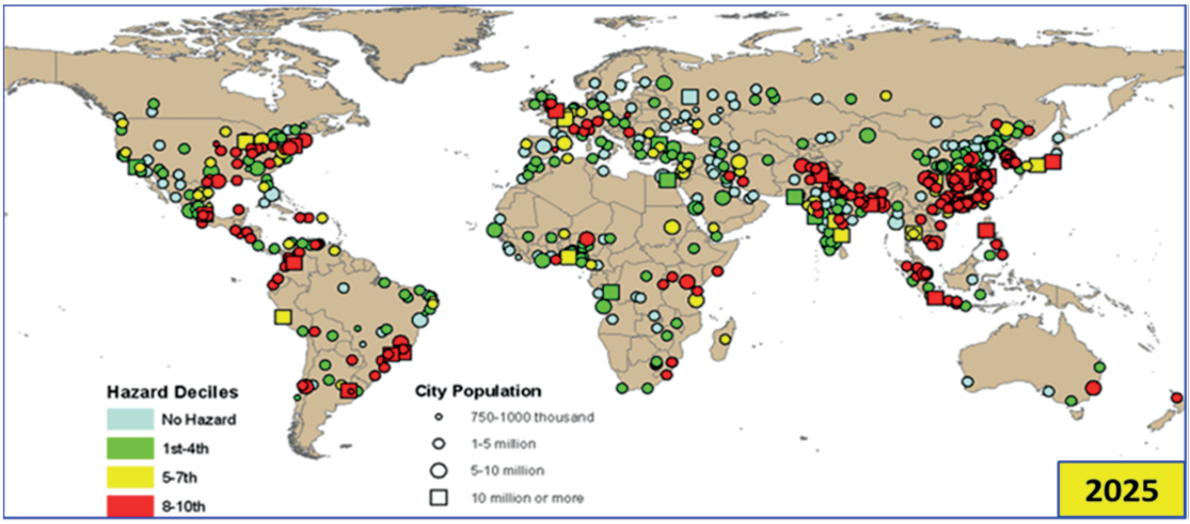

Figure 1-4 Global potential risk from urban flooding (UN, 2012)[4]

This documented severity of recent flood events and the increasing trend in losses as a consequence (Figure 1-2) show that there are deficiencies in the current flood management and there is a general consent that floods should be managed in a more sustainable[5] way. In the context of flood management, sustainability has been defined as: [taking account of future uncertainties, including climate change (1); urban development (2); land use (3); technology development (4); and affordability (5); in considering future generations' opportunities. It also requires explicit consideration of 'design exceedance' events, i.e. those that occur above and beyond the design performance of the flood management measures (6)] (FIAC, 2006).

Recognising the necessity for substantial improvements in flood management to meet the requirements of sustainable development, national and international legal institutions worldwide are reconsidering their policies and laws. In Europe, the overarching flood policy has been released within the "Directive of the European Parliament and of the Council on the assessment and management of floods" (short: 2007/60/EC), postulating **flood risk management (FRM)** as the appropriate strategy to manage floods rather than traditional flood defence strategies. In the sense of the 2007/60/EC, flood risk management can be defined as management practice that aims at preventing losses and damages by lowering the probability of flooding as well as reducing the vulnerability[6] of society in flood-prone areas (Flood Site, 2009). This means that flood risk management should focus on the measures in the flood plain rather than merely preventing a flood from reaching it by raising dikes and walls (Figure 1-5), shifting the paradigm in flood management from the traditional *"flood fighting"* to more integrated approaches referred to as *"living with floods*" (Figure 1-6) (e.g. Pasche et al., 2008).

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[4] http://esa.un.org/unup/Maps/maps_flooding_2025.htm (last accessed: July, 2014)

[5] Definition of sustainability: „Development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland et al., 1987, Agenda 21)

[6] The definition of the term vulnerability as one of the key terms when assessing risk will be introduced in chapter 3. Here it is meant as susceptibility to flooding.

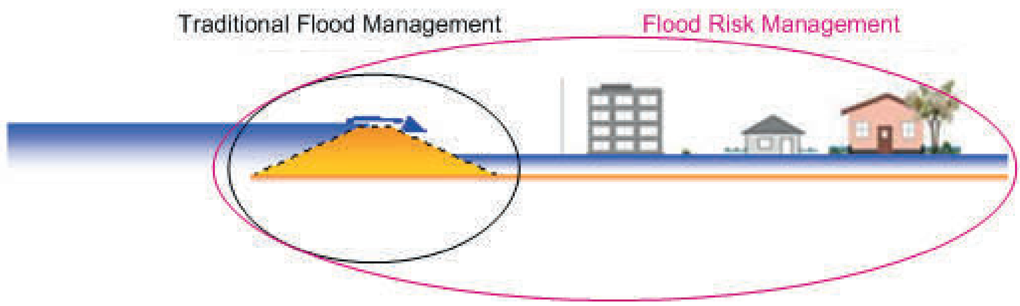

Figure 1-5 The scope of traditional and flood risk management

Introduction of the 'living with floods' paradigm opens questions on the appropriate strategies and instruments to be applied in order to practice FRM as well as the question as to the stakeholders to be involved.

The concept of *resilience*[7] is being crystallised as one of the key principles for managing floods in a sustainable way (e.g. Brinsmead et al., 2005) or even devised within frameworks for FRM e.g. the 4As strategic approach of the Scottish Government 2007[8]. Special attention has been given to urban areas (e.g. Szöllösi-Nagy&Zevenbergen, 2005, WMO, 2008, Zevenbergen et al., 2008). For their analysis, the idea of *flood resilient cities,* has been introduced by various international expert groups, projects and institutions which devote their research to explore ways to achieve these (e.g. UN group ESCAP, 2010, Zevenbergen et al., 2008, EU INTERREG IVb Project FloodResilienCity[9]).

In the legal instruments such as EC 2007/60, even if the objectives and general requirements of FRM are clearly stated, postulating flood risk management as an adequate strategy to cope with floods, little information is given about the specific strategies and concepts which are supporting the implementation process. The 2007/60/EC defines two implementation instruments of FRM, the flood risk map and the flood risk management plan. Flood (risk) maps are becoming basic instruments for raising risk awareness and decision making for flood mitigation measures (2007/60/EC, Article 4). Flood risk management plans at the level of the river basin district, for river basins, sub-basins and stretches of coastline, in close association with local and regional authorities and with the participation of all interested parties should be developed (2007/60/EC, Article 7). In terms of stakeholder involvement, 2007/60/EC sets challenges to all interested parties in flood risk management, emphasising their right to be adequately informed at the same time encouraging their active involvement in the development and implementation of flood risk management plans.

> *Member States shall make available to the public the preliminary flood risk assessment, the flood hazard maps, the flood risk maps and the flood risk management plans.] (Article 10 (1))*

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[7] The definition of the term resilience will be discussed in chapter 2. Here it is meant as the ability of the system to resist, recover and adapt from the unexpected shocks that are beyond the design capacities of the system. The adopted definition for this work and its elaboration is given in chapter 3.

[8] The 4As approach will be introduced in chapter 2 when analysing the existing approaches to flood resilience.

[9] http://www.floodresiliencity.eu/ (last accessed: June 2014)

[Member States shall encourage active involvement of interested parties in the production, review and updating of the flood risk management plans referred to in Chapter IV] (Article 10 (2))

Substantial changes are imposed as regards the private stakeholders/ dwellers[10] i.e. "non experts" that reside in the area prone to flood (Figure 1-6). They are given the right to be informed about relevant flood related issues (e.g. in Europe 2007/60/EC, Article 10 (1)), including provision of flood maps. At the same time, a great challenge is posed to them, as they have to contribute adequately to FRM. These requirements are taken up and promoted by national laws. For example, in Germany *The Water Act to Improve Preventive Flood Control -FCA, by the German Federal State (2005)* and its implementation in the German Water Act (WHG, § 31a) sets the basis for the involvement of dwellers in flood prone areas in FRM. They are now for the first time obliged to actively contribute to flood risk management.

"Every individual that can be affected by flooding is obliged to apply appropriate flood risk mitigation measures … "(§ 31a II and WHG)

However, the latest experience with the acceptance of the flood maps developed in the sense of the 2007/60/EC and made available to the public as given in *Article 10 (1)* in various European Countries e.g. in Germany[11] indicates that mere delivery of information is not likely to be an adequate strategy to motivate and empower dwellers to take a proactive role in flood risk management.

Although the methods and tools for supporting dwellers in decision making on appropriate measures are a matter of various research initiatives, they are still emergence (e.g. WMO, 2008, COST 22[17], Newman et al., 2011).

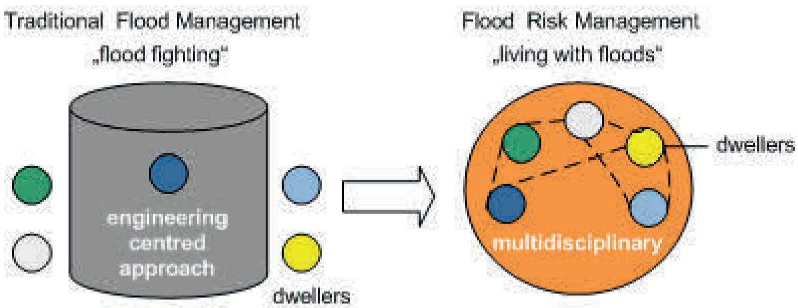

Figure 1-6 Paradigm shift in Flood Management and integration of stakeholders highlighting that the dwellers are to be integrated into FRM

[10] Within this work, the terms private stakeholder, dwellers and residents are being used interchangeably.

[11] Personal communication with the responsible agency for the implementaiton of the EC/60/2007 in Hamburg Agency for Roads, Bridges and Waterways, September 2014.

It is a research need to develop a methodology for the efficient involvement of the private stakeholders/ dwellers in flood risk management focusing on urban areas[12] to efficiently practice their role.

1.2 General objectives

Following up on the main challenges on involving dwellers in flood risk management and the current legal frameworks (in particular the EC Floods Directive 2007/60/EC), the general objective of this work is to enhance knowledge on how to empower dwellers to practice their role in (urban) flood risk management, moving towards Flood Resilient Cities, addressing the following sub topics:

I) Defining the domain or a general framework in which the stakeholder involvement should be practiced
   a. How to define the concept of flood resilient cities in urban flood risk management (UFM) as a framework for the dwellers involvement?
   b. How the strategies for dwellers' participation can be integrated in this general framework?

II) Methods and their implementation to support dwellers in the decision making process
   a. What is the required knowledge to be made available?
   b. How to make the required knowledge available to the private stakeholders tailored to their needs and abilities?

III) Strategies and their implementation to build capacity of dwellers to practice their role in UFM and take decisions
   a. How to deliver the required information and knowledge including flood maps and make them understandable and useful for dwellers (in particular, considering the requirements of the EC Floods Directive 2007/60/EC)
   b. How to motivate dwellers to accept their responsibility in FRM and become proactive?

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[12] For further discussion here, only flood management in urban areas (UFM)will be considered.

2 State of the Art and Open Questions

2.1 Flood Resilient Cities in the context of Urban Flood Management (UFM) as a general framework for the involvement of dwellers

It is increasingly worldwide recognised that Urban Flood Management (UFM[13]) should be practiced in an integrated manner considering measures to reduce flood probability and flood impact[14] (Szöllözi-Nagy&Zevenbergen, 2005, 2007/60/EC). There are various definitions that refer to UFM as a risk management cycle that implies activities and application of those measures before, during and after a flood event (FloodSite, 2010, WMO, 2010, and Swiss Civil Protection). A comprehensive example of such a definition is depicted in Figure 2-1.

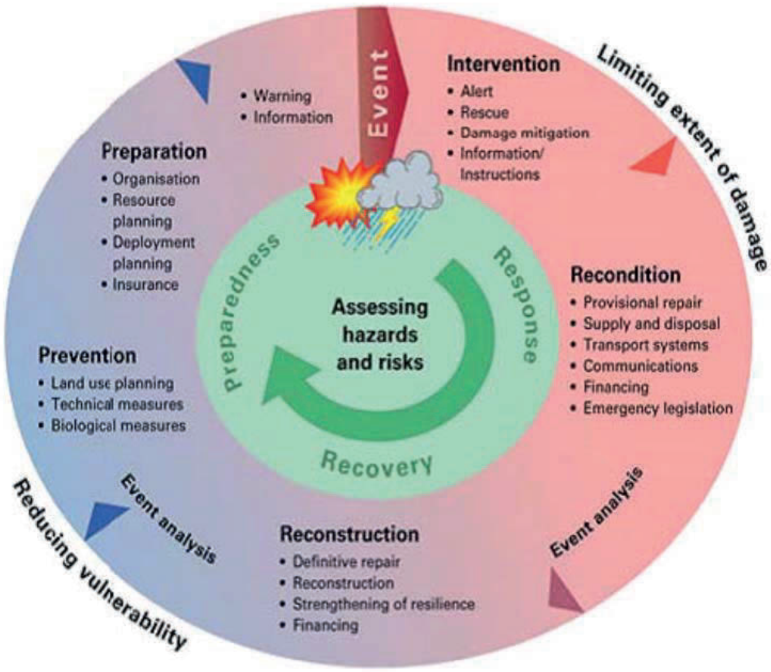

Figure 2-1 Flood Risk Management Cycle (Swiss Civil Protection, unknown)

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[13] In this work FRM and UFM are used interchangeably, as the focus is put on urban areas.

[14] Those terms will be defined in chapter 3.

UFM is also about maximising and maintaining the performance of the city as a whole, posing the question as to how this can be achieved in a sustainable manner (Zevenbergen et al., 2008). In order to manage urban floods, it is essential to understand the causes and impacts of each (WMO, 2008).

Urban floods can be defined as [an overflowing or irruption of a great body of water over land in a built up area which is not usually submerged] (Shepherd, 2007). As [urban landscapes represent a complex mosaic of land cover, a variety of land uses and their interactions] (McGranahan et al. 2005), the causes of urban floods are manifold, the main ones being meteorological (e.g. rainfall, cyclonic storms), hydrological (e.g. presence of impervious cover, natural surface infiltration rate) and human (e.g. landuse changes or occupation of the floodplain) (WMO, 2008). These factors interacting with the urban fabric can lead to different types of floods that are given as (e.g. WMO, 2008, Zevenbergen et al., 2008, Health Protection Agency UK, 2011):

- Pluvial- result from rainfall-generated overland flow, before the runoff enters any watercourse or sewer. It can also happen when water is ejected from a sewer downstream of where it has entered it. Urban pluvial flooding arises from high intensity ‘extreme’ rainfall events, but the soil saturation and surface characteristics have a decisive influence on it. Due to insufficient capacity or any malfunction of the system, urban underground drainage systems and surface watercourses may be completely overflowed.
- Riverine- occur when the river run-off volume exceeds local flow capacities and are usually triggered by heavy rainfall or snow melt in upstream areas, or tidal influence from the downstream. Ground conditions such as soil or land use have a direct impact on them (WMO, 2008).
- Coastal- caused by high tides and storm surges triggered by tropical depressions and cyclones and can affect urban areas located at estuaries, tidal flats and low-lying land near the sea in general. [15]
- Flash- occur as a result of the rapid accumulation and release of runoff waters from upstream hilly areas, which can be caused by various factors such as very heavy rainfall or cloud bursts. They are characterised by a sharp rise followed by relatively rapid recession causing high flow velocities.
- Groundwater- occur when the storage capacity of the underground aquifers is exceeded due to the water infiltrated to the ground. As a consequence, the groundwater moves towards the surface and endanger the elements of the built environment located below the ground.

Those flood types can be combined such as in the case of pluvial and fluvial floods, typical for small urban catchments (Pasche et al., 2008). The multiple hazard issues further contribute to the complexity of the flood related problems in urban areas.

Having recognised the complexity of the problems in the flood management in urban areas, a considerable number of projects and initiatives have dealt and are dealing with this issue (e.g.

[15] It can also be caused by deterioration and failure of assets (e.g. rodent burrowing).

COST C22[17], EU FP6 Project FloodSite[18], UFM[21], KLIMZUG-Nord[39], BMBF Funded RIMAX Research Cluster[20]).

Regarding urban areas as a complex multilevel system, the European COST[16] C22 initiative (2005-2009) has been devoted to creating a pool of the required expertise and knowledge to manage urban floods by exchanging the experience and best practices of experts EU wide and developing cutting edge, integrated approaches in urban flood management[17]. This action is based on a multi- and interdisciplinary approach and brought together scientists of different fields in flood management such as hydrologist, urban planners, civil engineers, social scientists, professionals in construction or insurance industry. The span of FRM in urban areas has been divided into units representing the key aspects of urban flood risk management being: [17]

- *Flood probability assessment*- focuses on models and tools to assess the probability of floods and on measures to reduce its probability and modify flow
- *Flood impacts assessment*- focuses on models and tools to assess the impacts (economic, ecological, social and cultural) of flooding and vulnerability to flood damage in urban areas and on measures and techniques to decrease this vulnerability (urban drainage and flood proofing, construction engineering and design).
- *After flood rehabilitation*- focusing on activities related to the flood resilient built environment as flood recovery measures or construction and maintenance engineering
- *Non-technical aspects*- is devoted to integrate the methods, outcomes and knowledge of the previous groups with particular focus and emphasis on policy, awareness, socio-economics and strategies for stakeholder involvement

The main outcomes of the four year research activities within the COST C22 initiative indicated that the key open issues are related to (1) the specific strategies and tools to achieve and evaluate the degree to which cities are flood resilient; (2) methods to deal with the uncertainties of the future development; (3) efficient data management and appropriate involvement of stakeholders.

The FP 6 Project FloodSite[18] was devoted to the development of strategies for flood risk management in the sense of the 2007/60/EC Directive. The methods for both, hazard and vulnerability quantification have been researched as well as guidelines for assessment of the efficiency of measures within FRM (e.g. Guideline for ex-post evaluation of measures and instruments in flood risk management), emphasising the importance of the holistic approach in FRM. The World Meteorological Organisation (WMO) devotes one of its tools to urban flood management covering the whole span of the issue (WMO, 2008), structuring the tool over the basic steps of an integrated management process that are risk assessment, planning

[16] The European project COST- European **Co**operation in the field of **S**cientific and **T**echnical Research) is an international platform where researchers and scientists exchange expertise and research data in a great number of fields. The COST-project is partly financed by the European Commission.

[17] http://www.cost22.org/ (last accessed: June 2010)

[18] http://www.floodsite.net (last accessed: January 2015)

and implementation of measures and evaluation and risk reassessment. Within the BMBF[19] funded research initiative RIMAX[20] (Risk management of extreme flood events), several projects addressed the complexity of urban FRM (e.g. URBAS, UFM-Hamburg[21]). The transnational project UFM between Hamburg[21], GER, Dordrecht, NL[21] and London, UK has been devoted to explore new planning strategies for flood prone urban areas to cope with the increased risk due to climate change by developing resilience concepts for the areas “behind the dikes” extended by innovative strategies for the existing and new built environments. The EU INTERREG IVb Project FloodResilienCity[9] aimed at the integration of [the increasing demand for more houses and other buildings with the increasing need for more and better flood risk management measures in North West European cities along rivers.].

The research on flood management in urban areas (e.g. COST C22[17], RIMAX[20], FloodResilienCity) highlights *flood resilience* and *flood resilient cities* as an overarching concept of urban flood risk management. As such, it should be the basis for the development and implementation of specific measures, definition of roles and activities of the stakeholder groups in urban flood risk management including private stakeholders. However, the concept of resilience is assessed as emergent and the definition, methodologies and tools to implement it are still a matter of research (Brinsmead& Hooker, 2005, RIMAX[20], COST C22[17]).

Summary:

The main issues to be addressed when defining and developing the framework for UFM, which are relevant for the dwellers involvement can be summarised as:

I) Definition of flood resilience and flood resilient cities in the context of urban flood risk management

II) Strategies and measures to implement flood resilience concepts within UFM towards flood resilient cities including the ones relevant for the dwellers' involvement

III) Strategies and measures for involvement of dwellers within UFM and their integration into the flood resilient cities frameworks

2.1.1 Definition of flood resilience and flood resilient cities in the context of urban flood risk management

The concept of flood resilience:

In the context of flood risk management, the concept of resilience is frequently used to describe behavioural patterns of elements at risk when exposed to flood hazard and is at the heart of a considerable number of scientific projects dealing with flood risk management (e.g. FloodResilienCity[9], CORFU[22], SMARTEST[23]). [Resilience theory offers insights into the

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[19] BMBF- Bundesministerium für Bildung und Forschung (Federal Ministry of Education and Research)

[20] http://www.rimax-hochwasser.de/ (last accessed: January 2015)

[21] http://ufm-hamburg.wb.tu-harburg.de/ (last accessed: January 2011)

[22] http://www.corfu-fp7.eu/ (last accessed: January 2015)

behaviour of complex systems and the importance of system criteria such as system memory, self-organisation and diversity] (Newman, 2008). However, the use of the term *'resilience'* is contested and in spite of intensive research activities and publications on the topic of resilience (e.g. Holling, 1996, Gallopin, 2006, Zevenbergen et al., 2008, Liao, 2012) the general consensus on its nature and determinants has not been finally agreed. Also there are numerous studies and scientific discourses about the differing resilience approaches (e.g. Walker, 2000, De Brujin, 2005, Gallopin, 2006, Gersonius et al., 2010). Thus, for assessing the applicability and importance of resilience for urban systems it is necessary to have some basic understanding of these variations in definitions and approaches.
Resilience as an idea has its roots in psychology described as [an individual's capacity for maintenance, recovery or improvement in mental health following life challenges] (e.g. Ryff et al., 1998), successful adaptation following exposure to stressful life events (Werner, 1989), and an individual's capacity for transformation and change (Lifton, 1993)) (all cited in Neil et al., 2001).
However, the concept of resilience as often used in flood management was derived from ecology. Holling refers to the three basic approaches to resilience- engineering, ecological and social-ecological resilience (Holling, 1996, Gersonius et al., 2010).
Engineering resilience has been defined as the notion of speed of return to equilibrium (Pimm 1991), and as such it is characterised by time required for the system to reach the initial state. In this approach, resilience refers to the behaviour of a system close to the state of equilibrium as shown in Figure 2-2a.

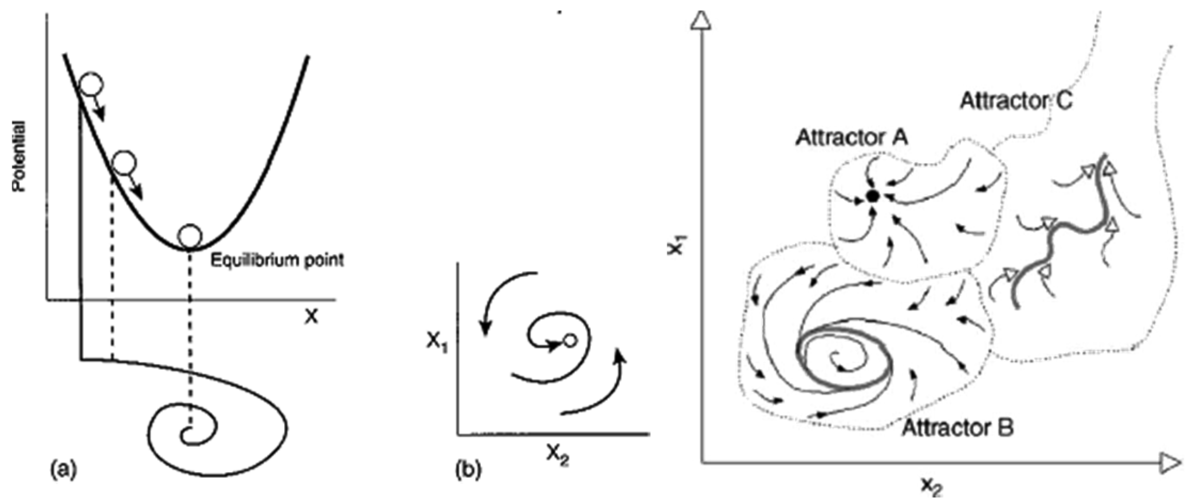

Figure 2-2 Basic approaches to resilience a) engineering with one domain of attraction, (Holling, 1996) b) ecological, multistable state with several domains of attraction (Gallopin, 2006)

Holling (1996) introduced another approach based on the non-equilibrium principle in ecology - ecological resilience, demonstrating that many natural systems are multi-stable with two or more domains of attraction (Figure 2-2b). Within each of those domains the system

[23] http://www.floodresilience.eu/ (last accessed: January 2015)

can fluctuate, but if it tends to stay within the border of one domain, it is considered to be resilient. Walker et al. (2004) extended this definition of ecologic resilience referring to it as [the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks—in other words, stay in the same basin of attraction]. Here the notion of robustness is usually considered to be a synonym to resilience but it is more relevant when applied to components of a system (Gersonius et al., 2010).

Resilience has also been identified within the social sciences as a concept that helps to better understand the occurrence of unexpected and disastrous events and how to better prepare for these (e.g. Gallopin, 2006). Gallopin et al. (2006) have argued for a socio-ecological system (SES) as a natural unit for sustainable development research. An SES is defined as [a system that includes societal (human) and ecological (biophysical) subsystems in mutual interaction] (Gallopin, 1991). Walker et al. (2004) regard the SESs as a [system moving within a particular basin of attraction, rather than tending directly toward an attractor.] In this sense, resilience is interpreted as a way of thinking or even a paradigm for analysis of social-ecological systems (Gersonius et al., 2010).

Apart from the main approaches addressing general resilience, resilience has been analysed in the context of specific system types. Addressing only human systems, Pooley (2010) defines resilience as the system's capacity to prevent, resist and recover from damage. The term 'community resilience' recognises that communities operate as networks and groups, rather than as discrete individuals (Nelson, 2007).

In the theory given above, the dominant aspect of resilience is its spatial extent, describing characteristics of a physical system (ecosystem, SES, cities). However, in the changing environment, the temporal aspect becomes more important; i.e. its development over time under changing conditions. Therefore, the capacity to *adapt* to future conditions is increasingly becoming an aspect of resilience (long-term response). According to Gallopin (2006), adaptability [is the capacity of actors in a system to influence resilience. For example in a socio-ecological system-SES, this amounts to the capacity of humans to manage resilience].

The Resilience Alliance has developed a model to characterise the behaviour of complex, non-linear systems in terms of an "adaptive cycle" of growth, crisis, transformation and renewal (Holling, 2002). Based on the definitions of (Holling, 2002) and (Alberti et al., 2003) urban resilience can be regarded as the degree to which cities are able to tolerate alteration before reorganising around a new set of structures and processes (Resilience Alliance, 2007). One of the main aspects for assessing the resilience of an urban system is the degree to which the system expresses capacity for learning and adaptation (Walker et al., 2004). Resilience, therefore, is the potential of a system to remain in a particular configuration and to maintain its feedback and functions, and involves the ability of the system to reorganize following disturbance-driven change. Adaptive capacity is an aspect of resilience that reflects [learning, flexibility to experiment and adopt novel solutions, and development of generalized responses to broad classes of challenges] (Walker et al., 2004).

Summarising the most prominent approaches of resilience tailored to flood risk management, influences of both of the main approaches to resilience (engineering and ecologic) are to be found. For example, Samuels et al., 2007 within the FloodSite[18] project define resilience as [the ability of a system/community/society/defence to react to and recover from the damaging effect of realised hazards.]. The Scottish Government, (FIAC, 2007) introduced the concept of resilience as the 'ability to recover quickly and easily', using it to deliver the 'four As': Awareness + Avoidance + Alleviation + Assistance. Adopting the definition of resilience after Wildawsky, 1991 as [an antipode to anticipation (resilience expects the unexpected)] Kuhlicke, 2010 explored the potential of the resilience approach in flood risk management, concluding that resilience is likely to be a more relevant concept in the development of long-term adaptation strategies as it is more aware of the uncertainties due to future development.

Also different approaches regard the resistance capacity of a system differently, either defining it as a complementary strategy in flood risk management or including it into the definition of resilience.

Considering the resistance as a part of resilience, de Graaf, et al., 2007 and Gersonius et al., 2010 delivered probably the most comprehensive approach to resilience in the context of flood risk management, addressing both its short and long term aspects. Here resilience, as a system characteristic, is treated as an integrative strategy to manage floods. Applied to the flooding system, it is defined here in a very broad sense as [the capacity of the whole system to absorb flood waves in annual variability and to reorganize while undergoing change in flood probability or severity.]

Resilience is strongly related to sustainability; Brinsmead and Hooker (2005), by analysing the alternative sustainability conceptions being (1) the reduction of environmental impact; (2) the preservation or enhancement of natural capital; and (3) the preservation or enhancement of adaptive capacity (i.e. resilience), concluded that [only the (3) concept has the ability to cope with the uncertainties and as such is the most convenient for structuring sustainability strategies] (Brinsmead& Hooker, 2005).

The concept of (flood) resilient cities- framing the concept of resilience in the research of urban systems:

The broad perspective and variety of approaches to resilience affect the concepts or terms that are based on it, such as *(flood) resilient cities*. A rather general definition of resilient cities is given as [a sustainable network of physical systems and communities] (Godschalk, 2002), further introducing their key features as redundancy, efficiency, autonomy, flexibility and adaptability. While there is an emerging research focus on sustainable cities, the understanding of processes and factors that make some cities vulnerable to shocks and others resilient is still poor and in its initial phase (Resilience Alliance, 2007)

Ashely et al. (2007) introduced the concept of "cultivating" resilience as a basis of flood resilient cities. It is primarily implying development and application of non-structural responses[24] and activities on the social environment since the majority of the cultivation

[24] The term non structural reposnses will be introduced and analysed in section 2.3.

process is undertaken by stakeholder interaction within the system and cultivation allows the plant to grow and it 'emerges' [emergence]. The INTERREG project FloodResilienCities[9] defines the resilient cities based on the 4A's concept of resilience introduced by FIAC, 2007, emphasising that the specific implementation and pace of this concept is still a matter of research. By defining the appropriate strategies in flood risk management in Asian Countries towards flood resilient cities, the UN group ESCAP, 2010 outlines the strategies for developing flood resilience in cities as:

- capacity of cities to cope with floods (urban characteristics, including institutional capacities and physical structures for water retention);
- risks to the cities, including identification of priority targets for risk reduction and analysis of the causes and frequency of flooding, for determining the risk posed by extreme events and regular flooding; and
- technology (e.g. radar) necessary to support flood management activities.

Considering urban systems as a whole, the question arises as to how to regard flood resilience in terms of its separate and individual components. As the focus of this work is the dweller's participation and the development of methods to support them in the decision making process about flood resilient measures for their properties, the issue is how to analyse the buildings or infrastructure together with the social environment (including dwellers) in the context of flood resilient cities.

In the recent years, there have been some research activities on the development of frameworks that can map the processes and relations relevant for improvement of resilience in urban contexts, considering the individual elements of an urban system and their interactions. Within the FP7 Project CORFU[22], the DPSIR framework for urban flood risk management and resilience has been developed. DPSIR was initially developed by the Organisation for Economic Co-operation and Development (OECD, 1994) and has been used by the United Nations (e.g. UNEP, 2007) and European Environmental Agency e.g. EEA 1999) to relate society and human activities to the environment. Through the use of a DPSIR modelling framework, [it is possible to gauge the effects of drivers, pressures, impacts and responses and asses their key dependences and interrelatedness as such study the changes in flood risk and resilience with the key factors contributing to those alterations.] (Djordjevic et al., 2014)

The elements of the DPSIR framework for urban flood risk management are defined as follows (Djordjevic et al., 2010):

- Drivers (D) – The social, demographic and economic developments in societies and the corresponding changes in life styles, overall levels of consumption and production patterns.
- Socio-economic drivers lead to environmental pressures (P)
- Environmental pressures lead to changes in environmental state (S).
- Changes in environmental state are reflected in environmental and socio-economic impacts (I).

- Stakeholder gains/losses from impacts lead to policy responses (R) which affect one or several of the components mentioned before.

The assessed interrelations between those elements are shown in Figure 2-3.

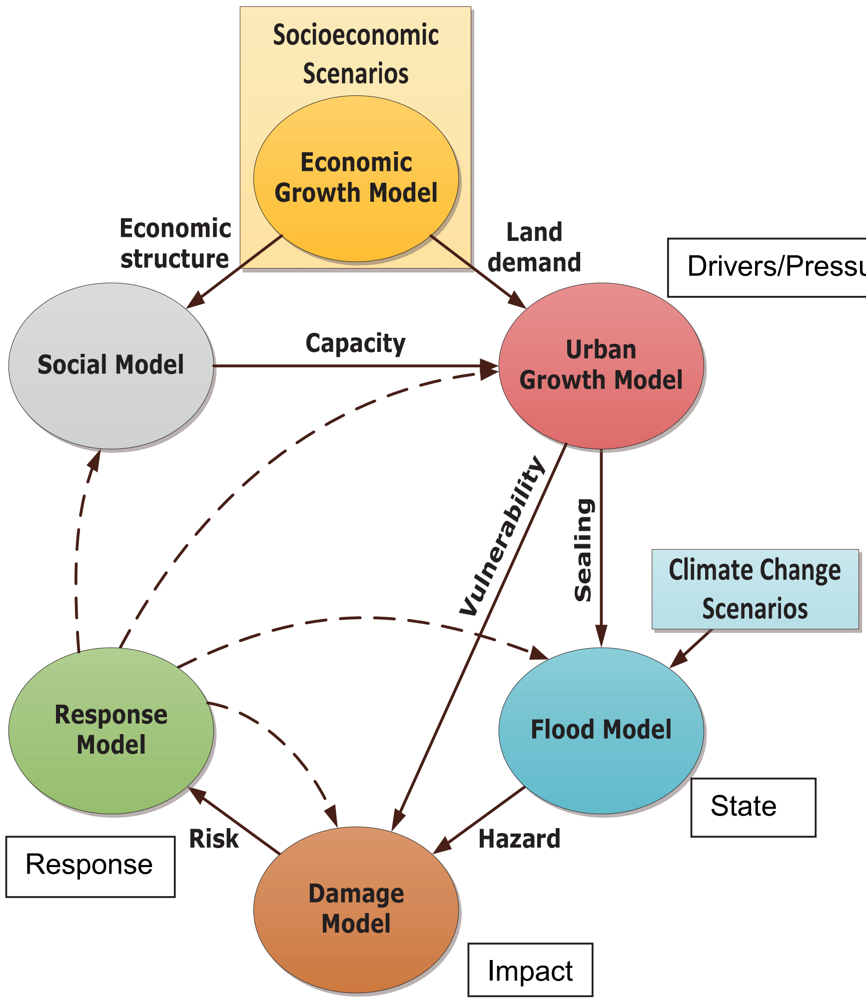

Figure 2-3 DPSIR Framework for studying urban resilience as defined in the FP7 Project CORFU (Djordjevic et al., 2015)

Although the framework enabled a better undestanding of the factors shaping resilience in urban areas, a number of shortcomings of the DPSIR framework to capture all complex interactions between different elements of the urban flood risk management could be identifed (Hammond et al., 2015). A particular challenge is to integrate the social component into the rather quantitative reseach of flood, risk or urban growth modelling (Svarstad et al., 2007, Hammond et al., 2015). This requirement opens a room for research on how to regard dwellers as an element of the flood risk management and how they interact with the other elements of an urban system exposed to a flood risk.

In the urban system research, different methodologies have been developed in order to deal with the complexity of cities. A comprehensive system approach should be applied for a better understanding of the dynamics of complex systems, such as urban landscapes, regarding their resilience and sustainability (Fiksel, 2006). Applying the system approach, a city can be decomposed to various components that are behaving as input-output units, defining it as a multi-level interacting system (Zevenbergen et. al., 2008). Regarding the temporal aspect of resilience, lifetime cycles of buildings should be shortened in order to adapt to long-term changes and in that way have more opportunities to correct mistakes (Zevenbergen et. al., 2008). This approach delivers a good basis for the analysis of cities as complex systems focusing on urban fabric i.e. buildings and infrastructure, however, it does not define the role and interactions with the stakeholders and dynamics of the transfer process to reach a resilient state for the system.

The potential of future research is seen in the holistic approaches focusing on the complex interactions of the elements of urban systems (such as people, built envioronment, urban landscapes or natural phemonena acting on them) and analysing their impact on the flood risk and resilience (Vojinovic, 2015).

Quantifying resilience:

By decomposing the urban system by application of the system approach, it is possible to assess the resilience of its components, including buildings. Most of the definitions are descriptive and describe the notion of resilience. However, as resilience is understood as something that improves the system qualities by application of certain measures, it should be quantified in order to assess their efficiency. By quantifying resilience, the concept becomes more tangible and enables the evaluation of different strategies. A possible way is to identify so called “resilience indicators” to enable the assessment of the complex behaviour of a system in terms of its resilience performance.

De Brujin (2005) identifies the proxies which help in quantifying the flood resilience as amplitude, graduality and recovery rate. Gersonius et al., 2010 applied conceptual models to assess resilience by identification of the main criteria for assessment being robustness and adaptive resilience, defining further parameters describing the main criteria.

The concept of the Resilience Index promoted by International Environment and Disaster Management (IEDM) Laboratory (Shaw et al., 2009) has been adopted by CORFU (Batica et al., 2012) to describe the resilience performance of an urban system looking at its natural, physical, economic, social and institutional dimensions. Each dimension contributes to the evaluation of flood resilience index for the particular system. Such a comprehensive view of assessing resilience opens room for bringing the resilience performance on single elements of urban environment in a broader context. [Multiscale resilience is fundamental for understanding the interplay between persistence and change, adaptability and transformability. Without the scale dimension, resilience and transformation may seem to be in stark contrast or even conflict] (Folke et al., 2010). An operational definition of multiscale resilience should be therefore achieved to bridge up this gap (Schertzer& Tchiguirinskaia, 2011). Also, the UNISDR presented the Resilience Scorecard as a document whose aim is to serve as a guideline to measure resilience in cities. This scorecard is based on ten pillars which comprise a total of 85 criteria and their valuation is a numeric value from 0 to 5, where five is the best practice (UNISDR, 2014). Different methods to measures resilience are summarised in Table 2-1, together with the main criteria considered and the type of variables (proxies) to 'measure' the achievement of those criteria.

Table 2-1 Overview of the selected mehtods to measures resilience

Name	Criterion	Variables & (Indicators)	Type of variables	Nr-Total
Resilience indicators (de Bruijn (2004)	Resilience to flooding	Amplitude (2), "Graduality" (1), Recovery (9).	Quantitative for Amplitude and "Graduality". Qualitative for Recovery. Thresholds for the qualitative variables based on interpretations	12
CDRI	Resilience to climate disasters	Indicators for natural (2), physical (8), social (3), economic (6), and institutional (4) dimensions.	Qualitative. Thresholds based on interpretations	23
UNISDR Score card	Resilience to disasters	Indicators for organization (10), budget (9), risk assessment (4), infrastructure (26), health & education (6), building regulations (5), education programs (4), ecosystems (3), emergency management (13), recovery (2)	Qualitative and quantitative. Thresholds mostly based on percentages	85

Summary:

Definition of resilience: Although representing different perspectives and approaches, the current resilience theories agree upon the basic postulates that can be summarised as (adapted from Zevenbergen et al., 2008):

- Resilience and adaptability become imperative for any strategic planning and decision making procedures in FRM including all its components in order to cope with and respond to future challenges/ uncertainties
- Resilience is an internal property of (complex, dynamic) systems
- Resilient systems have the ability to cope with and recover from disturbance (short-term response)
- Adaptability is the key feature of resilient systems reflecting the temporal aspect of resilience

The diversity of the definitions of resilience is a product of the evolution process on the perception and understanding of resilience (Francis& Bakera, 2014). The authors identify their convergence in the direction of a common definition, stating that those common elements are:

- o recoverability- ability to cope and recover from a reaction to short-term perturbations
- o adaptive capacity- ability of a system to re-organise into a possible adaptation after a reaction to long-term perturbations

- absorptive capacity- resistance i.e. ability to withstand perturbations
- retention of identity (structure and functions)

Main research needs and knowledge gaps for studying resilience frameworks in the context of UFM:

- A generally accepted definition of the flood resilience concept in the context of UFM has not yet been established and required further investigations [25]. Still some convergence in the current approaches could be identified (Francis& Bakera, 2014), which should be considered for further research
- A framework for studying the interactions and interrelations of the elements of urban systems (Vojinovic, 2015) including the role of stakeholders (dwellers) in pursuing the transition process towards flood resilient cities and the interactions of dwellers with the other elements of urban system
- The scope and characteristics of measures required for the development of flood resilient cities have to be defined for all levels in the multi-level interacting system (Fiksel, 2006) and the dynamics of their implementation developed.
- The concept for quantification of resilience applicable to the resilient built environment is still an emergence (Salagnac et al., 2013)

2.1.2 Strategies and measures to implement flood resilience concepts within UFM towards flood resilient cities including the ones relevant for the dwellers' involvement

There is a general consensus that (urban) flood risk management and flood resilient cities should be based on the appropriate combination of *non-structural* and structural measures, with more emphasis on the former (2007/60/EC, Crue EraNet, 2005, FloodSite 2005, FIAC 2007). There is a significant body of literature and studies on the scope and development of concepts and of non-structural measures (NSM), but a considerable heterogeneity among these can be observed. It differs among authors, projects and initiatives.

The differences are reflected in the basic understanding of the term "non-structural" between the various projects, many of which derive their concepts based on different approaches.

The first group bases their concepts on the idea that *non-structural* means *non-tangible* i.e. something that is more related to regulations, capacity building or economic instruments. For example, Taylor& Wong (2002) define NSM as [responses to urban flood risk that do not involve fixed or permanent facilities and usually work by changing behaviour through government regulation, persuasion, and/or economic instruments]. Newman et al. (2011) further developed this approach and defined non-structural responses (responses are regarded as equivalent to measures) as [responses to urban flood risk that may not involve fixed or permanent facilities and their positive contribution to the reduction of flood risk is most likely

[25] [Multi-interpretability of resilience as a notion introduces problems when attempting to use such a concept in real-world terms] (Newman, 2007).

through a process of influencing behaviour, usually through building capacity in all stakeholders through active learning and appropriate and effective engagement between stakeholders] based on an adaptation of Australian practice (Taylor& Wong, 2002). Within the INTERREG IVb project SAWA [26] the issue of (non) structural measures has been discussed based on the etymology of the word *structure* that is "something (e.g. a building or an organism) made of parts fitted or joined together" (Webster's Dictionary of the English Language[27]), subdividing these into traditional and emergent measures (Newman et al., 2007). In this case the NSM are antipode to *(structural)* measures that have strong material or constructive connotations. Still the problem occurs as each measure is composed of tangible and intangible elements. For example, flood forecasting and warning involves infrastructure as well as the process of warning and alarming. It means that this is both a structural and non-structural measure. The classification problem increases further with the level of detail.

The second group derives the concept of NSM based on the paradigm they are representing and that is "living with floods", i.e. the measures that are alternative to traditional, "flood fighting" approaches.

Defined in the sense of the (Crue EraNet, 2005) initiative the non-structural measures include all mitigation measures that are not based on large-scale defences. Within the INTERREG IIIb Project FLOWS, the NSM were defined as [..measures taken to protect people or property in order to reduce damage without influencing the flood hazard itself, this term is often used as a synonym for passive protection measures.]. FloodSite (2005) states that flood hazards may be reduced through engineering or "structural" measures, which alter the frequency (i.e. the probability) of flood levels in an area. The exposure and vulnerability of a community to flood loss can be mitigated by non-structural measures, for example, through changing or regulating land use, through flood warning and effective emergency response, and through flood resistant construction techniques. Andjelkovic (2001) introduces NSM as a set of complementary approaches to already well-known engineering, structural measures.

The measures to improve the resilience of the built environment is included in any of the above mentioned approaches, however they are differently classified either as "structural" or "non-structural" measures, depending on the definition of those terms as explained above.

Independently of which classification of non-structural measures has been adopted, the crucial issue is to understand the scope, contexts and applicability of each of them in order to combine them into strategies. A range of international projects addressed this issue in their research portfolios (e.g. INTERREG IVb projects SAWA and MARE) intending to develop a database of measures while giving a brief description of their properties (e.g. the SAWA outcomes in the IWA Platform Water Wiki http://www.iwawaterwiki.org/xwiki/bin/view/Articles/GreenRoofs). However, a systematic analysis of measures including the resilient measures for the built environment is still a matter of research (e.g. Salagnac et al., 2013).

[26] http://www.sawa-project.eu/index.php (last accessed: January 2015)

[27] http://www.merriam-webster.com/ (last accessed: January 2015)

Summary:

Although non-structural measures as an approach are generally accepted as a means to reach flood resilient cities and are considered and delivered in a range of projects and initiatives, there are different understandings and interpretations of what these are. Also, the measures devoted to the management of the built environment are generally included, but their attribution and scope vary in the different approaches presented above. An approach of a "knowledge base" is needed which describes those measures in their modes of applicability, scope or costs in order to understand better their potential for combining into strategies independently of which classification of non-structural measures has been adopted.

2.1.3 Strategies for involvement of dwellers within UFM and their integration into the flood resilient cities frameworks[28]

Management of flood risk in urban areas is a complex task, covering the implementation of the whole span of the measures (e.g. the 4As of FIAC, 2007) and managing interests of various stakeholder groups, including dwellers. The 2007/60/EC requires the active participation of all interested parties in the development and implementation of flood risk management plans (Article 10 (2)), which are to be delivered by December 2015[29] by the member States (see also section 1.1). Also a number of national laws have included this requirement (e.g. FCA, 2005 in Germany).

This legislation delivers just a framework for the involvement of dwellers without giving any guidance for development of the efficient strategies on how to put this into practice. Thus, the problem of dweller engagement has gained in importance recently in research agendas of a considerable number of national and EU funded projects (e.g. DIANE-CM[30], Crue EraNet Programme[76], SAWA, MARE[32] FloodSite[18,] CapHaz Net[73], FloodScan[74], Newman et al., 2011). As a result of the Crue EraNet project IMRA, a guidance document on how to plan and implement communication and public participation processes in flood risk management has been developed[31]. It delivers a comprehensive toolbox of methods and steps to perform for the efficient participatory planning, however without a specific focus on the role the dwellers should take in the flood risk management.

There are different approaches to stakeholder involvement and the role of dwellers. In literature, the two basic approaches of developing involvement of "non experts" including dwellers in decision making are given as a top-down and a bottom-up approach. In the first

[28] Parts of this chapter have been published and submitted as the authors contribution to the report Manojlovic N., Hodgin S, Manheimer J., Waagø O.S, Annamo E., Evers M, den Besten J., Pasche E.*, Marengwa J., Von Haaren M., Braskerud B., Lawrence D., (2012): Adaptive Flood Risk Management Planning: Experience from the SAWA Pilot regions, Working Group 1, SAWA INTERREG IVb project report

[29] this does not apply to urban drainage systems

[30] http://hikm.ihe.nl/diane_cm/alster/ (last accessed: January 2015)

[31] http://www.umweltbundesamt.at/fileadmin/site/umweltthemen/nachhaltigkeit/imra_handbook.pdf (last accessed: January 2015)

case the plan is developed by professionals and the "non-expert" opinion is requested at the end of the approval process through public hearings and written objections (Pasche, 2009). Within this process, the public is not participating in seeking out and developing solutions, but is expected to understand and accept the final outcomes of developed plans. Following this approach it is difficult to fulfil the requirements of the 2007/60/EC that encourages *active* involvement of stakeholders in the whole planning process, which calls for the bottom-up approach. Here all stakeholders, professionals and "non experts", are involved right from the start and together they develop the plan in a continuous collaborative process. Pahl-Wöstl (2007) has defined a general framework for such a bottom-up approach of participatory planning in water management. A key element of this framework is the implementation of a collaborative platform in which representatives of all relevant stakeholders are members including dwellers. The EU INTERREG IVb projects SAWA[26] and MARE[32] explored the ways to involve dwellers in the participatory process for the development of flood risk management plans, defining them as one of the key stakeholder groups. The project results[33] indicate a high heterogeneity in approaches and attitudes in the partner countries in the North Sea region. Within the Crue EraNet Project DIANE- CM, the method of collaborative modelling has been applied to involve all relevant stakeholders including dwellers in the Alster catchment area of Hamburg. The results indicated high potential of online participation to engage with all relevant stakeholders including dwellers (Evers et al., 2011). Dwellers' engagement and their appropriate role in flood risk management in Scotland, and more specifically Glasgow, is a major theme throughout the study performed by Ashley et al., 2008 and acknowledges the Scottish Government's consultation that put the dweller in the forefront of the response to flood risk. Different methods have been applied in order to better understand the 'appropriate' role of dweller engagement. By conducting forums or door-to-door interviews, it was found essential to establish trust from the community and to obtain respect from the dwellers in order to initiate reliable participation from private stakeholders. The aspect of the participatory planning of dwellers in flood resilient planning should include consistent social science research on the attitude of the stakeholders such as dwellers to take responsibility to improve the resilience of their buildings and on efficient ways to trigger activities in these directions.

Based on the research on the flood risk orientated spatial planning in the urban areas within the Trent River corridor, White& Richards (2008) identified a number of key barriers inhibiting private stakeholders from contributing towards flood risk management. These are mostly related to the lack of motivation, knowledge and appropriate avenues of communication.

Different authors introduce the concept of "participation ladder", describing different levels of participation of "non experts" (e.g. Armstein, 1971, Rowe& Frewer, 2005, WMO, 2005). The method used by WMO, 2005 is depicted in Figure 2-4.

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[32] http://www.mare-project.eu/ (last accessed: January 2015)

[33] Outcomes of the project meetings and final report (Mnaojlovic et al, 2012)

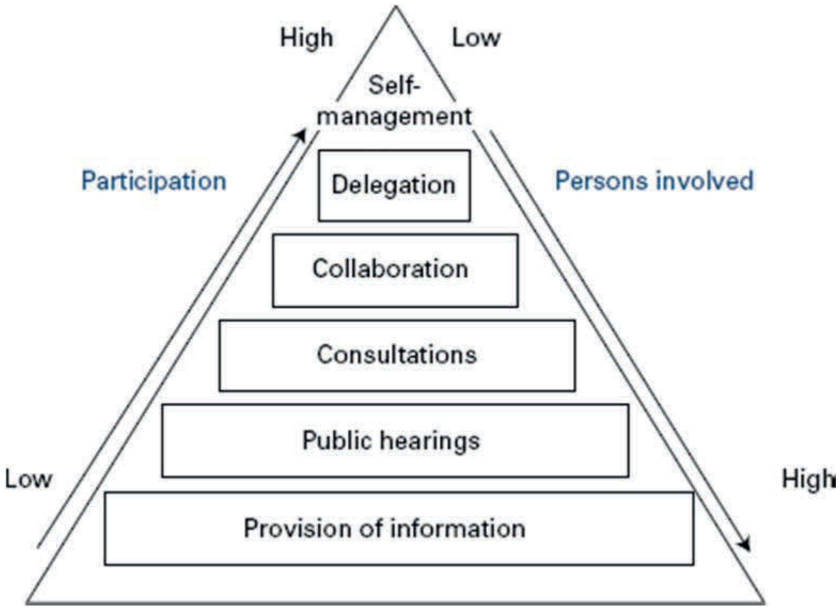

Figure 2-4 Levels of stakeholder participation (WMO, 2005)

The greater the extent of participation and control over decisions, the fewer the numbers of stakeholder representatives that are engaged in the process. Which level of participation will be adopted depends on the given social, political and legal conditions. Surpassing simply provision of the information, the next participatory level, public hearings, requires more interaction with the public and dwellers, as their feedback is sought in the decision making process. A consultation means engaging stakeholders in a dialogue. A step further is made through collaboration with the stakeholders, meaning that different groups come together with the authorities to share, negotiate and control the decision-making process. Delegation involves joint decision-making. Here stakeholder involvement is intensive, but is carried out through the representatives. Under self-management, the community or individual makes its own decisions (WMO, 2005).

WMO, 2006 emphasises the importance of taking an integrated approach to stakeholder participation in flood risk management, assessing the main purposes of stakeholder participation as:

- to build consensus and support towards flood measures
- to provide and obtain information on flood risks, prevailing values, interests and potential solutions.

The outcomes of the research activities and projects of FRM EU-wide (e.g. COST C22, RIMAX, Crue EraNet) converge in the idea that active involvement of the key stakeholders including dwellers is one of the key pillars of efficient UFM towards flood resilient cities (e.g. Pasche et al., 2008). Also, identifying roles within the system and linking the roles to appropriate stakeholders will increase the efficiency of the decision making process (Ashley et al., 2007).

Also, the research on the public and dwellers involvement in the UFM can benefit from the research and experiences in the adjacent fields such as environmental sciences (e.g. Renn, 1995) or water resources management (Soncini-Sessa& Weber, 2007), where the participatory

planning has been on the research agendas before it reached the flood risk management. It mainly implies the generic participatory models and steps to undertake for practicing an efficient participatory planning.
Referring to the responsibilities of different parties in UFM, Farmer developed a curve, which relates the frequency of the event and the role of the key stakeholder group as shown in Figure 2-5. Following this approach, the individuals are responsible for their own properties (micro scale) and that in case of the high frequency events.

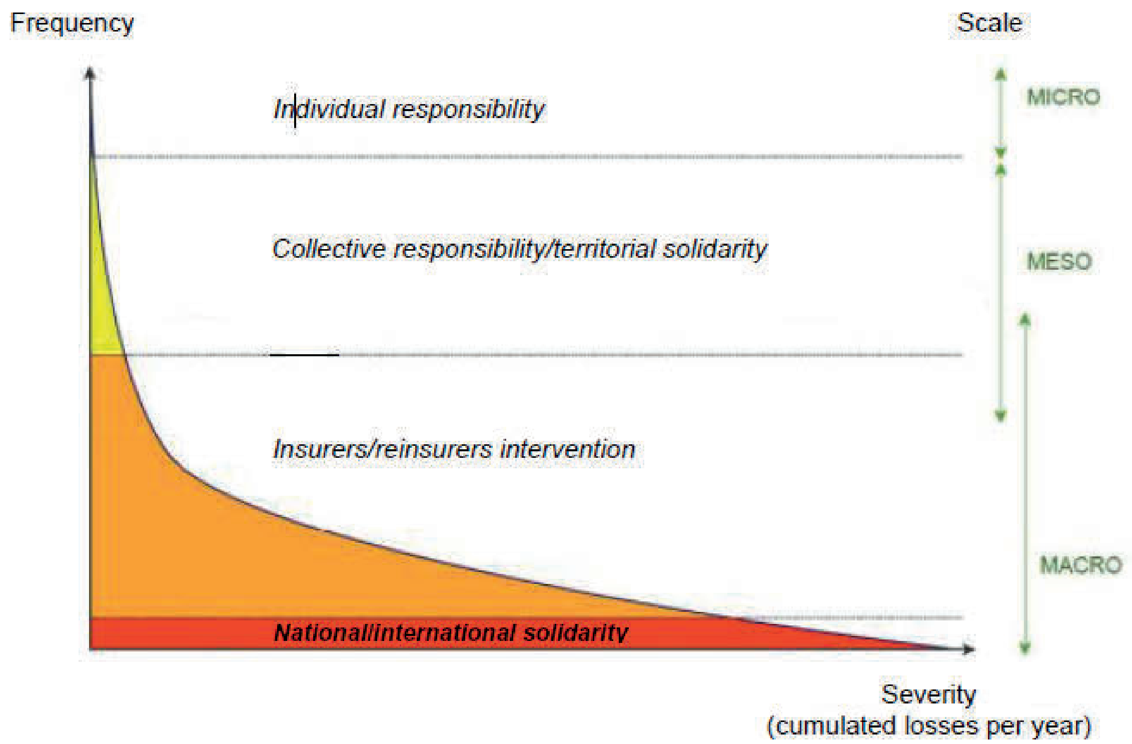

Figure 2-5 Farmer Curve (adapted from Mission Risques Naturels (http://www.mrn.asso.fr/), taken from SMARTEST D3.1 report, Salagnac et al., 2011)

Summary:
Although pursued by the 2007/60/EC and identified by research establishments as a key to efficient transfer towards integrated flood risk management, [the examples of good practice in participatory flood risk management are still scarce] (Pasche, 2009) and there is still a lack of standardised methods or widely recognised guidelines for participation of the key stakeholders including dwellers. The integrated approach to stakeholder involvement, including dwellers are emphasised (e.g. IMRA, 2011), but the specific strategies to involve dwellers and at the same time meet the needs of UFM are an open research issue. The bottom up approach is likely to support the requirements of 2007/60/EC (e.g. Pasche, 2009), but the methods for the efficient involvement of dwellers is still a matter of research (e.g. Pasche, 2009, CapHazNet Consortium[73]). The individuals i.e. dwellers have to take an active role in UFM (e.g. 2007/60/EC) and following the Farmer curve, Figure 2-5 are to be responsible for their properties (micro scale) for the high frequency events.

2.2 Methods and tools for supporting dwellers in the decision making process within their role in UFM

Decision making processes in UFM are addressed and researched by a number of projects aiming to identify the main requirements of different stakeholder groups, including dwellers, for efficient decision making process (e.g. FloodSite[18], SMARTEST[23], CORFU[22]). Within the FloodSite project[18] the issue of long term decision making has been selected as one of the key aspects to be further researched. It implies improvement of the interface between technological knowledge and the decision making and development process of responsible actors and the dwellers (people affected) as well as the improvement of understanding of users and their needs (Mc Gahey, 2009).

Out of the issues and conclusions raised within these projects and by a number of authors, taking into account the role of dwellers in UFM, the following points are considered for the analysis of the decision making process:

1. Definition of the expertise required for the active involvement of private stakeholders
2. Methods for assessment of the performance (evaluation) of the measures
3. Strategies to support dwellers in the decision making referring to the phases of the UFM cycle
4. Decision support tools

2.2.1 Definition of the expertise required for the active involvement of dwellers

The main role of dwellers in UFM following the legal requirements (e.g. WHG, 2005) and research outcomes of a number of the EU and national projects, is to protect the own properties from floods (e.g. SMARTEST[23]). Thus, the support of dwellers is related to empowering them in decision making processes on the adequate flood resilient measures that are to be applied to their own properties.

Flood resilient measures for buildings are already well established and made available to the general public in a form of spreadsheets, dedicated websites or brochures (e.g. National Flood Forum – blue pages[34], SEPA[35], FLOWS85). These techniques, mostly based on the dry- and wet-proofing principles, are recommended and promoted by numerous institutions and agencies (e.g. SEPA[35], DEFRA[36], German Ministry of Traffic, Construction and Urban Development[37]). Correspondingly, extensive material is available related to options on how to manage floods at the property level before, during, and after floods. In general, this advice commonly relates to the following strategies:

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[34] http://www.floodforum.org.uk/ (last accessed: January 2015)

[35] http://www.sepa.org.uk/ (last accessed: January 2015)

[36] http://www.defra.gov.uk/ (last accessed: January 2015)

[37] http://www.bmvbs.de/ (last accessed: January 2015)

- dryproofing of the property, i.e. the water is kept out of the building
- wetproofing, i.e. the water is allowed to enter the building but the building fabric and the contents are "waterproofed" by application of flood resistant materials such as lime based plaster or tiles.
- relocation/elevation of the building

In the past years, the following strategies are gaining more interest and acceptance among the dwellers and municipalities:

- floating homes
- amphibious buildings

The single measures as well as different materials and modes of application are usually well described (e.g. CIRIA-Advice sheet, 2004), in some cases roughly estimating the costs (ABI, 2005 and ABI, 2005a). They reflect the current practices and specific modes of application at the regional/national level. In general, the current scientific activities relating to flood resilience technologies are going in two basic directions:

- improving the existing systems and measures (e.g. project Noah's Ark[38])
- developing new technologies (e.g. projects SMARTEST[23], KLIMZUG- Nord[39])

Both, existing buildings and new developments are being considered. The already realised shortcomings of the existing systems and techniques (e.g. limits due to limited flood depth) are to be overcome by the development of new strategies and technologies (e.g. SMARTEST[23]).

Additionally, the interactions of resilient materials with other requirements for buildings such as passive housing, are being researched (e.g. INTERREG IVb Project Build with Care[40]), which leads to a necessity for the definition of building codes or standard procedures when applying resilient measures for the built environment.

Flood resilient measures for buildings can be combined in a way to protect several blocks of properties or city quarters, encompassing other elements of urban fabric such as infrastructure or combined with other non-structural responses such as warning systems. In some cases, these have to be integrated into landscape planning such as in the case of the City of Bad Kreuznach, Germany (Umrisse, 2007[41]) or the city of Wörth, Germany (Moser, 2008). The combination of resilience technologies for buildings and early warning has been researched within the Crue EraNet- SUCA project[42] for a combination of fluvial and pluvial flooding, opening room for the development of new automatic systems that can respond with a very short reaction time. Referring to the outcomes of the EraNet Crue- SUCA project Pasche et al., 2008 emphasise the research need for these combined solutions for flood resilient measures for buildings.

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38 http://noahsark.isac.cnr.it/ (last accessed: January 2010)

39 http://klimzug-nord.de/ (last accessed: January 2015)

40 http://www.buildwithcare.net/ (last accessed: January 2010)

41 http://www.umrisse.de/Archiv/umrisse_2007_05.pdf (last accessed: January 2015)

42 http://suca.wb.tu-harburg.de (last accessed: March 2014)

Development and greater acceptance of resilience strategies[43] for buildings has opened a niche market for flood products. At present there are numerous institutions or companies offering flood resilience products or services (e.g., IBS[44]). Within the EU FP7 Project SMARTEST[23] over 200 companies across Europe have been identified as manufacturers of flood products[45]. Although these products are in some cases well documented and available to the interested public (e.g. Blue Pages[34]), the transparency of their performance and the efficiency in case of flooding is low[46]. This also applies when they are combined with other non-structural measures (e.g. SMARTEST[23]).

Summary:

Although the measures of dry and wetproofing are well established and generally accepted, a systematic analysis of their performance under given conditions and the possibilities to combine them into systems is still emergent. Also, a systematic assessment of their performance is in its initial phase (Garvin et al., 2013).

2.2.2 Evaluating the flood resilience strategies and measures for buildings

Resilience measures and systems can be assessed in terms of their performance, expressed in monetary and non monetary values. In the sense of the monetary assessment, the reduction in damage achieved by the measures is compared with the cost of the measures to be applied (e.g. DEFRA, 2007). For such an analysis, methods and tools for damage assessment are required as well as assessment methods for the performance of the measures. Cost benefit analyses as well as multi criteria analyses are often used for the final evaluation of different variants (e.g. DEFRA, 2004).

2.2.2.1 Methods for damage assessment[47]

Damage assessment is the basis for any risk management related decision making, irrespective of scale (e.g. Penning- Rowsell et al., 2003). It gives an input for the decision

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[43] It is evident that there is inconsistency in terminology throughout the promotional and published material available. For example, in the DEFRA (2007) document, dry-proofing measures are referred to as “flood resistant” measures whereby wet-proofing is denoted as “flood resilience” measures. Similarly, free standing barriers are described as temporary resistance products. Contrary to this approach, the Crue EraNet Consortium denotes all these measures as flood resilience measures, as they fall under the banner of “living with floods” strategies and as such are devoted to enhancing the resiliency of the system.

[44] http://www.hochwasserschutz.de/ (last accessed: January 2015)

[45] http://tech.floodresilience.eu/companies/ (last accessed: January 2015)

[46] The performace of the measures will be addressed in section 2.2.2.

[47] Parts of this section have been published and submitted as the authors contribution to the report 4.2 of the FP7 Project SMARTesT, Manojlovic, N., Nauman T., Schinke R., Spekkers M., Toumazis A., Giangola-Murzyn A., Deroubaix J-F, Barocca, B., Moulin E. (2012) Flood reislience Tools, Report 4.2, SMARTeST

making and planning of flood risk mitigation measures. There are numerous definitions of flood damage in the literature, differing in scope and level of detail of the term damage.

FloodSite (2005) defines flood damage as [damage to receptors (buildings, infrastructure, goods), production and intangibles (life, cultural and ecological assets) caused by flood]. All these refer to direct damages and losses to properties. But also, floods can cause indirect losses by disrupting industrial production or social activities. A more detailed definition of damage is given by EU-MEDIN[48], where damage can be defined as [the economic loss caused by floods, including damage by inundation, erosion, and/or sediment deposition. Damages also include emergency costs and business or financial losses. Evaluation may be based on the cost of replacing, repairing, or rehabilitating; or the comparative change in market or sales value; or on the change in the income or production caused by flooding].

These definitions show a rather general connotative level encompassing not only direct monetary but also indirect and intangible losses. Types of damage to properties can be structured as depicted in Table 2-2

Table 2-2 Definition of damage – examples (Penning- Rowsell et al., 2003)

		Measurement	
		Tangible	**Intangible**
Form of loss	**Direct**	Damage to building and contents	Loss of an archaeological site
	Indirect	Loss of income/earnings	Inconvenience of post-flood recovery

Or more detailed:

Table 2-3 Commonly used definition of main types of damage and typical examples (adapted from Penning-Rowsell et al., 2003)

DIRECT TANGIBLE LOSSES FOR FLOODED HOUSEHOLDS	**INTANGIBLE LOSSES ON FLOODED HOUSEHOLDS**	**INDIRECT LOSSES ON FLOODED HOUSEHOLDS**	**INDIRECT LOSSES FOR NON-FLOODED HOUSEHOLDS**
▪ Damage to building fabric ▪ Damage to household inventory items ▪ Clean-up	▪ Worry about future flooding ▪ Loss of memorabilia and irreplaceable items and pets ▪ Damage to	▪ Permanent evacuation from area ▪ Disruption to household due to flood damage ▪ Evacuation costs	▪ Increased travel costs ▪ Loss of income ▪ Loss of utility services ▪ Loss of other

48 http://www.eu-medin.org/ (last accessed: January 2015)

costs	physical and/or mental health, death or injury ▪ Loss of confidence in authorities and services	▪ Disruption due to flood warnings or alarms ▪ Loss of utility services ▪ …	services ▪ Loss of leisure and recreational opportunities ▪ …

Whereby Penning-Rowsell et al., 2003 define different types of damages as:
Direct damage is direct loss to properties, i.e. physical, chemical or biological degradation of fabric and contents. Direct damage is also related to people i.e. deaths, illnesses and infirmities.

Indirect damage is the loss that represents the additional effort caused by the flood event and not the loss that occurs on the object itself (e.g. loss of income, evacuation costs)

Tangible damage can be expressed in monetary values in contrast to intangible damage.

It is also necessary to acknowledge that the underlying definition of the term ***damage*** can also vary significantly depending on the interests of the stakeholders involved. (Meyer et al., 2005)

Although it is acknowledged that direct intangible damage or indirect damage play an important or even dominating role in evaluating flood impacts (Penning-Rowsell et al., 2003), the largest part of the literature concerns direct tangible damage (Merz et al., 2004). Within this work, the focus will be put on direct tangible damage. The aspect of indirect damage will not be discussed in more detail here, but considered on a general level.
The methodology for assessment of tangible direct damage [is well-known and relatively uncontroversial] (Penning-Rowsell et al., 2000). It is a substantial part of the risk assessment that combines probability of future flood events to be averted, and a vulnerability assessment in terms of the damage that would be caused by those floods and therefore the economic savings to be gained by their reduction (FloodSite, 2006).
Also, damage has an individual and cultural aspect and is related to lifestyle and quality of living (Penning-Rowsell et al., 2000), but the research on this issue is rather scarce and mostly not addressed when discussing the damage assessment methods.
Depending on the decision making level on flood risk mitigation, different scales of approach are applied, being *macro, medium and micro* (Messner et al., 2007).
Methodologically the macro and medium scale approaches assess damage assigned to a spatial unit or a certain area. The overall damage is then obtained by summation of the damages in the individual spatial units.
This approach is performed on the state or regional level (macro) as well as on the regional/community level (medium). The outcomes of the damage assessment at the regional level are rather coarse and usually serve as a basis for prescreening of the mitigation or resilient strategies, i.e. for a preliminary assessment (e.g. IKSE, 2001). On the regional/community level, the level of detail is higher but still the dwellers do not get the

possibility to assess damage for their own property as the information is given for the area and not for the individual properties. Due to the fact that very precise methods require more effort (i.e. time and money) than less detailed approaches and that the resources are usually limited, the most precise methods are often restricted to small areas under investigation, while studies with a research area of regional or even national size mostly have to rely on less detailed methods (Meyer et al., 2005).

Therefore, for defining property scale flood risk mitigation, a more detailed approach has to be applied. This approach is based on the OBJECT related damage assessment, i.e. that the assessment is being performed at the property and building level.

As there is a substantial difference between these two approaches, different methods and models have to be developed to support the damage assessment at different scales.

Methods for the medium-scale approach

A central idea in flood damage estimation at the medium scale is the concept of ***damage functions*** (Kron, 2007). The basic idea of damage functions is to relate the flood parameters or intensity of flooding (such as flood depth, velocity or duration) and the description of the built environment to monetary expressions of direct damage (Smith, 1994). These show the damaged share (relative damage functions) or the absolute amount of damages (absolute damage functions) of a certain group of elements at risk as a function of the magnitude of defined inundation characteristics. Relative damage functions for each asset or unit of assets defines the damaged share of the total value as a function of inundation depth, or flood parameter (see Figure 2-6, IKSE, 2003). Absolute damage functions are derived based on the asset values and their susceptibility against different flood parameters (see Figure 2-8, Penning- Rowsell et al., 2003). In current practice, the main inundation parameter considered in these damage functions is the flood depth defining the depth-damage functions. Others, like velocity, duration and time of occurrence are only sporadically taken into account. As relative damage functions define a percentage of an overall value, they are “normalized” and as such it is to be expected that they are easier to transfer to other regions and units. The advantage of the absolute functions is that they already contain the asset value data that need not be further researched (Penning- Rowsell et al., 2003). Regarding the applicability of these function types to private stakeholders, the idea of delivering absolute values should be more convenient as percentage values can be confusing or misinterpreted by them.

In terms of the timing for damage estimation, there are two main approaches in estimating direct flood damages. They are the *ex post* and *ex ante* method (e.g. Zevenbergen et al., 2007, Mayer et al., 2005)

The ex post method is based on the damage data collected from historical flood events. Relevant parameters influencing damage (description of built environment as well as the flood parameters) are stored in databases and **averaged** functions are derived expressing the dependences between the flood parameters and direct damage for different built environment conditions (Kron, 2007).

For the functions developed for planning on large and transboundary areas such as the Rhine Atlas (IKSR 2001) total asset value was taken from economic statistics and distributed based on the landuse categories, distinguishing between investments in building fabric and movable assets. An example of such a function is (IKSR, 2001):

Settlement, immobile $Y = 2x^2 + 2x$

Settlement equipment $Y = 12x + 16.25\{x = 1...7\}$

The relative functions within the (IKSE, 2003) study have been developed based on the ex-post analysis of the floods in the summer of 2002. They are given for different use categories such as settlements, industry or traffic as depicted in Figure 2-6.

These approaches have an advantage of being simple and easy to apply in the case that the asset data are available. In terms of their applicability for local properties, the information provided is unsatisfactory when downscaling it to the property level. For example, for the flood depth of 1m the settlements have a damage equal to 20% of the asset value independently of which types of buildings and contents are in the settlement (Figure 2-6).

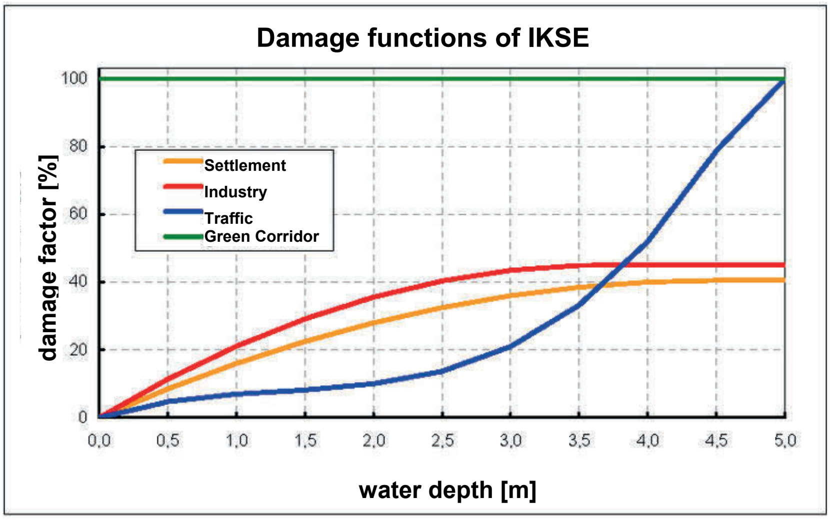

Figure 2-6 Example of the damage function (IKSE, 2003)

Damage assessment can be performed as a part of risk assessment procedures, where damage assessment modules are integrated into platforms or modelling tools for risk assessment. Such an approach can be appreciated in the works of various authors such as (Dutta et al., 2003) or (Vojinovic, 2008). Dutta et al., (2003) introduced an integrated model for flood loss estimation in a river basin based on hydrologic models and a distributed flood loss estimation model. The loss estimation model is based on stage-damage relationships between different flood inundation parameters and landuse features. It calculates the economic loss to different landuse features based on the simulated flood parameters obtained from the hydrologic model for any flood event applying relative stage-damage curves. This approach, although offering integral risk assessment damage functions, is still too coarse to be applied for planning at the property level.

Vojinovic (2008) used an integrative hydroinformatics system for risk assessment, including hydrodynamic models for flood probability assessment and GIS and remotely sensed data.

For the calculation of tangible direct damages the costs are calculated on the basis of model results and cross-referenced against depth damage curves for a series of rainfall events. The damage estimation was based on the general assumption that the monetary damage depends on the type of building and its size. Different size classes are defined for residential, commercial and industrial buildings ranging from 50 to 1000 m^2. Based on historical data, flood stage damage curves have been developed for each category of building which has been visualised in a GIS system within the applied platform. An example of the functions for small and large residential buildings and their representation in a map from Vojinovic, 2008 is given in Figure 2-7.
This approach represents a more detailed version of the medium scale method as it classifies buildings based on size and type criteria. The possibility of using one platform for calculation and GIS based processing of data can be advantageous, as in this way both the building and the regional scale can be combined. Although introducing a certain level of classification achieving a higher level of detail, this method of damage assessment is still based on statistical values and as such is not sensitive to differences in the built environment in individual cases. As such, it is not suited to the dwellers needs.

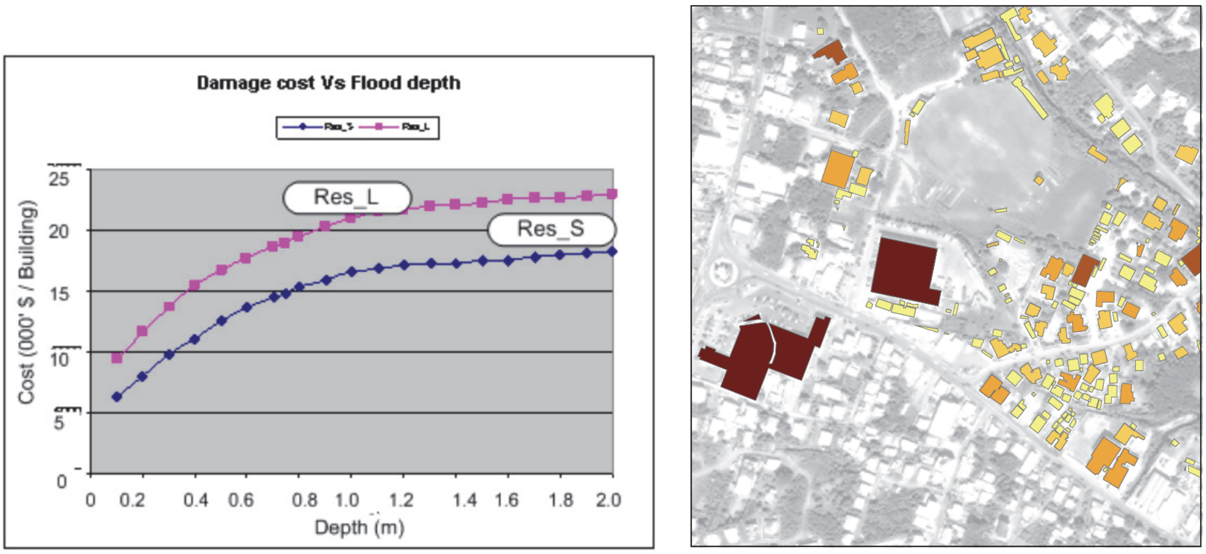

Figure 2-7 a) Flood damage curves (Res_L- large residential units, Res_S- small residential units); b) damage visualisation in a GIS system expressed in $ US(legend: light yellow: 0.00- 10176.10; yellow: 10176.11-31402.00; orange: 31402.01-70112.70; light brown: 70112.71-197107.61; dark brown: 197107.62- 334326.00) (Vojinovic, 2008)

Micro scale approach-Object related; including physical analysis of the materials and building components

A physically based approach is needed to fully understand the behaviour of the building fabric and assess the potential damage in a flood prone area (e.g. Neubert et al., 2008, Kelman, 2003). Instead of using spatial units for assessment of flood damage, the object related approach considers the characteristics of the built environment and its susceptibility to flood damage for different flooding parameters. This approach is usually performed applying the *ex ante* method. This method is based on predefined relationships between flood parameters and flood damage deriving so called synthetic functions. Synthetic means that these functions are not directly derived from an analysis of real properties which have been flooded in the past, but are instead defined for standardised, typical property/ building types (see e.g. Penning-Rowsell et al., 2003) based on the susceptibility of the building components. Firstly these building types have to be defined, the value of the assets assessed and finally the susceptibility of each of these items, i.e. the proportional damage depending on inundation depth, estimated by expert assessors. Summing up these damage estimates of all items, a damage function for each building type can be derived.

The most comprehensive example of such a method and corresponding data sources are developed at the FHRC[49], published within their blue coloured manual and multicoloured manual containing such synthetic functions for residential and commercial buildings in the UK. The buildings are classified into categories based on their type, building periods, and different social class of the dwellings' occupants (Penning-Rowsell et al., 2003). The hypothetical (or potential) damage for building fabric and content is given in form of depth/duration/damage curves for different classes of buildings reaching a total of 100. An example of such a curve can be appreciated in Figure 2-8. Green et al. (1994) state that the main difficulty in this approach is ensuring that the synthetically constructed standard property types truly represent actual properties with all their components. Also, such functions are strongly locally related and it is difficult to transfer them to other regions. It gets even more complicated in the case of the absolute functions as the stock values have to be changed by a certain factor, which introduces further approximations.

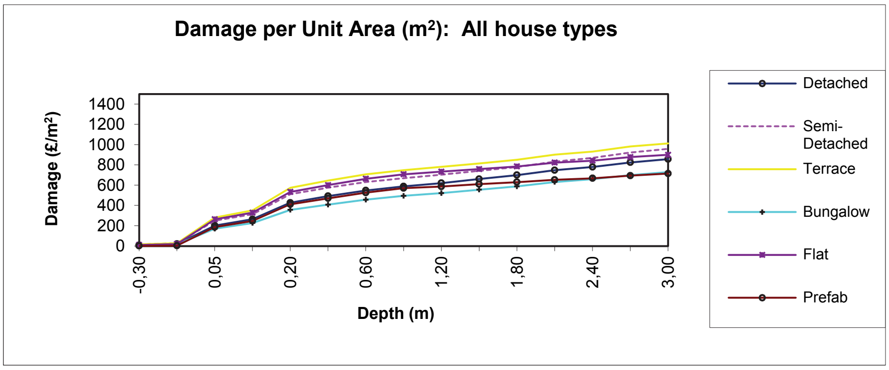

Figure 2-8 Example of standard depth/damage/duration data for different house types (Penning Rowsell et al., 2003)

In German speaking countries, comprehensive damage assessment methods can be performed based on the data of the HOWAS[50] database. The last update of the methodology has been performed within the MEDIS project. It has been focused on the development of methods and tools for assessment of economic losses, where the damage to the built environment has the dominant role. By means of interviews with the experts from different fields (e.g. flood management or insurance; in total 58) a list of 20 to 30 core criteria were identified for each of the categories which contribute most to overall damages, i.e. private households,

[49] http://www.fhrc.mdx.ac.uk/ (last accessed: January 2015)

[50] More about HOWAS database can be found in the section development of databases of flood damage data

businesses or public sector. For each sector the core criteria are classified into four areas of information and are given as (Thieken et al., 2009):

- Event information (e.g. type of flood, date, water level)
- Object information (address, building and basement occupancy, building type)
- Damage information (e.g. replacement costs for building and contents)
- Information about loss reduction (e.g. flood defence measures, advance warning time)

The authors define minimal criteria for describing damage in the residential sector. As this approach aims for the standardisation of data the collection procedure and is a result of multi stakeholder involvement in the process of criteria definition, it can be taken as an orientation. However, for any detailed property level assessment of potential damage it is not of a high enough level of detail and should be further refined.

For the purpose of assessing the efficiency of flood proofing in the Netherlands, Gersonius et al., 2010 developed synthetic damage functions for defined building types. Damage potential is therefore assessed based on the susceptibility of the structure to damage if it is flooded. Repair costs are adopted for building fabric and contents using secondary data sources and consulting a loss adjuster. Repair costs are divided into differentiated subgroups including costs for clean up and disinfection as well as costs for walls, floors, installations etc. This approach is an improvement in refining the damage analysis of single elements, making it more modular in the sense of damage assessment as different “modules” or damage categories can be exchanged, gaining flexibility. Still the assessment of different combinations of materials in one building element is not sufficiently considered when assessing flood damage. Also, the susceptibility of the content taken from FEMA, 2001 is rather general, with little transparency in terms of the assumptions taken and as such is subjected to refinement.

A novel approach in assessing damage to buildings has been achieved within the Urban Flood Management project for the city of Dordrecht, the Netherlands (Veerbeek, 2009). Aiming at developing a flood damage model that adopts the urban scale in flood damage estimation, the model incorporates methods of analysis linking the spatial distribution of flood damages, feature types, typological categories, and damage components age of the building stock to gain a comprehensive view on the financial consequences of urban flooding. The functions presented in Figure 2-9 are given as aggregated values for different neighbourhoods in the study area for annual exceedance probability.

Veerbeek, 2009 concluded that [although a comprehensive set of stage-damage curves has been composed, the absence of historical flood damage records in the Netherlands increases uncertainty about the estimated damage levels. More stage-damage curves are still needed for a multitude of features of housing types]. Still, this method offers a deeper insight into the sensitivity of flood damages in dependency of building features.

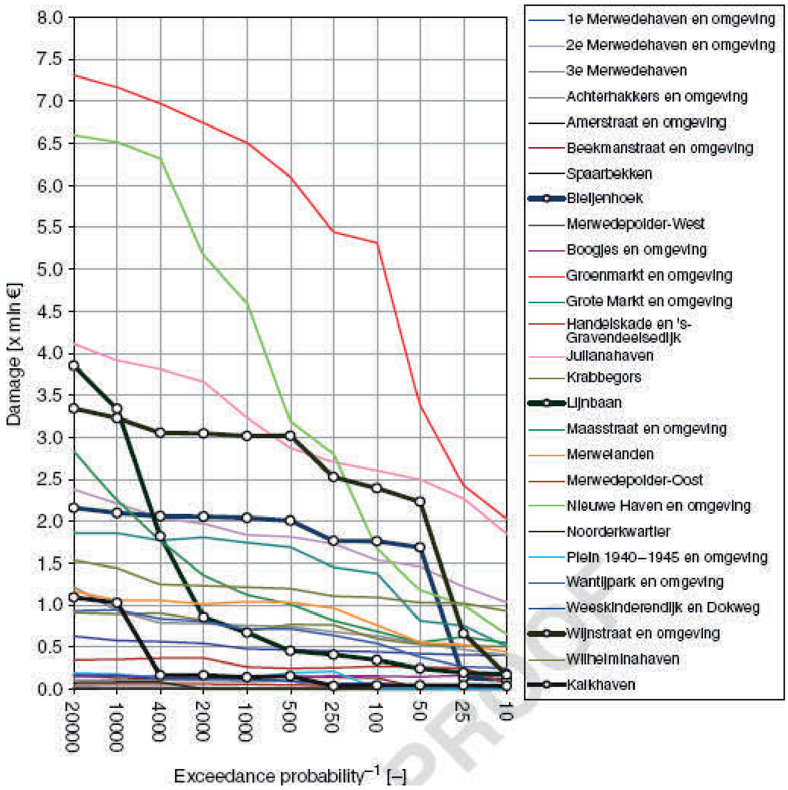

Figure 2-9 Damage curves for individual neighbourhoods within the case-study area for annual exceedance probabilities between 1:10 and 1:20 000 (Veerbeek, 2009)

A new bottom up approach and simulation model for potential damages of buildings and constructed assets has been introduced by Neubert et al, 2008. The core of the simulation model HOWAD for potential damages to the built environment and constructed assets are so called Urban-Structural-Types (UST) that are defined by physiognomic homogeneous characters of the built environment. The representatives of UST are defined based on building types and regional particularities, using building age as a general guidance for classification.

Damage functions based on refurbishment costs and authorised building surveyors are created. Damage has been assessed based on the step-by-step virtual flooding of a typical building and the assignment of costs for craftsman work for any replacement needed, drying up of the building components and restoration according to current technical standards (Figure 2-10). Damage is considered due to water and moisture, contamination and load bearing construction.

Although this approach delivers a considerably high level of detail and physical considerations when defining damage, it is still based on typologies, averaged costs and spatial distribution of damage and as such is not dedicated to private stakeholders and damage assessment of single properties. More flexible tools for calculation of damage for single properties defined by the users are needed which are able to assess damage for different combinations of building structure and contents, and which reflect the real configuration of the properties.

Figure 2-10 Virtual flooding of buildings for determination of refurbishment costs of a representative based on construction works (Neubert et al., 2008)

Kelman (2003) developed a method to determine the impacts on residences in coastal, eastern England, selecting Canvey Island on the Thames Estuary and Kingston-upon-Hull on the Humber Estuary as the case study areas. Field surveys determined the characteristics of the physical vulnerability of residences in these locations to floods. A first-order analysis indicated the failure modes of most prominent concern to be analysed in detail. For example:

- Analysis of glass failure, focused on large, low units in doors.
- Analysis of wall failure, focused on cavity walls of unreinforced masonry.

The observations and calculations were applied to developing a new form of vulnerability profiling: two-dimensional "vulnerability matrices" with a flood depth differential along one axis, flood velocity along the other axis, and the matrix cells displaying a damage outcome. The "loss equivalent percentage" method of describing quantitative risk was presented for simulated storm surge scenarios on Canvey Island. The results apply specifically to modern residences in England because these were the residences observed in the field surveys. The techniques and methods nevertheless could be used for similar analyses for other locations, other residence types, and other disasters. This study provides new knowledge and methods which contribute to understanding, describing, and managing society's risk to natural disasters (Kelman, 2003). Kelman gave the overview of studies of residence flood damage and losses outside the UK. The study is very thorough, however, very locally related and hardly can be applied for the other regions without considerable effort of transferring the outcomes from the areas researched within the project to an arbitrary area.

Contribution to damage assessment from material science research

Material science methods analyse physical processes in the materials that are directly or indirectly related to the flooding process, such as influence of the moisture content in the brickwork. Indirect studies are, for example, the studies on mechanisms of concrete deterioration due to efflorescence or performance characteristics and practical applications of common building thermal insulation materials including moisture aspects (Al-Homoud, 2005).

These methods consider the physics of the materials and aim at understanding of the damage mechanism (e.g. Chow, 2004, Deluchi et al., 2001). They often remain on the research level, giving little guidelines on practical application or quantification of such damage. A monetary expression of potential damage is however needed for assessment of the performance of the measures applied in terms of CBA (e.g. DEFRA, 2004).

Data collection procedures

The decisive contribution to high quality damage assessment is the quality of data (e.g. Thieken et al., 2009). The quality and reliability of data vary, depending mostly on the type of collection methods and timing of collection. Method of collection is also related to the selected damage assessment approach. In case that the *ex ante* method is applied, data collection implies the assessment of the building fabric and contents independently of the timing. In case that *ex post* analysis is applied, damage data has to be collected.

There are two basic methods for performing data collection - interviews with the dwellers (either personally or by telephone interviews using questionnaires) and on site collection by experts (e.g. Merz et al., 2004; Gersonius et al., 2010, Kron, 2007). Whereby the expertise on site is a costly method, the quality of such data is considered to be better (MEDIS[51], 2005, Thieken et al., 2009). Data collection is much faster when interviewing the residents than individual assessment by experts, but the quality of data is difficult to control. Due to this heterogeneity in methodology and quality of collected data, there is an attempt to standardise the methods for data collection in the research projects and initiatives EU wide. Within the RIMAX Project- MEDIS an assessment of data collection methodologies has been done with the objective of developing a standardised procedure for data collection. Assessing the intensity of the data collection for an *ex ante* damage assessment approach UTM via collection onsite (see Figure 2-10), within the EU FP7 SMARTEST project[23], Naumann et al., 2010 described it as a very time and resources intensive process with a high potential for improvement.

Regarding the damage data, in the case that the residents are interviewed directly after the flooding, the reported damage is usually higher than the actual one due to emotional stress and the impression of lost quality of life (Kron, 2007). Also, some of the damage develop later (e.g. due to moisture in walls) and can be wrongly estimated if assessed immediately after floods (e.g. Garvin& Kelly, 2004). But also, in the case of the retarded data collection, some damage data can be forgotten and omitted to collect. Also, in the case that the insurance reimburses the costs, even aesthetic damage can be reported as total damage and replaced (NSV[52], 2006). Although for the ex ante damage assessment the description of building fabric

[51] http://www.rimax-hochwasser.de/458.html (last accessed: January 2015)

[52] Personal communication, April, 2006

is required, damage data after a real flood can be collected and used to “calibrate” the *ex ante* model. However the main problems of damage data collection should be mitigated applying methods that are not sensitive to timing of the data collection.

Development of databases of flood damage data

Collection of damage data is resources and time intensive and independently from the source the collected data are to be stored and managed in a way that their analysis or easy handling can be achieved. Such requirements can be fulfilled by the application of databases. There is a large number of databases of damage data, but they are mostly collected for their own purposes and are usually not available to the general public or for research projects (i.e. insurance companies have their own databases such as NSV[70]). They differ in level of detail of the attributes describing built environment and flood parameters and number of datasets collected. Probably the most prominent databases are HOWAS21[53] and FHRC-MCM (Penning-Rowsell et al., 2003).

HOWAS21

In the German-speaking countries, a prominent data source of direct flood losses has been the HOWAS database of the Working Committee of the German federal States’ water Resources Administration (LAWA). The HOWAS database covers inundation depths up to two meters. For a long time the HOWAS database has not been publicly accessible, and [there has been a considerable uncertainty introduced by the raw data scatter (Merz et al., 2004). Much of that uncertainty is based on the large variability of the buildings’ vulnerability and on influences such as oil, raw sewage and chemicals (Egli& Wehner, 2002, Kreibich et al., 2005). Within the RIMAX Project MEDIS the HOWAS database[53] has been further developed and opened to various user groups including the interested public. The database contains object-specific information about flood damage and damage determining factors. This database contains 5167 damage cases (state: July, 2009) collected in different periods within different projects (e.g. MEDIS, MULTISURE[54]) and for different sectors (residential, business units). The data collected complied with the standardised procedure, enabling a comparison and analysis of the collected data. The database is available via the internet, enabling easy access. Although HOWAS21 is with some restrictions open to the interested public, it does not target the public as one of the key user groups. As such, the level of detail of the data to be collected is not optimised for non experts included dwellers and their interests. Still, a browser based database has an advantage as due to its accessibility it is easier for non experts to access it and make use of the data.

FHRC-MCM

[53] http://nadine-ws.gfz-potsdam.de:8080/howasPortal/client/start (last accessed: January 2015)

[54] http://elise.bafg.de/servlet/is/7332/ (last accessed: January 2015)

The Multi Coloured Manual (MCM) for damage evaluation in the UK (Penning-Rowsell et al., 2003) contains data for residential properties, classified by type, age and social status. For each of these 100 residential property types a typical inventory is compiled by means of expert judgement and different statistics and publications. Each of the building fabric and household inventory components is then assessed with its depreciated (average remaining) value. Here again different statistics and publications on market prices of different building components and household goods are used. As in the case of HOWAS21, it is not targeting the non experts, including interested public.
The way of managing data to be useful for dwellers is still a matter of research and should be related to the methods of data collection.

Summary
Although the methods developed for the ***medium scale*** approach are widely applied using stage damage curves, the question of their limits has to be raised. It is mostly related to their accuracy (reliability), with the main shortcomings being:

1. Not enough level of detail for planning of flood resilience measures on the property level
2. No information about the hazard and risk awareness of the stakeholders
3. Stage damage functions are “two dimensional”, i.e. they express the dependence between the flood parameters and potential damage for different built environment scenarios. The information regarding the flood preparedness and the capacity level of stakeholders, among all of the residents, is not being included in such assessments.
4. No understanding of processes in the building and consequently no possibilities to assess improvements. Moreover, some materials behave differently in a compound (such as wall or floor) than when observed separately.

More transparency and understanding of the processes is provided by the ***physically based approach*** at the building or microscale level, but they are either rather theoretical and as such are difficult to apply for assessment of potential damage in a specific case or they have a strong regional aspect.
Although has partly been acknowledged that the damage is also a function of the lifestyle (Penning- Rowsell et al., 2003), the existing assessment methods do not sufficiently consider this aspect by estimating damage in an area. The work performed by (Penning Rowsell et al., 2003) introducing different social classes when defining damaging functions, is a step towards this.

In terms of data collection as research challenge is to develop a high resolution data collection module (that describe a property) but improving the time efficiency of the existing methods. A solution could be the provision of a collection method that enables ‘non experts’- dwellers entering the data independently of the flood event, i.e. a system that should be constantly available for such a process. Appropriate data management and their visualisation should be designed to meet the needs of dwellers (high resolution but easy to understand and access).

2.2.2.2 Assessment of the performance of resilient measures for buildings

The resilient measures to be applied to buildings are assessed in terms of their effectiveness and cost efficiency (e.g. SUCA- Crue EraNet,[42] Pasche et al., 2008).

The efficiency is related to performance of different measures and products. Within the EU FP7 Project SMARTEST[23], the performance of different products is being researched and tested for different flood conditions. A matrix based on the results of these test should serve as a decision support tool for end users (including dwellers) to select the appropriate products for own condition. Also, the projects emphasises the necessity to have a “hands on” performance assessment of the products before they are deployed in a real case. It also attempts to standardise testing procedures at the European level. In some EU countries the national approval procedures already exist (e.g. PAS 1188-2:2003 of the BSI, 2003 in the UK). However, wide implementation and acceptance of these procedures encounter some obstacles, the main one being the affordability of such procedures for small manufacturers. Additional challenge addressed within the project is the performance assessment of the combination of single measures. A set of criteria is to be developed that enable assessment of the resilient performance of the combined strategies (Garvin et al., 2011).

Jackson (2010) has developed several methods to ensure safe use of inter alia combined resilient measures such as FMECA (Failure Modes, Effects and Criticality Analysis). For example, the failure mode analysis has an aim to assess the performance of a resilient system as a result of e.g. inappropriate decision taken or mismanagement of the given system. Still this approach has not been implemented and operationalised sufficiently to meet the needs of the performance assessment of the resilient measures by definition of concrete parameters or criteria) and is still a matter of further research (e.g. Garvin et al., 2011)

For the assessment of the cost effectiveness, the results of the damage assessment is required to perform a cost benefit analysis (e.g. DEFRA, 2004, Zevenbergen et al., 2007)

DEFRA, 2007 is devoted to broadly determine the suitability and cost effectiveness of a variety of flood resilience measures at the property level. Based on the case studies from the UK, [the resilience measures have been proven to be effective, both through laboratory testing and more recently through anecdotal evidence of flooded properties.] (DEFRA, 2007). The document also delivers some best practices and concrete recommendations for efficient application towards individual properties.

The research carried out by CIRIA, 2007 for Communities and Local Government (DCLG) and the Environment Agency investigated the optimal application of measures for the built environment, including both existing housing and new developments. For example, it has been recommended that for new buildings the use of [resistance measures (which are designed to cover or protect the building fabric) should be limited to floods at a certain depth (up to 600mm predominantly due to stability issues). Within the FLOWS project[85] the Norwich Union assessed the cost and time savings for the repair of standard and resilient houses for different water depths for the case study areas[55]. The results demonstrated

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[55] http://www.floodresilienthome.com (last accessed: March 2009)

monetary savings of approx. 23000 GBP and up to 42 days in time in the case that flood water reaches 1 metre. Although the study could show obvious benefits of resilience measures to minimise damage by flooding and speed up repair time it can hardly be generalised. More research on different building types and different combinations of resilience measures is still required.

Zevenbergen et al. (2007) assessed the economic feasibility of flood proofing domestic dwellings based on the selected case studies in the Netherlands. Economic assessments of different types and combinations of flood proofing options were performed using the cost benefit analysis as criteria. The study showed that for the new dwellings in the case study areas in the Netherlands, simple flood proofing techniques can provide cost effective measures for flood protection in low lying areas. Still, further systematic analysis in both, the damage assessment and measure performance are required. Also, an analysis on the building has not been targeted by this research. Ashley et al., 2007 developed a GIS based system for assessing the resilience level in urban areas. The 4As concept of resilience (FIAC- Scottish Government, 2007) has been used for defining the criteria of the resilience level. This level is then assessed based on site visits and dwellers' feedback. Apart from the resilience level, the actions to be undertaken have been defined. Figure 2-11 depicts the GIS representation of these areas.

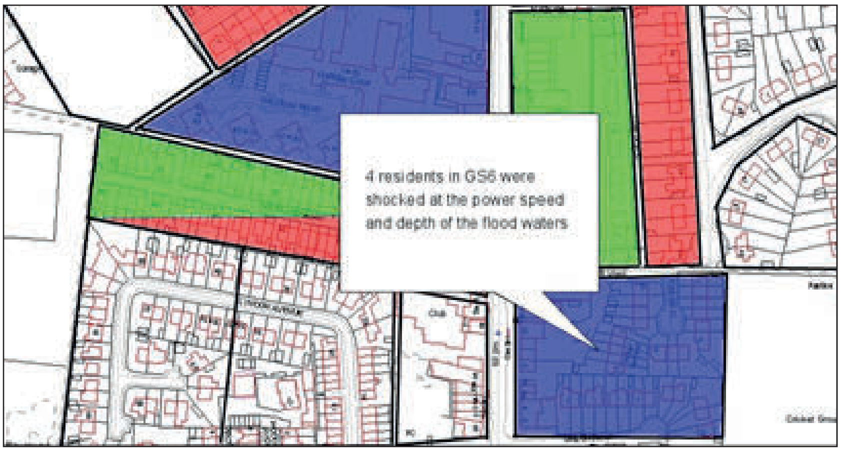

Figure 2-11 Highlighting the areas where requirements of the 4As are lacking and therefore have low resilience level (based on the dwellers feedback) (Ashley et al., 2008)

Different colours define the actions to be taken and whom they are addressing. For example, red means that actions are to be undertaken to help dwellers understand their vulnerability level, which should be the task of professionals. Although this approach intends to assess the resilience level of the dwellings and their tenants, little help is given to the dwellers themselves. Still, the mapping of the dwellers' feedback helps to give a more realistic representation of the situation and already helps towards the first step of getting them "on board". It also helps in maintaining long term activities in the area.

Apart from the studies based on observed and collected data on site and based on the residents' feedback, experimental studies are being performed to assess the performance of different resilient measures and materials. Research on flood resilient construction has been carried out through a consortium led by CIRIA to improve the flood performance of new buildings through improved materials, methods and details. The outcome of the study is a guidance document for key stakeholders on resilient building (Tagg, unknown, CIRIA 2007).

Summary:

Although flood resilience of the buildings and the associated measures are gaining importance and is being increasingly appreciated both by research institutions and practitioners, a systematic approach of the assessment of their performance is still a matter of research, especially related to the combination of single measures (e.g. Zevenbergen et al. 2007, SMARTEST[23]). The hands on experience/ tests of flood products and materials should be considered for the performance assessment. Criteria for assessment of the measures performance based on the resilience principle as introduced in section 2.1.1 are an open issue and are to be developed.

2.2.3 Strategies to support dwellers in the decision making referring to the phases of the UFM cycle

Analysing the flood risk management cycle as depicted in Figure 2-1 (also, WMO, 2008 LAWA, 2011) and the role of dwellers in UFM, the strategies and phases to support of dwellers are before, during and after a flood event as following:

[1] Support in the planning phase of the resilience measures (before and after a flood event)

[2] Support during a flood event

[3] Support in the implementation phase (before and after a flood event)

2.2.3.1 Support in the planning phase of resilience measures

Planning procedures for a resilient built environment are dealing with problems where the solutions are not a priori known, creating a pool of options that can be considered for the final decision. Selecting the final flood resilient option is based on a set of criteria, predominantly economic but should not limit to this. The National Technical Advisory Group on Flooding Issues (2004) delivers the recommendations for sustainable decision making on the resilient buildings within FRM as: (1) A whole-life (construction, maintenance, running and renewal) view of the costs and benefits is essential, (2) each option considered will require its own assessment of the sustainability of the solution, (3) decision-making tools will include Cost Benefit Analysis but will not be limited to this, (4) and should make the ‘values’ applied explicit. It means that all possible solutions and criteria should be considered by dwellers, qualifying the planning activity as the key process for achieving resilient buildings. Due to the complexity of these processes and system functions, tools and instruments are usually needed in the decision process that should facilitate an efficient planning procedure (see 2.2.4).

Support in the planning process is usually offered by the authorities and agencies, non governmental institutions (e.g. NFF[34]) and industry (insurance or construction). The strategies vary from personal, tailored support through on site visits of experts to creating solutions for concrete buildings (e.g. insurance companies such as NSV[90]) to rather generalised support in the form of defined steps to be done (e.g. websites of national or local agencies e.g. Federal Alliance for Safe Homes- FLASH[67]). An overview of the main tools supporting decision making in the planning phase is given in section 2.2.4. The adequate planning strategy should make sure that the dwellers have available all expertise required for decision making on their own properties. In case of the personal support (by experts) this is likely to be the case, but the question of its feasibility should be raised, especially in the case of large communities with a high number of properties to be managed. The strategies should be considered that combine the experts knowledge tailored to concrete problems and situations, but applying a system where this knowledge can be made available to a larger group. A potential is seen in using computer based tools to support this strategy, which will be discussed in section 2.2.4.

2.2.3.2 Support during the flood event

The act of providing resources (staff and equipment) during a flood event[56] is mostly regulated by laws and provided by the responsible authority. The efficiency of these measures depends on available response time and the preparedness level of the stakeholders (i.e. dwellers, responsible authorities and institutions). One of the most commonly used methods of preparing the residents for a flood event is in the form of brochures or checklists issued by the responsible authorities (e.g. BfBVS, 2008, Environment Agency).

This strategy, although it gives a good overview of the actions to be taken in the case of a flood event, is not considered as the best strategy to empower local people to react effectively in emergency situations. Adequate reaction in the case of an emergency starts with the raising of flood awareness, demonstrating how difficult it is to rely on a rational and rapid response in the case of a flood (e.g. Musahl, 1997, 2009)[57]. The responsible authority of the city of Hamburg (the Ministry of Internal Affairs) organises regular events called "Katastrophenschutztag" with the objective to inform dwellers about the procedures and responsibilities when there may be an extreme flood event due to storm surges. However, the efficiency of this method is difficult to assess and the carrying out of more "hands on" events has been assessed as crucial to gain motivation from participants[57] [58].

Examples of the means to support the dwellers in emergency are depicted in Figure 2-12.

[56] As this work concentrate on improvement of the built environment, the support during the evacuation and contingency management will not be here addressed.

[57] This aspect will be analysed in more details when in section 2.3

[58] Ministry of Internal Affairs: Poser A.: personal communication during the Katastrophenschutztag on 20.09.08.

Figure 2-12 Support in an emergency: a) extract from the Environment Agency's new „Preparing for a Flood's guide; b) extract from the Hochwasserschutzfibel, (BfBVS 2003, 2008)

Additionally, the research outcomes of several EU Projects (e.g. SUCA- Pasche et al., 2008) indicate that resilience measures can only be efficiently applied if the responsible authorities have a good knowledge of the local conditions in the area; if possible based on input and feedback from local people. This leads to the conclusion that there is a necessity for provision of a system which enables such communication and is linked to both planning and implementation of resilience measures.

2.2.3.3 Support in the implementation of flood resilient measures (before and after a flood event)

Support to residents in the implementation phase can occur either in the form of consultancy, i.e. expert knowledge or by provision of financial aid. The provision of consultancy usually extends the support offered during the planning phase by some governmental institutions and municipalities or insurance companies (e.g. NSV[90]). This kind of support "inherits" the problems of the support in the planning phase, the main one being the availability of the experts. Financial assistance can be provided by insurance of the residual risk e.g. FIAC, 2007), as well as financial and non-financial stimulation (e.g. Bichard& Kazmierczak, 2010) of the application of flood resilience technology.

Insurance:

The idea of insurance is not novel. It is a model which has been applied for managing natural hazards, including floods, for decades (e.g. the UK, as a pioneer, started including floods in the package policies in 1961, Crichton, 2005). There are numerous studies and publications giving the overview of the main insurance systems in Europe and worldwide (e.g. Crichton, 2005, Lamond et al., 2008) subdividing private insurance into bundles[59] (e.g. in UK or Japan)

[59] Cover of flood is only available if it is „bundled" with other perils such as such as storm, earthquake etc.

and option systems[60] (e.g. in Germany, Australia). But in the context of FRM, the role and business model of insurance companies is still an emergent issue. How and to what extent could and should insurance consider resilience measures when defining their policies and the requirements for it? In the UK, flood resilient buildings are generally encouraged by the insurance industry and flood resilient repair is a potential opportunity to reduce vulnerability in the building stock. However, the responsibility and cost for flood resilience generally has to be borne by the homeowner (Lawson, 2008). Still, there is also an additional cost that is involved in flood resilient repair that is not welcomed by most insurers, influencing the competition in the market for insurance. The problem generally occurs in case of floods in small urban catchments. For example, in Germany this is in its initial phase. At present insurance companies define without proof a zone of 100 m adjacent to urban watercourses as a risk zone in which no insurance is given to buildings (Pasche et al., 2008). However, the insurance companies have started to determine flood prone areas based on mathematical models, for which they rely on their own methods. The “Zonierungssystem für Überschwemmung, Rückstau und Starkregen” (ZÜRS) is a zoning system of the German insurers for estimation of potential risk due to overflow and storm events, which is unique for the whole of Germany. The French system of solidarity discourages those at risk from doing anything as they know they will be compensated.

Insurance should take a more proactive role in raising risk awareness among the insured (Pitt, 2008, Kron& Thumerer, 2002, Kron, 2004). Sir M. Pitt (2008) in his report referring to the flood events in England in 2007, recommends that [the insurance industry should develop and implement industry guidance for flooding events, covering reasonable expectations of the performance of insurers and reasonable actions of customers.] Insurers should influence the attitudes of the clients by adopting incentives for risk reducing behaviour, so that efforts to minimise damage are encouraged, not undermined (Baan, 2005). In other words the insurance companies are not perceived as mere contractors in the area and should take a more active role in UFM, which also includes more intensive communication with those insured.

Within the KLIMZUG-Nord project (http://klimzug-nord.de/), a “safety chain” of resilience, composed of the manufacturers, a certification institution (TÜV-Nord) and an insurance company (Hamburger Feuerkasse) has been built in order to assess the insurability of buildings prone to floods when equipped by the resilience measures. The outcome of the KLIMZUG- Nord Project is that the insurance needs a reliable tool that would support insurers in the risk assessment and resilient planning. It is important to quantify the effectiveness of such measures.

The Association of German Insurers (GDV) has started the initiative to issue the Flood Resilience Certificate as a new and promoted web based tool in order to enable object-specific hazards evaluation. It should serve as an indicator of the insurability of the tested buildings and further contribute of the insurance industry to support the risk management in the practice (GDV, 2012).

[60] Insurers agree to extend their policy to include flood on payment of an additional premium

There is a clear need stated in the above mentioned publications to develop tools that reliably can assess the estimated damage at the building scale for different flood types. It has been seen as beneficial to involve dwellers in the process of data collection allowing them to use tools and assess their own level of affect.
Also, insurance databases are a promising source of quantitative damage data, although access to data is often difficult (Spekkers et al., 2013). Therefore, it is assessed as beneficial to utilise this data when developing methods and tools. It can also contribute to better involvement of the insurance as one of the key player in resilient planning.

Financial Incentives:
Financial aid for the implementation of flood resilience measures is a strategy used by governmental institutions or municipalities as well as by the industry (e.g. insurance companies). This strategy implies that the residents are granted a certain sum of money if they implement flood resilience measures on their properties. Steinführer et al. (2009) recommend the investigation of possibilities of financial or other mechanisms to support lower income groups to adopt flood resilient measures as one of the key strategies to manage communities at risk, based on case studies in Germany and Italy. Financial aid can be used as additional support offered by insurance companies. The insurance company NSV in canton Nidwalden, Switzerland financially supports 10% of the resilience measures of those insured, with still a rather sporadic response (Kohler, 2006).
Although the idea of incentives sounds attractive as they imply less expenses that are to be borne by dwellers, their effectiveness should not be taken for granted. Capacity of the community plays an important role, as well as the timing and the context this strategy is applied in. Such an example is the community of Wertheim, Germany, on the river Main, where due to local conditions it was not possible to protect the frequently flooded historic area in a conventional way. Finally, the community decided to “live with flood”. Even with financial incentives, the implementation of the concept is moving slowly, accompanied with low interest from stakeholders (Moser, 2007).
Within the FloodSite project (Steinführer et al., 2009) the extensive compensation based on the German cases has been evaluated positively in terms of rapid recovery, personal well-being and high satisfaction. The outcomes of the project, however, question the sustainability of this strategy and evaluate it as being frequently counterproductive with regard to personal preparedness.

Non- cash rewards
Instead of providing financial incentives, the stimulation of the application of resilient technology on private properties can be achieved by the provision of non-cash rewards such as vouchers for public transportation or other public services. The research study performed in a deprived area in North West England on 1043 households (Bichard& Kazmierczak, 2010) indicated a high potential for such measures in promoting resilient technology, as nearly 60% of the respondents would accept this type of support.

Summary:
Insurance policies, financial incentives and non- cash rewards cannot be considered in isolation as flood risk response measures. Only combined efforts of the residents, government and (insurance) industry can lead to the minimisation of total costs and damage reduction in the future (Pitt, 2008, Kron& Thumerer, 2002). The insurance industry is increasingly being challenged to take an advisory role in preparing and coping with floods, but also needs to get a better insight into the performance of resilience measures in order to assess better the insurability of buildings. At the same time there is an increasing pressure to open the insurance databases with the quantitative damage data to the research as they are considered to be of high quality and can deliver a necessary insight in the origin and extent of the flood damage (Spekkers et al., 2013) but also in the behaviour of dwellers in respect to floods.

2.2.4 Decision support tools for a flood resilient built environment[61]

The required knowledge and expertise for the resilient built environment has to be made available to the users, i.e. dwellers, on how to protect their own properties. There is a significant body of literature addressing different methods and tools to support dwellers (e.g. Kelman& Spence, 2004). The main methods can be summarised as:

- Brochures
- Guidelines
- Computer based tools
- Web based tools/aids (Forums, Platforms, Multimedia tools)
- Face to face support

Brochures:
In parallel with initiating involvement of the "non experts" in flood risk management, a large number of institutions started publishing and distributing brochures with the main objective to inform residents about the measures to be applied. As they deliver the relevant expertise, even if in a rather plain form, these can be considered as decision support tools. They are offered either by governmental institutions (e.g. Federal Ministry, Germany see Figure 2-13a), local authorities (e.g. Regierung der Oberpfalz, Niederbayern, Vorbeugender Hochwasserschutz an Regen und Naab), the construction industry, or insurance companies and also by non-profit and non-governmental organisations (such as National Flood Forum in the UK).
Independently of the source, the content of the brochures is rather similar, including the overview of the measures available, short descriptions with examples and the scope of application of single measures and a link to important institutions for further help. In some cases, a rough cost estimation of the measures is given (e.g. Norwich Union[62]). The

[61] Parts of this section have been published and submitted as the authors contribution to the report 4.2 of the FP7 Project SMARTesT, Manojlovic, N., Nauman T., Schinke R., Spekkers M., Toumazis A., Giangola-Murzyn A., Deroubaix J-F, Barocca, B., Moulin E. (2012) Flood reislience Tools, Report 4.2, SMARTeST

[62] http://www.floodresilienthome.com/downloads/NU_COSTS_DRYINGTIMES.pdf (last accessed: June 2010)

disseminated information is rather general and is usually applicable to a wider population. In some cases it is, however, of local relevance, such as sites offered by municipalities in Bavaria, Germany on oil heating in flood prone areas referring to local legislation and standards (e.g. the city of Regensburg, Germany)[63]. Depending on whether the brochure is meant for the local conditions or a certain region, some of the brochures contain suggestions for defined house types and are adjusted to the building style of the region such as the Advice sheets series published by CIRIA (2003, 2004) referring to building conditions and type in the UK[64]. These sheets give a detailed description of the measures, considering different types of walls, floors or openings. Although in some cases the brochures tend to tailor their information to a certain region or a certain type of problem, they contain rather general information about the possible measures to be applied, i.e. they do not consider the single case or given conditions. They also do not provide thorough enough information on procedures to be applied in order to protect properties, which makes them inadequate for providing what is needed for the active involvement of the users within flood risk management. These are therefore only to be considered as a first step in delivering the required expertise to the end users including dwellers.

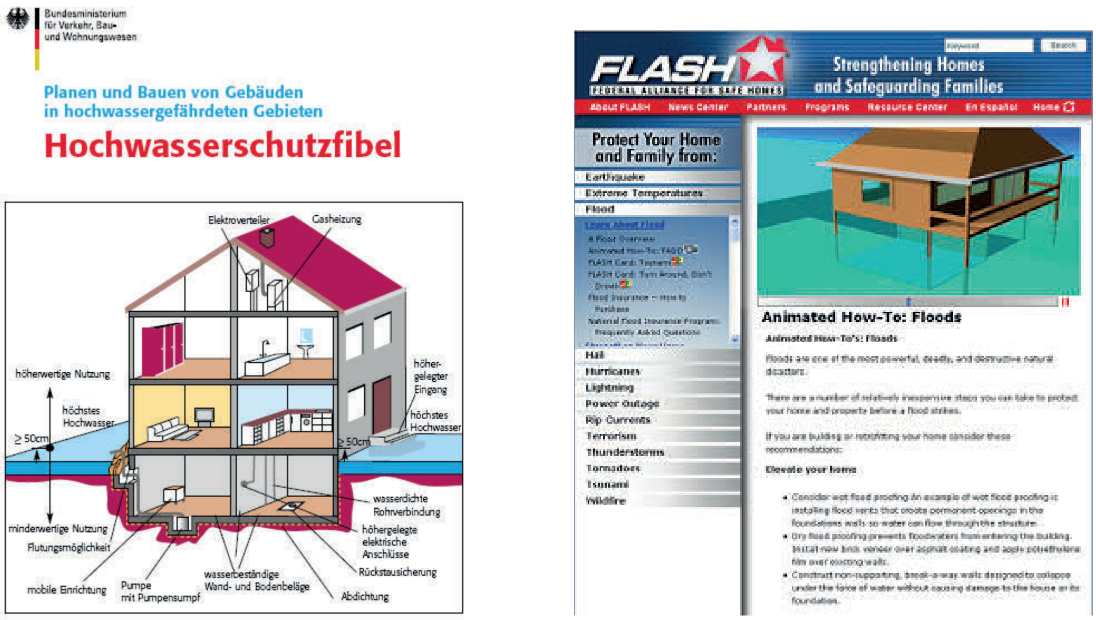

Figure 2-13 a) Brochure for protection of properties issued by the BfBVS 2003 b) Animated tool on how to protect properties from floods[67]

Guidelines:

[63] http://www.regensburg.de/hochwasser/vorsorgemassnahmen/vorsorge_heizoeltanks.shtml (last accessed: June 2010)

[64] http://www.highpeak.gov.uk/environment/flood/CIRIA_Advice4_resilient_walls.pdf (last accessed: June 2010)

A higher level of support is being provided by guidelines[65]. In addition to the measures to be applied, guidelines contain the description of the procedure to follow in order to protect properties. The GVZ (2003) provided by the Building Insurance Company- canton Zurich, apart from detailed description of the measures, gives the recommendations on their combined application depending on defined hazard situations. The ABI (2005, 2005a) published documents on repairing property or business after a flood, defining steps to be taken, but giving a rather poor description of the actions to be taken in specific cases.

Some of the guidance documents, although targeting experts, can be used by private stakeholders. The UK insurance industry published a guide to repair and investigate flooded buildings (Flood Repairs Forum, 2006) with the object of bringing some clarity and systematic procedures into the complex area of insurance and repair of flooded buildings.

Guidance documents are also provided for damage assessment procedures as a part of decision making procedures. Messner et al. (2007) give comprehensive guidelines for direct, tangible flood damage evaluation but, although the methodology considers all methods available including even the micro scale approaches being thoroughly described, dwellers can hardly benefit from it. Damage curves are either not available or not applicable for their cases as they are rather too general. The experience and knowledge collected during the creation of the HOWAS21 database will be published in a revised form as recommendations in the "Guidelines for Flood Damage Assessment" together with a package of measures to ensure high data quality (Elmer et al., 2007). The WMO initiated a Flood Mapping Tool (2007) and Flood Loss Estimation Tool (2007), giving recommendations and guidance for efficient mapping of flood prone areas, but although available to the public, this tool is targeting flood managers and practitioners and the content is likely to be too abstract for dwellers.

The guidelines, although they provide more information and are presented in a more systematic way, contain content that is rather static and still primarily targeting dwellers and their interests.

Computer based tools

Recognising the complexity of the decision making process and the necessity for individual consideration of flood protection at the individual property level, many institutions are considering the development of computer based tools for decision support. [Computer based tools are systems in which a non-expert has the possibility to analyse complex problems and to find appropriate solutions] (Hahn& Engelen, 2000). Their scope and focus vary from focusing on the built environment and development of multi-hazard mitigation strategies to starting from the flood management perspective, considering *inter alia* built environment and construction processes as the aspects. The aim of the Pre-Empt Project[66] is to [ensure that a more resilient built environment is attained through the systematic integration of hazard

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[65] There is a considerable number of guidance documents on resilient building meanwhile targeting rather designers or practitioners (e.g. in Germany, the guideline "*Wasserundurchlässige Bauwerke aus Beton (WU-Richtlinie) DafStb 11/2000* for facilitation of the design and building of waterproof constructions (CIRIA, 2008) on recommendations for the construction of flood resistant and resilient building), but here the research will be focused on the guidelines targeting private stakeholders.

[66] http://www-staff.lboro.ac.uk/~cvlb/Pre-empt/index.htm (last accessed: June 2010)

mitigation strategies into construction decision-making processes]. To achieve this, a web-based hazard mitigation toolkit for use by a wide range of stakeholders that are (or should be) involved with hazard mitigation strategies has been developed. Resilience has to be systematically integrated into the planning and design process and the resilience agenda has to be embraced by all key stakeholders, including dwellers. Among all the threats to the built environment in the UK, flooding has been identified to be the most significant (Pre-Empt Project[66]). Based on the UK case study, Kelman (2007) introduced some simple tools for decision making for flood threatened properties. This threat is either imminent (existing properties) or in the future (existing or planned properties). The tool emphasises the application of dry or wet flood resistance [reducing recovery duration and implementing resilient reinstatement] (Kelman, 2007). The outcome of the study, a decision-making matrix, is however, rather general and does not adjust the recommendations to the user's property data.

A step further is being made within the CIRIA proposal 2561, where a self-diagnostic tool to help with the identification of property-based flood resistance and resilience solutions is being developed. The overall objective of the tool is [to improve awareness of flooding issues and some of the options that can be undertaken to manage flood risk better at a property level.]. It is a computer based tool that should [guide users to key sources of information and advice on flood resistance and resilience measures suitable for their homes, but also guiding them through the process of improving the flood resistance and resilience of their property.] (CIRIA, 2008).

Apart from computer based tools for resilience performance, the tools for assessment of benefits of alleviation measures can be considered as decision support tools. Messner et al. 2007 give an overview of the main software for damage assessment. These are usually combined with databases of flood data. Regarding the technology used, they may vary from Fortran based software (e.g. ESTDAM developed by FHRC in England), Access based (HWSCalc) or GIS based (e.g. HIS-SSM Flood Information System Damages and Casualties Module (Huizinga et al., 2005)) or MDSF Modeling and Decision Support Framework, (DEFRA, 2004). These tools are developed for application by experts and as such are not easily accessible and understandable by private users.

Although computer based tools already offer a more tailored approach for homeowners to protect their homes, the available tools still do not provide a full risk assessment as damage assessment is not being offered and not tailored to the users' input data and as such these are usually not convenient for resilience planning on a property level for given building conditions and data.

Web based aids/tools:

Advancements in web technology can be used for facilitating the decision making process for resilient buildings. The possibilities are mostly related to the interactivity and availability of the service offered. However, most of the existing platforms reduced their offer to the publishing of brochures and guidelines in the form of pdf or html files (see also 2.1.5). But this by far does not exploit the possibilities of the technology available. A possibility to go beyond this practice has been used by the Federal Alliance for Safe Homes- FLASH[67]. Instead of delivering mere text, multimedia tools and animations have been used to advise people on how to protect their homes against flooding (Figure 2-13 b).

Surpassing simply dissemination, more efficiency can be achieved by enhancing interactivity in the system. The next level of more interactive communication with the residents is by offering online consultancy. According to Stone (2002) [allowing the user to interact with and even control the content is one of the primary reasons for the success of web based systems]. In recent years an increasing number of governmental institutions, research establishments or industry have provided assistance to residents via forums or contact between the experts and residents via internet. An example of such a service is the forum of the IB Rauch company[68]or Bauforum[69], advising on the relevant issues such as refurbishment or sealing of buildings which are constantly being used. This constant communication shows that people need confidence and reliability of the tool in order to make use of the consultancy service via the internet.

Another possibility for using web technologies for supporting dwellers to protect their properties is to individualise the problem and tailor it to their specific case. Such an attempt has been undertaken by the NSV, aiming for the selection of an adequate flood protection system. Here the residents can assess the type and the dimensions of the flood barriers for openings protection for their own situation as depicted in Figure 2-14 and for given flood conditions and building layout.

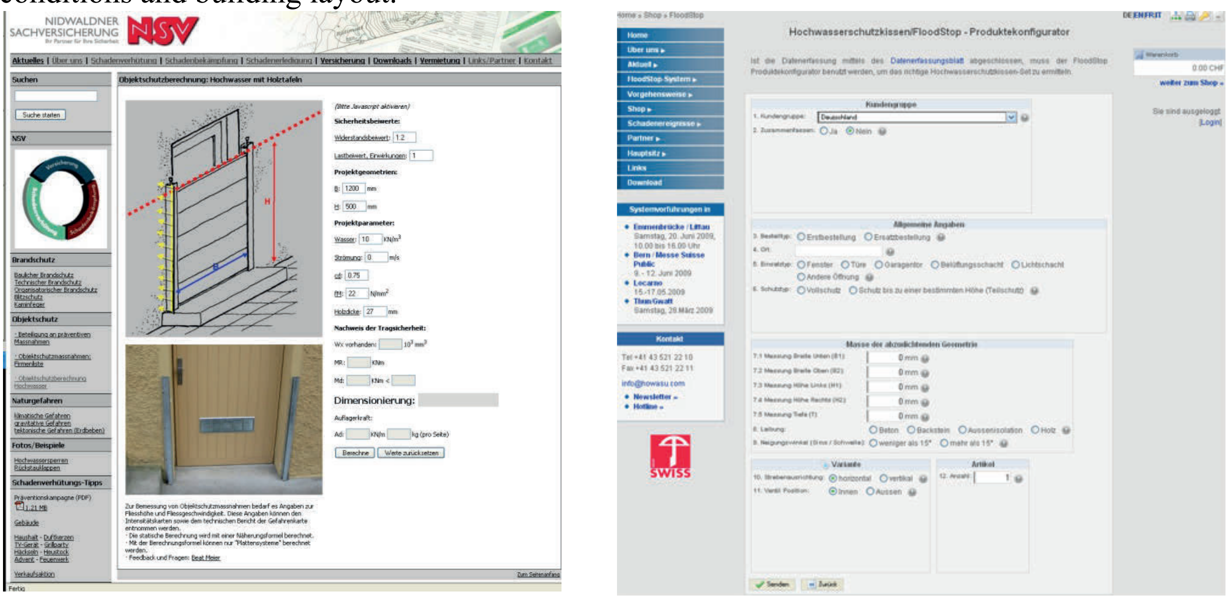

Figure 2-14 a) Tool for assessment of flood barriers (source: NSV[70]) b) definition of the appropriate products kit for private properties (HOWASU)

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67 http://www.flash.org/activity.cfm?currentPeril=2&activityID=148 (last accessed: February, 2010)

68 http://www.ib-rauch.de (last accessed: February, 2010)

69 http://www.bau.net/forum/index.html (last accessed: February, 2010)

70 http://www.nsv.ch/schadenverhuetung/objektschutz_hochwasser.html (the tool has been removed from the internet (last accessed: July 2014)

The users are expected to read off the values for velocity and water depth from the maps offered by the NSV and enter it for the calculation for flood barriers. Similarly to this service, the manufacturer of the product HOWASU offers online support for assessment of the appropriate configuration of this product (Figure 2 14b). Still, these tools, although enabling a higher level of interactivity, offer expertise only for one type of measure, flood barriers, without considering other potentially more appropriate combinations of measures.

Summary

The decision support tools available for dwellers presented above show different characteristics based on the main performance and content related criteria as given in Table 2-4.

Table 2-4 Summarised evaluation of the main decision support tools (+ true, +- partly true, -not true)

Aspect	Requirements/ Tools	Brochures	Guidelines	C- based tools	Web based aids
Content related	Expertise on measures	+	+-	+	+-
	Damage assessment	--	-	+-	+-
	Assessment of performance of the measures	+-	-	+-	+-
	Level of detail	+	-	+-	-
	Level of personalisation (concretisation)	+-	-	+-	-
Performance related	Transparency in DM process	-	+-	+-	+-
	Scalability	-	+-	+-	-
	Actuality of information	+-	+-		
	Quick& easy handling	+	+-	-	-
	Interactivity (feedback) with the system	-	-	+-	+-
	Easy and free access	++	++	-	+

The analysed body of literature indicates a large number of tools, mostly in the form of brochures. This illustrates that a research challenge is to develop a reliable decision support tool tailored to the dweller needs for the given personalised problems (protection of single buildings), enhancing the motivation for its use. This should be capable of continuous improvement as the market for flood products is developing rapidly, and these emergent and innovative techniques after being tested, should be considered for decision making and integrated into decision making processes (see also 2.2.2.2). Due to its easy accessibility, the internet can be considered as the most appropriate media for delivering the tool.

2.3 Strategies to empower dwellers to practice their role in UFM

[There can be no meaningful stakeholder participation effort, unless there is an educated set of participants] (Tippett et al., 2007); which applied to the case of dwellers' participation in UFM postulates their empowerment for the decision making process. One of the key outcomes of the Crue EraNet initiative summarised in the synthesis report[71] is that dwellers need to be involved in a learning process to enhance their capacity both to be willing to engage, and to engage effectively. At the same time as the key to initiating this process and motivation for it, the flood (risk) awareness has been assessed (e.g. IKSR, 2003, FLOWS, 2005, Crue EraNet- SUCA, 2008, FloodSite, 2009). In this sense, the raising of flood awareness and the learning process within the capacity building need to be analysed for the assessment of the strategies to be applied to most effectively empower dwellers.

2.3.1 Raising hazard/risk[72] awareness

In the research on FRM, there are a large number of studies researching the strategies and methods to raise the risk awareness of the stakeholders, including dwellers (e.g. FLOWS Project, Crue EraNet, FloodSite, Flood SCAN, CapHazNet[73]). Within the INTERREG IIIb Project FLOWS[77], risk perception and communication have been major pillars in the research agenda. Based on case studies in the participating countries in the North Sea Region, new strategies and methods for raising risk awareness have been developed and evaluated. The FloodScan Project[74] is researching the effectiveness of traditional methods for raising risk awareness such as flood signs and markings and development of new strategies and tools. A special research focus is given to flood maps, assessing their accuracy and exploring new ways of dissemination to different stakeholder groups. Within the FloodSite Project[75] (2009) recommendations for raising risk awareness are given as [*Keep the issue hot in times of no flood event , Find regular, repeated ways to raise flood risk awareness, Use different modes and media to raise flood risk awareness (newsletters, handouts, leaflets, SMS, radio and TV spots ...),]* (Steinführer, 2009). These appeared to be the key outcomes based on the project case studies in Italy and Germany. The research agenda of these projects, although based on similar strategies, provides a wide range of methods and tools that are being explored. Special attention is given to flood maps, which are emerging as the key instrument for raising risk awareness.

Summarising the main outcomes of the international research projects (e.g. Crue EraNet-SUCA, Steinführer, 2009) it can be concluded that raising risk awareness is a necessary step

[71] http://www.rimax-hochwasser.de/fileadmin/RIMAX/download/Allgemeines/CRUE_Synthesis_report.pdf (last accessed: January 2014)

[72] Here: flood awareness encompasses hazard and risk awareness

[73] http://www.caphaz-net.org/ (last accessed: June, 2008)

[74] http://www.wzw.tum.de/floodscan/ (last accessed: February, 2010)

[75] Subproject: *Communities at risk: vulnerability, resilience and recommendations for flood risk management*

to make stakeholders act, but it is just a means to an end. [There is no linear link between risk awareness for mitigation behaviour; i.e. there is no automatic link between being aware of the risk of flooding and actual behaviour] (Steinführer, 2009). Therefore, raising hazard and risk awareness should be treated in a chain of strategies to initiate public participation in UFM, where the trajectory of the chain from awareness to proactive behaviour should be supported by learning activities.

2.3.1.1 Methods for raising hazard/risk awareness

There are a large number of tools and methods for raising risk awareness. Out of a wide range of different methods the following have been assessed as the most important or frequently used and are legally bounded (e.g. Hagemeier-Klose, 2007, Steinführer, 2009, Pasche et al., 2008):

- flood maps (2007/60/EC)
- flood symbols and tools
- public events

Flood maps

Nowadays, as of the latest adoption of the 2007/60/EC, flood maps are considered to be basic tools when developing strategies for raising risk awareness within a community. One of the key outcomes of the Crue EraNet[76] initiative calls for high priority to be given to research on a range of [regulatory, social and economic approaches in the mitigation responses, including improved information and maps on flood risk to inform citizens]. The main objective of flood maps is [to provide information on the past, likely or potential extent of flooding which (sometimes in combination with other related information) helps in making decisions on various aspects of flood risk management] (WMO, 2005). The 2007/60/EC has declared flood (risk) maps together with flood risk management plans as the main control instruments in FRM. For all river basins, sub-basins and coastal reaches, flood risk has to be assessed and documented in ***hazard and flood risk maps*** (Article 6 (1)). The basis for the assessment will be floods with a high probability of return (e.g. every 10 years), a medium probability of return (return period ≥ 100 years) and with a low probability (in the German Flood Act, 2005 a 200-year flood).

The consequences of the flood have to be indicated by the number of inhabitants potentially affected, the potential economic damage in the area, the potential damage to the environment, and the technical installations with the potential of pollution and major-accident hazards. The maps should determine specific points with higher flood risk, which have to be taken into account in land use planning. Maps and textual documents encompass the flood risk assessment. Although it defines the flood maps as a key instrument, 2007/60/EC delivers little or no information about the level of detail, demanding only the "the most appropriate scale for the areas" (article 4 (a)). Also, as the 2007/60/EC requires completion of the flood maps up to

[76] http://www.crue-eranet.net (last accessed: January, 2015)

the 22nd of December, 2013, the relevant institutions EU wide are producing these maps, often using a different terminology and connotation of the terms flood hazard and risk map. For example, depth maps defined within the FLOWS[77] project are the same as the extended inundation maps of the Flood Risk Mapping Tool, (WMO, 2010). Also, the national agencies (e.g. LAWA in Germany) are issuing the guidelines on how to produce different flood maps (LAWA, 2010). For the scope of this work, the definitions given in Table 2-5 have been adopted (adapted from Flood Mapping Group- WMO, 2007, updated 2010 and LAWA, 2010a).

Table 2-5 Overview of the main flood map types (adapted from Flood Mapping Group- WMO, 2007, updated 2010, LAWA 2010)

Type of map:	Inundation Map	Hazard Map	Risk Map
Definition	Depicts the extent of flooding for a selected event. They map either an event or they are related to a given return period, as for instance; 10 years floods, 50 years floods, 100 years floods etc.	Depicts the extent of flood prone areas for different return periods considering the impacts on the environment and the variability of magnitudes of the expected events. Outcome: different zones, classifying the intensity of hazard in relation to the probability of occurrence (low, medium, high hazard potential).	Combines the information on probability and consequence (damage potential). An example of a risk map is depicted in Figure 2-15b (LAWA, 2010)
Content	Flooded area in case of a flood event Extended map: relevant flood parameters (e.g. water depth)	Flood Parameters such as: - Extent of inundation - Water depth - Flow velocity … any other relevant flood parameter for the given conditions	Risk parameters such as: Probability of flooding Flood vulnerability Probable damage
Purpose of use	Preliminary screening in landuse planning and management	-Landuse planning and management -Watershed management -Water management planning -Hazard assessment at local scale -Emergency planning and	-Basis for policy dialogue -Priority setting for measures -Flood risk management strategy (prevention, mitigation) -Emergency

77 http://www.northsearegion.eu/iiib/projectpresentation/details/&tid=58&theme=2 (last accessed: January, 2015)

		management -Planning of technical measures -Overall awareness building	management -Overall awareness building
Scale	National level, whole river basin: 1:50000 to 1:100000	Local level: 1: 5000 to 1:25000 Urban planning: 1:2000 to 1:25000	Local level: 1: 5000 to 1:25000 Urban planning: 1:2000 to 1:25000
Target group	National/regional land use planning Flood managers Residents in flood prone areas Public at large	Regional/ local landuse planning Flood Managers Public at large Residents in flood prone areas	Insurance National/regional/local emergency services National/regional/local water and landuse managers

Apart from these main map types, flood vulnerability and exposure maps, that show [damage potential, exposed key infrastructure, vulnerable sections of society such as old age homes without appropriate response capacity] (Flood Mapping Group- WMO, 2007, updated 2010), are being used.

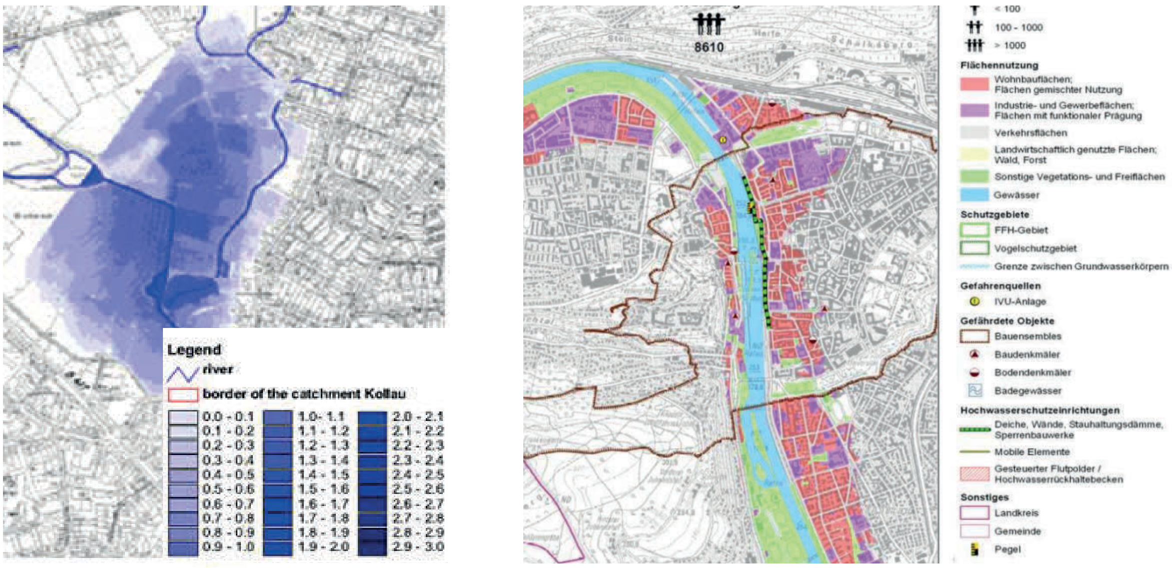

Figure 2-15 Examples of flood maps of the river Kollau, Hamburg: a) inundation map (Krässig, 2007) b) risk map (source: LAWA, 2010a)

There are three basic issues that are addressed in research related to flood maps in order to use these maps as the key tool for raising the risk awareness of different stakeholder groups (e.g. EXIMAP, 2007, ELLA[78]:

- Further development of methodology to improve accuracy and level of detail of flood maps *(quality)*

- Development of flood maps for the whole span of flood types *(availability)*
- The content, layout and way of presentation of the flood maps tailored to different stakeholder groups, their requirements and level of understanding *(appropriateness)*

The accuracy of flood maps (including methodology for their generation) has been researched within a considerable number of national and trans-boundary initiatives and projects EU wide. EU funded projects are good examples of trans-boundary activities on flood mapping in Europe (e.g. EXIMAP, 2007, ELLA[78], Rhine Atlas[79], SAFER[80]).

WMO- Hydrology and Water Resources Branch started an initiative and founded an international working group on flood mapping with the objective to provide guidance for practicing flood mapping for different data quality and availability, depending on their purpose, target group and type (Flood Mapping Group- WMO, 2007, updated 2010).

Addressing the issues of availability and quality of flood maps and analysing the existing flood maps given in Table 2-5 and their scope of application, it is becoming obvious that a high-resolution approach is still missing that would meet the needs of dwellers. Achieving a higher level of detail in flood maps is mostly related to high resolution spatial data but also, assuming high resolution data is provided, damage models that consider the physical processes in the building in their aim to understand the origin and nature of flood damage to buildings (see section 2.2.2.2). Also, following the outcomes of the research projects (e.g. Crue EraNet- SUCA) the problem of missing flood maps is becoming evident. According to 2007/60/EC "the flood maps should be available for "the areas for which the Member States conclude that potential ***significant*** flood risks exist" (2007/60/EC, Article 5 (1)), without quantifying the term significant and allowing its subjective interpretations. While policy and flood experts are aware of the flood risk along rivers and large streams and have developed future oriented and sustainable strategies for their management (2007/60/EC, BMU, 2005), the combination of pluvial and fluvial floods in small urban watercourses has been largely neglected so far and flood maps of these areas are still scarce (Pasche et al., 2008). This impedes the efficient planning of measures of resilient measures for buildings these areas.

Together with the establishment of flood maps as key tools for raising risk awareness the question of their appropriate dissemination is emerging as an upcoming research issue. Realising the importance of a tailored approach in delivering flood maps depending on different stakeholder groups, there is meanwhile a considerable amount of research work devoted to this issue. The Crue EraNet Project RiskCatch (Fuchs, 2008) has been devoted to developing recommendations and guidelines for visually efficient flood maps for the key stakeholder groups, applying the method of experimental graphic semiology (Fuchs et al., 2008). The recommendations obtained from a pilot study are mostly related to the colours, spatial distribution of information and concentration of relevant information.

One of the objectives of the EU LIFE Project FloodScan74 is to design an application of flood maps to be user friendly and understandable for both groups of users, professional and

[78] http://www.ella-interreg.org/ (last accessed: June, 2008)
[79] http://www.rheinatlas.de/ (last accessed: January, 2015)
[80] http://www.EU-SAFER.de (last accessed: January, 2015)

private. The requirements of different end users have been assessed at a workshop with the key stakeholder groups (Hagemeier, 2007), setting the colours, content, level of detail and background map as parameters. Although assessed as the key tool for raising hazards/risk awareness (2007/60/EC), the information presented by flood maps is usually not understandable other than by experts (e.g. Hagemeier& Wagner, 2009, Wagner, 2004). For non-experts, simplicity and reduction to provide only the key information are of the highest importance. Also, the natural selection of colours (e.g. blue for inundation areas) turned out to be important for the test persons. Regarding the background maps, aerial photos and digital site maps are preferred by local residents as they depict "real" objects or buildings and as such deliver a tangible, easily recognisable background (Hagemeier- Klose, 2007). The residents also stressed the importance of a sufficient resolution of the maps, being able to assess the hazard and risk to their own properties.

A high potential has been realised for the dissemination of flood maps via the internet by many institutions and agencies. In the current practice, most EU countries are disseminating their flood maps on the internet (e.g. Environment Agency in the UK[81]or Saxony, Germany[82]). This way of dissemination of flood maps provides considerable advantages such as [single-point update, low cost dissemination, and reduced risk of superseded dat] (de Moel et al., 2009). From the user's perspective, such maps are usually easy to access without plug-ins or download. The user can zoom over scales, so that such maps to a certain extent can be considered as interactive. If they are targeting general public or private stakeholders, the maps are often supported by additional information on what to do and how to react in case of flooding. The Environment Agency UK[81] offers the service for the stakeholders in England, in which, based on their postal code and address, each stakeholder's own exposure can be assessed.

Summary:

In spite of the increase in research activity and being provided with a framework that legally anchors flood maps as the key instrument in flood risk management, their systematic and exhaustive application is still pending. Addressing the three basic issues of application of flood maps, the main drawbacks of this systematic application can be summarised in the following issues:

1. resolution and accuracy of data displayed in the map are the most important as these have to provide a reliable planning basis for all relevant scales from the macro down to the micro scale, i.e. property level planning. The current approaches lack the delivery of high resolution information on flood hazard and risk, hampering the dwellers in their role in FRM.
2. Flood maps are required for all types of floods including small urban catchments, which are usually neglected or given lower priority.

[81] http://www.environment-agency.gov.uk (last accessed: January 2015)

[82] http://www.umwelt.sachsen.de/de/wu/umwelt/lfug/lfuginternet/interaktive_karten_10950.html (last accessed: January 2012)

3. Flood maps can be rather abstract to dwellers. Efficient tools for the visualisation of the information on flood maps and making this information accessible and tangible to the stakeholders are still scarce and should be further investigated.

Although flood maps are an important source of information, they only serve this purpose. Referring to the experience in the Rhine region, Grothmann& Reusswig, 2006 concluded that mere application of flood maps can hardly lead to an improvement of proactive behaviour from private stakeholders. The method of how to make use of flood maps in a more efficient way is a matter of further research, implying that flood maps should be used as an integral element of an integrated risk awareness strategy (e.g. Hagemeier- Klose& Wagner, 2009).

Flood symbols and tools

Apart from flood maps, other more traditional strategies for raising hazard and risk awareness are being used, such as the application of sign posts or flood markers (e.g. Hagemeier-Klose, 2007). Although considered as a traditional means of flood dissemination, they are not yet outdated. They are used in almost any community prone to flood risk to warn and inform people about relevant flood related issues. The possible success of these strategies lies in the fact that they are rather simple in both their implementation and understanding aspects, as they visualise the phenomenon and in this way make flooding understandable and keep it topical. There are a great variety of flood symbols that are converging in the way they are being used, i.e. posts or marks on private or public spaces reminding locals of historical flood events in the area (Figure 2-16a). Some of these are pieces of art (e.g. sculptures created within the FLOWS Project[83]). Moreover, '*Flood'* as a symbol has ever since inspired artists, such as musicians, painters or writers [84].

Figure 2-16 Means for raising risk awareness: a) *traditional*: Balingen, the river Eyach, Germany; b) *emerging*: flood telephone box developed within the LIFE Project FloodScan; c) *emerging*: an advisory internet based animation tool for resilient built environment Norwich Union, 2005

[83] http://flows.wb.tu-harburg.de/index.php?id=648&no_cache=1&sword_list[]=sculpture (last accessed: January 2010)

[84] For example, "Louisiana 1927", a famous song of the songwriter Randy Newman, is directly devoted to the victims of big flooding in 1927 which killed hundreds and displaced hundreds of thousands across six states of the USA.

In recent years, as this topic has gained importance, more innovative approaches are being developed which are more diverse in the way they address the stakeholders. An example of such a tool is the *flood telephone box* developed within the EU LIFE Project FloodScan[74], which has the idea of attracting attention to flood problems in public spaces or during local events as depicted in Figure 2-16b. Visualisation and animation of relevant processes and procedures are enhancing traditional methods enabling even more interactivity. Multimedia features are increasingly being used as an aid to support the raising of risk awareness. Within the FLOWS project[85] Norwich Union has developed a flood support microsite which, apart from the usual flood related information, includes a so called flood simulator (Figure 2-16c).

This simulator visualises different damage scenarios (expressed in monetary values) for different water stages and, in the case that the building is not flood resilient, initiates risk awareness within the people. Although it reaches a higher level of interactivity, this tool is rather fixed in content, i.e. the building contents cannot be exchanged, which limits its utility for the assessment of individual situations for private stakeholders.

These traditional and emergent symbols and tools are another means to attract the attention of the public and give another perspective to flooding as a natural phenomenon. They are assessed to be suitable for the raising of risk awareness (Hagemeier-Klose, 2007). The tools are shown to be a good source of information but they are locally related and can only inform users about the type and extent of the problem, without providing any answer as to what is to be done or empowering stakeholders to adequately respond to this flood hazard. Also, although there is an increasing number of new tools/symbols, there is still the potential to develop new approaches and if possible to combine classical and modern media and to use them as a part of integrated strategies.

Public events

Public events and local festivals can be used to reach people, enabling them to deal with flood problems in a rather relaxed atmosphere. Hagemeier-Klose, 2007 lists exhibitions, flood fairs, quizzes & games, flood exercises and public initiatives as the most commonly applied strategies in selected areas of Germany, Austria, Switzerland, the Netherlands and the UK. The interactivity of such events is considerably higher in comparison to other means of dissemination, but at the same time they are usually limited in time and space, which limits the numbers of people addressed. Interactive exhibits, realistic models or videos are much more "catchy" for the audience, but assessed as being relatively seldom applied (Hagemeier-Klose, 2007). Flood Protection Centre Cologne[86] initiated numerous events involving public stakeholders with the main objective of raising risk awareness in a playful and relaxed atmosphere. The evident improvement of the hazard awareness of public stakeholders in the Cologne area can be attributed to a set of constant and intensive actions for raising public awareness performed over a number of years (Vogt, 2009). Vogt, (2009) emphasises the

[85] http://flows.wb.tu-harburg.de (last accessed: January 2010)

[86] http://www.steb-koeln.de/hochwasser.html?&L=0 (last accessed: January 2015)

importance of a constant presence of flood issues in the mindsets of people, which should be achieved by a variety of methods and activities, targeting all key public stakeholder sub-groups (e.g. children, school kids, adults). Special attention is given to live events, which attract people and enable a live experience of flooding. An example is the “cinema event” at the main railway station in Cologne, where a film has been shown to the people using sandbags as seats. The experience showed that people are reluctant to endure long sessions, meaning the information has to be presented in an attractive but concise way (to deliver the main message in a maximum of 10 minutes). Another example, “Flood event day”, is a family event that enables people to participate in the actions of rescue teams or interactive flood games in a playful environment (Figure 2-17 a).

Figure 2-17 a) “Flood event day” in the City of Cologne (source: Vogt, 2009) b) House model for raising risk awareness in info sessions of the Suffolk County Council

In order to approach a larger group of stakeholders, the Authorities of Paris together with research institutions (e.g. CEREVE) organise the Festival D’Oh (water festival), targeting both professionals and “non-experts”. During the festival days, which are being organised annually, a range of presentations about the main water issues (including flooding) are organised, enabling the public stakeholder to get an insight into and learn about the relevant topics and get acquainted with the latest research developments (Schertzer, 2008). As a part of the program, the participants take part in a field trip such as visiting water streams or visiting exhibitions about water related issues. An assessment of the efficiency of such an event is difficult to carry out, but the fact that it is being regularly repeated indicates that there is an interest among the people for such kinds of events. Within the FLOWS[87] Project, Suffolk County Council initiated an information campaign by showing videos and using a model of a house to show the after-effects of a flood. In order to make it more realistic, ruined building contents and personal belongings have been displayed together with a model of a house (Figure 2-17 b).

In addition to the physical damage, a “sewagey” smell could be activated at a touch of a button (so common and unpleasant in flooded homes, but unrecognised by most of the general public)[87]. In some cases, public events are used in combination with flood symbols such as a regional event to launch flood symbols combined with storytelling sessions in the Netherlands[88]. In a partnership with the EA, Norfolk County Council, UK initiated a road show with a multi-mobile vehicle equipped with info material, laptops and maps[89].

Summary:

Summarising the main outcomes from the research activities, the following requirements for development of concepts and tools for raising flood awareness have been identified, indicating the opportunity for further development:

- Flood maps are a key tool for raising flood awareness and the information has to be effectively "visualised" and made understandable for non experts including dwellers. However, the current research activities indicate room for improvement especially in terms of tailoring the information to dwellers' needs (e.g. Grothmann& Reusswig, 2006).
- Live events are assessed as being very important (e.g. Vogt, 2009, Hagemeier, 2007). Experience shows that these should not take too long and should be effective in order to be remembered by people (e.g. Vogt, 2009).
- The static nature of live events can be overcome by making them mobile and in this way enable them to reach more people. Experience from road shows with a multi-mobile vehicle[89] confirms this.
- Real models and tools such as a telephone box (Hagemeier, 2007) or house model (FLOWS[87]) are assessed as efficient and should be used. However, such models are considered to be pioneers and the full potential of these tools has been assessed to be not exhausted.
- Integrated concepts are expected to deliver the best results for raising flood awareness, combining different methods and media such as flood maps, live events or flood symbols, taking advantage of their strengths and overcoming their deficiencies.

2.3.2 Building capacity of stakeholders

One of the main tasks of any efficient stakeholder involvement strategy in FRM is to bridge the knowledge and motivation gaps of the stakeholders and build the capacity of stakeholders to overcome the "entrapment effect" (Pasche et al., 2008). This entrapment is reflected by a reluctance of the stakeholders toward involvement or to new approaches that are associated with the unknown, at the same time implying changes in the existing business or lifestyle

[87] http://flows.wb.tu-harburg.de/index.php?id=653 (last accessed: June 2009)
[88] http://flows.wb.tuharburg.de/fileadmin/BackUsersResources/flows/Downloads/KnowledgeBase/Fact_Sheets/2B_5_NL_event.pdf (last accessed: June 2009)
[89] http://flows.wb.tu-harburg.de/fileadmin/BackUsersResources/flows/Downloads/KnowledgeBase/Fact_Sheets/2B_16_UK_info_campaign.pdf (last accessed: June 2009)

(Ashley et al., 2008). Capacity building is a long-term, continuing process that was defined in Agenda 21 (Chapter 37, UNCED, 1992). In 1991, UNDP defined 'capacity building' as:

- the creation of an enabling environment with appropriate policy and legal frameworks;
- institutional development, including community participation;
- human resources development and strengthening of managerial systems.

Much of this has been neglected for a long time and replaced by concepts such as raising risk awareness, as alternatives require considerable resources and effort that are usually not available. A number of studies undertaken by the Pennine Water Group have shown that [the most important attribute for adaptability is capacity, both of the actors and the associated infrastructure used in response to risk] (e.g. Ashley et al., 2008). Referring to the flood events in England, 2007, the Sir Michael Pitt Report (2008) states that [the impact of floods and the high level of risk involved could have been significantly reduced with stronger local leadership of flood risk management, clarification of roles… and wider and deeper public engagement] (Pitt, 2008) including amongst dwellers. Wider and deeper engagement should go beyond raising awareness and aim at developing the knowledge, skills and operational capability of stakeholder groups to achieve their purpose (Tippett et al., 2007). In that sense the capacity building has a strong component of *active learning.* Internationally there is an increasingly recognised need for considering flood risk management in terms of integrated systems (e.g. Tippett et al., 2007), which set high requirements on the stakeholders especially those who are not experts to understand the elements of the systems and their interactions.

Recognising the importance of learning for participation, the strategies and methods for capacity building of stakeholders have been on the research agendas of many national and translational projects (FloodSite[18], DIANE-CM[30], Crue EraNet[42], CapHazNet[73], the activities under the umbrella of the COST 22[217], RIMAX[20]). Capacity building is increasingly reaching the agendas of local and regional authorities that are trying to initiate the understanding and acceptance process among residents. Other institutions such as insurance companies are intending to educate the residents and those insured by organising public campaigns such as Nidwaldener Sachversicherung- NSV[90], an insurance company in Switzerland.

However, these communication and educational sessions and initiatives face some common problems. One of the most frequent is the language used for explaining the problems and situation. Expressions such as 100-year flood or design flood should be explained in an adequate way (e.g. Hagemeier-Klose, 2007).

The role of capacity building of stakeholders as an outcome of the Glasgow study within the Crue EraNet project SUCA[42] can be comprehended in Figure 2-18. The driver for the change from “entrapped” to “resilient” are so called *champions* that should build their capacity to gain momentum for conveying this transfer. Ashley et al., 2008 define champions in a society as the persons that are open to new approaches and are ready to actively participate in the implementation of these new approaches.

[90] http://www.nsv.ch/ (last accessed: Janaury 2015)

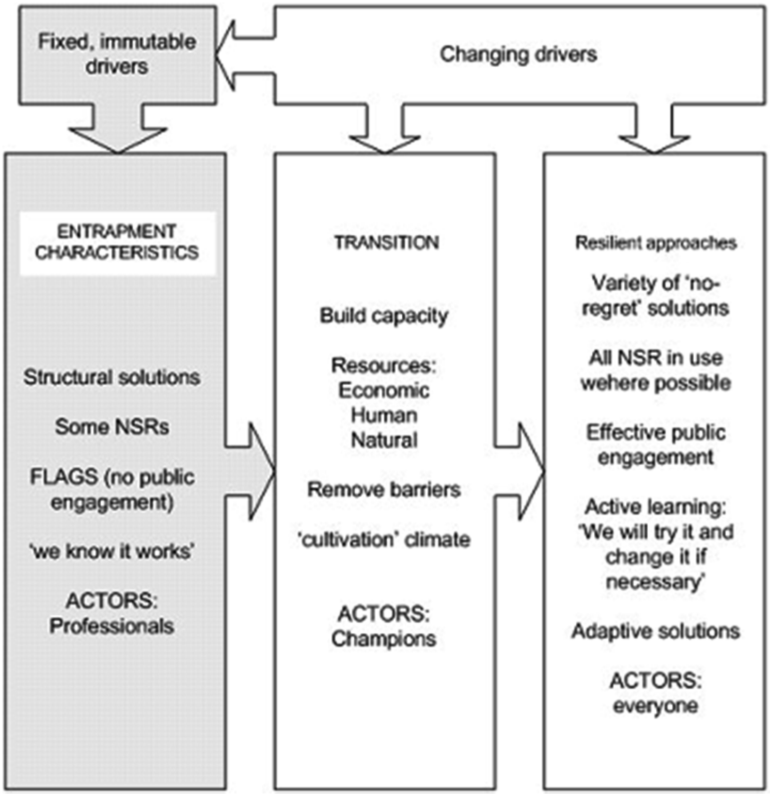

Figure 2-18 The transition to resilience via capacity building, the example of Glasgow (Ashley et al., 2008)

Probably the most remarkable example of the champions activity and self organisation is the National Flood Forum[34] in the UK. It is a charity run by people who have experienced flooding or have first hand experience of supporting the victims of flooding both during and after an event. Within the scope of their activities, [the activists go into communities armed with a laptop and give presentations around kitchen tables about how the public can best interface with those in flood risk management or organise flood fairs or instigate multi agency collaboration] (Dhonau, 2010). The positive results so far have initiated the development of the European Flood Forum that would bring forward the experience gained in the UK and "snowball" the interest and awareness of dwellers Europe wide.

Steinführer, 2009[91] defines the question as to how can people at risk be encouraged to take up private precautionary measures as a remaining gap in knowledge and one of the key questions for further research. Assessing the motivation for taking their share in risk mitigation, Grothman& Reusswig, 2006 concluded that [it is essential to communicate not only the risk of flooding and its potential consequences, but also the possibility, effectiveness and cost of private precautionary measures], shifting risk communication towards the capacity building process. Addressing the issue of social capacities as the key to resilience to natural hazards, the EU FP 7 network CapHazNet[73] has been established. Here, social capacity building is

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[91] http://www.floodsite.net/html/partner_area/project_docs/T11_07_15_Vulnerability_resilience_ExecSum_v2_2_p01.pdf (last accessed: January, 2015)

understood as an umbrella term which comprises all efforts to build individual, organisational, technical as well as institutional capacities. In this sense, the capacity building of private stakeholders has to be undertaken as an integrated element of a broader framework including all the elements mentioned above, and by paying appropriate attention to their interactions. One of the key outcomes of the COST C 22[17] four year activities called for finding new ways to motivate and build the capacity of all stakeholder and actor groups emphasising the role of champions as the “active” representatives of these groups. Trust in professionals by dwellers is essential, and is most effectively built by “champions” within the community (Ashley, 2008). A developed strategy for capacity building has to answer the question of how to reach and motivate the stakeholders or champions for learning and to develop didactic concepts.

2.3.2.1 Methods for building capacity and dwellers participation

Although the importance of capacity building and its didactic nature is increasingly being recognised and there are more studies that can document its efficiency to mitigate the risk of flooding in urban areas (Ashley et al., 2008, Pasche& Geissler 2005), a broad and systematic application of capacity building methods is still underdeveloped. Without communicating the possibilities of resilience measures to private stakeholders in addition to raising risk awareness, proactive behaviour from these stakeholders can hardly be expected (Grothman, 2003), which calls for research on the appropriate methods. The main methods of delivering the required knowledge are given as dissemination, communication and education (Pasche et al., 2008). The process of dissemination implies a one way information flux from one source (expert) to receptors (professional or private stakeholders). But to empower stakeholders it is necessary to apply more interactive means i.e. to communicate *with* stakeholders rather than communicate *to* stakeholders (Pasche et al., 2008, Steinführer, 2009). Communication and education implies more active involvement of the addressed stakeholders. Tailored approaches are to be developed which address the underlying abilities and interests of different stakeholder groups. The current research (e.g. Crue EraNet Project-SUCA[42], 2008, FloodSite[18]) defines different means to enhance stakeholder capacity, the most important being:

Delivering information and knowledge by means of hard copied material (e.g. brochures)
Dissemination of flood related information by means of hard copied materials targeting dwellers is the most commonly used method. Brochures are at the same time considered as one of the means for supporting decision making on the resilient built environment and are discussed in section 2.4.1. The scope of these brochures covers a wide range of topics from general flood issues to specific advice on how to improve the resilience of properties. Although they are usually easily accessible in the form of hard copies or via the internet, their full acceptance by dwellers is still lacking. Referring to the results of the survey in the area around the river Rhine after the flood events of 2002, Grothmann& Reusswig, 2006 concluded that brochures, although available, are rarely used by private stakeholders. By mere application of brochures, the effective capacity building of dwellers can hardly be achieved.

Web-based learning material and platforms

Recently a significant amount of flood related information which also targets dwellers has been published via the internet, either in the form of .pdf/doc document or as an html file (e.g. SEPA[92]). The advantages of the internet as dissemination media have been acknowledged in most European countries and meanwhile most of the governmental agencies, local and national authorities or utilities offer material where the residents can learn about the relevant issues as in the case of the French Ministry of Environment[93] or the Environment Agency Dresden[94], offering a website for the public giving an overview of the flood situation in the area and informing the residents how they should act.

The ILP Platform developed within the FLOWS Project[85], targeting both experts and the interested public (including dwellers), delivers the information about flood protection at the property level based on the outcomes of the FLOWS project. Here for example dwellers can learn about the best practices in dry and wet proofing obtained for the case study areas in England. Following the integrated approach to UFM, a certain number of institutions offer a supporting platform for all relevant issues of UFM and FRM in general, including the issues related to flood resilience measures for buildings. An example is the HelpDesk launched by the WMO[95]. Within the platform, private stakeholders can find information regarding the protection of their own properties given in the form of brochures or html pages, and also get an overview of the relevant topics of UFM and FRM.

Although containing relevant information, the learning effect of these platforms is assessed as rather limited. The main reason is that the material is usually static and targets in the same way all users, independently of their underlying ability and level of interest. More integrated approaches are required, giving the context of the problem, but also tailoring the content to the interests of different users. The application of multimedia tools, the possibility to control the content and interactivity increase motivation for learning (e.g. Pryadko, 2005) and should be considered when designing such a learning platform.

Face to face learning (Workshops)

Face-to-face learning differs from the info sessions and discussion rounds, as they follow a didactic concept tailored to the targeted stakeholder groups. Sessions with the stakeholders are not only supporting the learning, but fostering communication and the idea of "learning from each other". Face to face learning strategies are being used by academia and research projects. Within the FloodScan Project[74], the issue of best practices for info sessions and personal communication with the stakeholders has been discussed. The outcome indicates that important aspects for successful communication are figures and facts to be provided to the residents, but at the same time the uncertainties of today's mathematical models are to be clearly stated. It implies that in order to bring figures and facts and show sovereignty in the area, the experts performing the communication have to be familiar with the hydrologic

[92] http://www.sepa.org.uk/flooding/being_prepared/protection_products.aspx (last accessed: January, 2015)
[93] www.prim.net/ (last accessed: January, 2015)
[94] http://www.dresden.de/de/08/03/055/015/c_0300.php (last accessed: January, 2010)
[95] http://www.apfm.info/helpdesk.htm (last accessed: January, 2015)

situation in the area, i.e. mathematical models should be available. Face-to-face methods for "non-professionals" are increasingly being considered as a part of strategies in the context of FRM, although their implementation is still in its initial phase. Tippett et al., 2007 developed a concept for action learning for different stakeholders (including dwellers) in FRM. It is a training session composed of the reflection, hands-on and interactive parts. The results of the methods applied in a case study in Manchester indicate that learning from discussing with the other participants, a comfortable environment for learning and encouragement of holistic views and learning across the scale were pointed out as being keys to successful action learning (Tippett et al., 2007). An innovative approach to capacity building of private stakeholders in FRM via the face-to-face method has been developed and implemented within the FLOWS[77] Project. The method of *Interactive Learning Groups (ILG),* based on the experiential learning theory by Kolb& Fry, 1975 aims at building capacity of the stakeholders by bringing them through different learning phases summarised in Kolb's cycle (Kolb and Fry, 1975). These phases are implemented in the form of face-to-face sessions dealing with different aspects and applying different didactic tools, such as games or storytelling. The results of the pilot case studies in Hamburg (Geissler, 2006, 2014) and the Netherlands (Kappe et al., 2006) show that the participants demonstrated great interest in the topic of the increased risk of flooding in the areas they lived. The experience in Frysland has been considered as an "eye opener". In Hamburg it has provided a better hazard awareness to the participants, and delivered insights into the developing process and necessary conditions (Geissler, 2006).

Although assessed as an important aspect of capacity building in FRM, the face-to-face methods are still underused as they are usually related to high time and resources efforts (e.g. Kappe et al., 2006). The developed and implemented ILG method, although delivering initial satisfying results, also showed that there is still capacity to further strengthen the method to intensify its impact (Kappe et al., 2006). The main improvement potential is to be found in the following aspects:

1. The pace of the overall program, based exclusively on the face-to-face sessions, was too slow with long interruptions between the sessions. More continuity should be maintained in order to keep the topic present in the mind of the participants. The topic is rather complex and it is not enough to cover all relevant facets of the issue by mere face to face sessions.
2. The rather heterogeneous groups in terms of interests and level of involvement and knowledge, resulted in different engagement and motivation levels of the participants throughout the learning groups
3. General concepts and problems were dominant rather than local issues, which reduced the identification of the groups with the problems presented, lowering the overall motivation of the participants
4. There was a problem with attracting participants, in spite of active campaigns by means of "conventional media" such as local newspapers, flyers, announcement on selected internet pages.

As capacity building is a continuous learning process, the substantial improvement of the efficiency of this method can be seen in the development and implementation of the combined learning methods, i.e. using face-to-face learning as a basis but enhancing it with other methods to achieve more continuity and presence of the topic and to better tailor the single methods to the learning units within the scope of the ILGs.

Blended learning

The deficiencies of the face-to-face methods presented above can be improved by a combination of learning methods in the form of blended learning[96]. In this way the web based tools can be combined with other methods such as multimedia or face-to-face sessions. This is additionally supported by development and implementation of Web 2.0[97].

For private/community stakeholders there are still a limited number of examples of blended learning available, although the importance of an integrating capacity building process for private stakeholders has been acknowledged by various authors (e.g. Hagemeier-Klose& Wagner, 2009). Blended learning, as integration of different learning methods opens possibilities to cover the whole span of the capacity building process and tailors different learning methods to the corresponding tasks.

Learning (and action) alliances- LAAs and collaborative platforms- CP

The highest level of integration of different stakeholder groups and full implementation of the governance strategies in FRM can be achieved by the application of a framework for stakeholder involvement such as learning (and action) alliances and collaborative platforms.

Pahl-Wostl& Möltgen, 2007 introduced the concept of collaborative platforms as the key instrument for managing cross scale linkages in terms of spatial and organisational scale and improving vertical and horizontal interactions of the stakeholders in river basin management. This is based on two pillars: social learning or building social competences and content and knowledge management. Learning alliances are tightly related to active learning or capacity building. This is a process, not a single activity and as such should be supported by didactic concepts and methods. For dwellers the participation in learning alliances is an opportunity to take part in the decision making process and actively cooperate with the professionals, which requires an adequate capacity for efficient participation. The experience from the Crue EraNet DIANE-CM Project indicates very good acceptance of the online participation model called collaborative modelling and the corresponding tools used during the process (including online capacity building platform (Evers et al., 2011), emphasising the potential of web based tools for capacity building and collaboration between professionals and "non experts".

The generic concept of the Learning and Action Alliances (LAAs) has evolved along a range of EU and national projects. Its origin is to be found in the concept of the Learning Alliance as defined and developed in the SWITCH project (Batchelor& Butterworth, 2008). There, a Learning Alliance (LA) is defined as [a group of individuals or organisations with a shared

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[96] Blended Learning is learning that is facilitated by the effective combination of different modes of delivery, models of teaching and styles of learning, and founded on transparent communication amongst all parties involved with a course (Heinze& Procter, 2004).

[97] http://oreilly.com/web2/archive/what-is-web-20.html (last accessed: January, 2015)

interest in innovation and the scaling-up of innovation, in a topic of mutual interest.] This concept of Learning Alliances is built around the central proposition that an integrated approach to the process of innovation can only be achieved through the establishment of formal networks of professionals (e.g. water resources management, environmental management) and public and private stakeholders which all share a special interest in flood risk management and development in the area. These should provide a collaborative environment for all stakeholders, exchanging opinions, information, results, and supporting the process of learning from each other.

In the context of UFM, these methods are increasingly in use. However, the examples are reduced to a few projects and initiatives (e.g. INTERREG IVb Projects SAWA[26] and MARE[32], Matisse[98], SWITCH[99]). Within the INTERREG IVb projects SAWA and MARE the concept of the LA has been adopted and further developed to include the 'active' component, delivering the concept of the Learning and Action Alliances (LAAs). The LAAs have been applied in various EU, international and national project to pursue the innovative way of thinking in addressing the flood related issues. There, the LAAs have been understood as vehicles for learning together actively in order to innovate to address complex, or even wicked problems (Ashley et al., 2011) and as a generic concept, they are considered to be widely applicable including the flood risk management planning in the sense of 2007/60/EC.

Summary:

Capacity building methods should support the active learning process (e.g. Ashley et al., 2008). By mere delivery of information and knowledge in the form of info material, it can hardly be achieved. A blended learning strategy that extends the (Geissler, 2006, 2013) is an open research issue. Web based tools due to their accessibility and increasing acceptance among a wider group than professionals alone (e.g. Evers et al., 2011) should be considered as a part of the blended strategy.

A step forward in integration of the dwellers in the decision making process is seen in the concept of the Learning and Action Alliances (LAAs) which can be used as a vehicle for the development of the concepts for dwellers participation.

2.4 Open questions and the objectives of this work

The presented study on the state of the art indicates that the current knowledge and the existing strategies to support dwellers involvement in FRM (and UFM) encompass either direct or indirect providence of advices and assistance (personal consultancy, web based tools, brochures etc.) or providence of different incentives or aids (financial such as insurance, cash rewards or even non cash rewards as illustrated in Figure 2-19). Also, there is a range of research activities on capacity building and raising of risk awareness that have been applied at

[98] http://www.matisse-project.net/projectcomm/ (last accessed: January, 2010)

[99] http://www.switchurbanwater.eu/ (last accessed: January, 2015)

real cases, however they are often tested in isolation, without connecting them to the decision making process. The holistic methods combining both are still scattered.

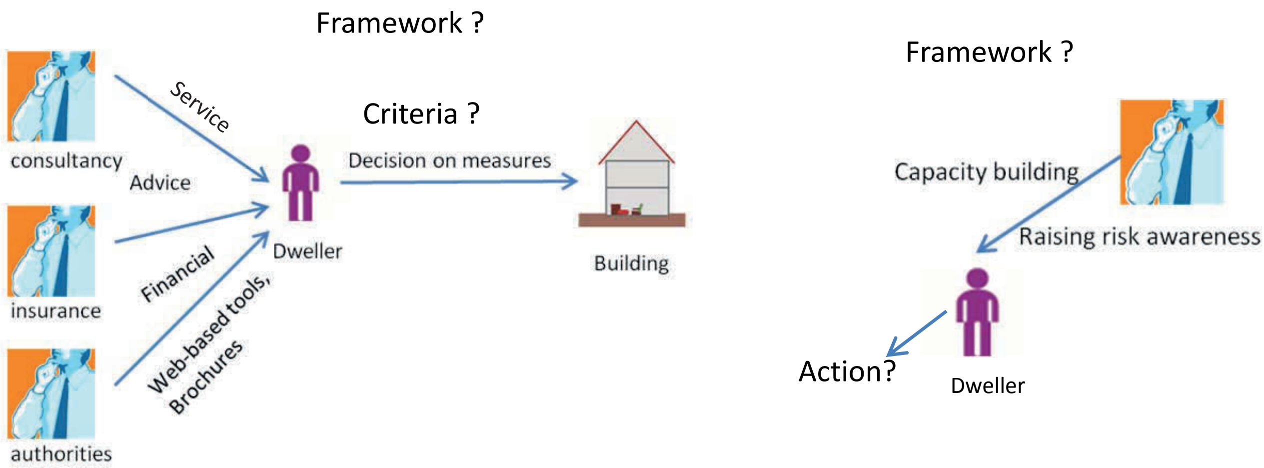

Figure 2-19 The existing research activities and practices to support dwellers in the decision making process on how to protect their properties (left) and in the capacity building process (right)

The state of the art in research indicates that resilience as a concept is of multi scale nature (e.g. Folke et al., 2010) and applying the system approach to urban systems (e.g. Fiksel, 2006, Zevenbergen et al., 2008) it can be decomposed to smaller interactive and interrelated units at different scales. The research need is seen in the understanding on how resilience can be improved at the building level and how dwellers, as integrative elements of urban environment, can be empowered and involved to contribute to it.

The corresponding research needs identified within the state of the art analysis that will be addressed in in this work are given as follows (and are envisaged in Figure 2-20):

(1) Definition and understanding of a context for the dwellers involvement and empowerment- framework

- Definition or adoption of an overarching- holistic concept of urban systems where dwellers and built environment represent an integral element and where their interactions can be mapped and studied
- Definition of flood resilience as a key concept for development of flood resilient cities, regarding both the spatial and temporal scale and that is applicable for the built environment- a multiscale resilience concept (Folke et al., 2010)
- Contribution to the development of a strategy for stakeholder involvement focusing on dwellers and their role in UFM throughout the process - utilising a bottom up approach by making use of the generic concept of the Learning and Action Alliances (LAAs, Ashley et al., 2011)
- Exploring the potential and the corresponding requirements to combine the decision making process and the capacity building of dwellers

(2) Development of a methodology to map the knowledge on flood resilient built environment to the decision making process:

- Definition and understanding of the scope of the flood resilient technology in a form of a “knowledge base”, which should contain a context based assessment of their modes of application
- Definition of a framework for combinations of different flood resilient measures for buildings at a property level. Further, the criteria for the assessment of their performance are to be developed

(3) Enhancing knowledge on the decision making process and decision support tools

- Developing a methodology addressing the decision making process for the resilient built environment tailored to the need of dwellers, containing:
    - A method based on the physical assessment of the direct tangible damage enabling a high resolution analysis of the potential damage of a building that is sensitive to the individual (dwellers’) input data. This method should extend the work on synthetic damage curves (e.g. Neubert et al., 2008, Penning Rowsell et al., 2003), by developing a generic framework on how a high resolution data can be regarded
    - Regarding the damage as a factor dependent on social aspects and lifestyle; i.e. considering individual perception of damage when assessing the acceptable risk, extending the work of Penning Rowsell et al., 2003
    - Development of a method that enables different combinations of resilient measures at the property level and map them to the users’ property data and flood conditions.
    - Methods to deliver the expertise required to the users in an adequate way that is convenient for “non experts”.
    - Concept for data collection that involve ‘non experts’ i.e. dwellers
    - Consideration of the multi criteria when assessing the measures to be adopted by the dwellers, also including the cost benefit aspects

(4) Capacity building of dwellers

- Development of an integrated, blended learning strategy and the corresponding tools to build capacity of dwellers in fulfilling their roles in the decision making process. It should extend the work performed by Geissler, 2006 on Interactive Learning Groups (ILGs), but
    - Enhance its blended nature i.e. introducing the combination of face-to-face sessions and web based learning that facilitates continuous knowledge delivery and communication with the participants-dwellers and is tailored to their interests

- Development of a concept for raising risk awareness that enables a hands on experience of floods and visualisation with flood maps in a way that is understandable for dwellers

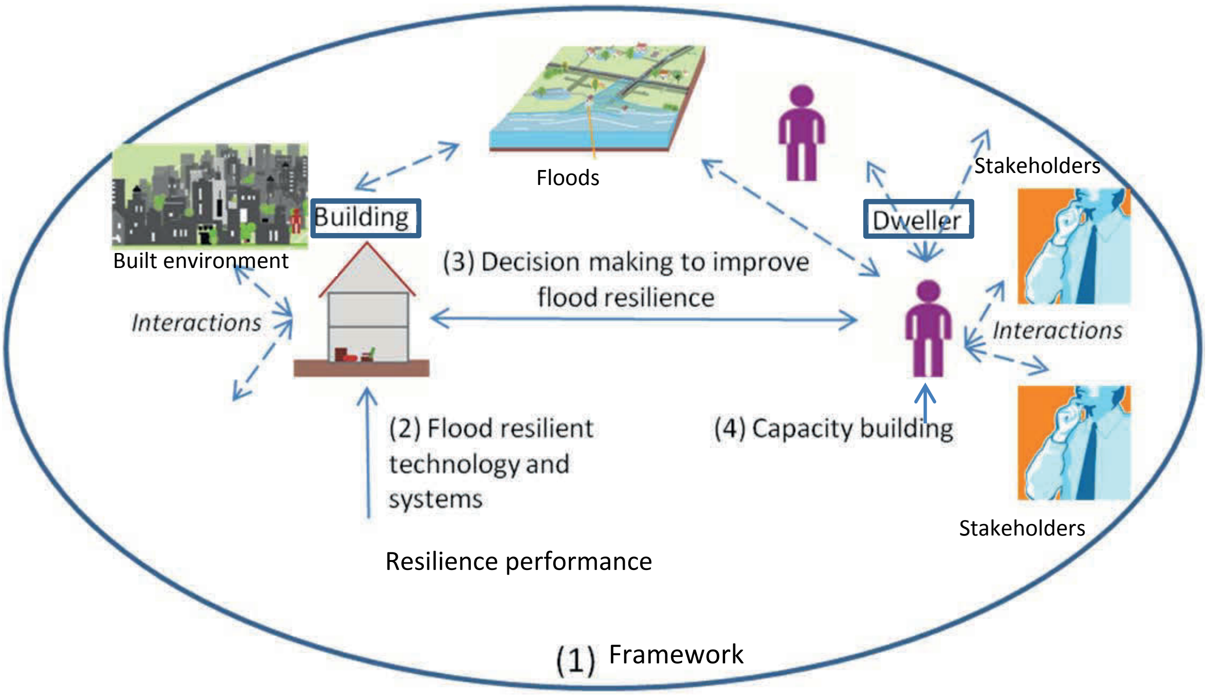

Figure 2-20 A summary of the main research challenges posed within this work given as (1)-(4)

3 Theory

3.1 Flood Resilient Cities - a Framework for Managing Urban Systems within Flood Risk Management[100]

3.1.1 Holistic view of urban systems and flood risk

Due to their structure and heterogeneity of the constitutive elements, urban systems can be defined as complex, adaptive (evolving) systems- CAS (e.g. Zevenbergen et al., 2008, Batty et al., 2004). CAS systems involve many components that adapt or learn as they interact (Holland, 2006). For being CAS, urban systems inherit their major features that are (Holland, 2006):

- parallelism
- conditional reactions
- modularity
- adaptation and evolution

According to Holland, 2006, parallelism describes the CAS as systems that consist of large numbers of elements or agents that simultaneously interact with each other, producing large numbers of simultaneous signals. The actions among elements are usually conditional and depend on the input they receive. CAS are also considered to be modular, tending to form blocks whose elements are conformed to common rules. The most distinguishing feature of CAS is their ability to adapt and evolve as their elements change over time. Although those changes are not a priori known and depend on a wide range of external and internal factors, these are usually adaptations that improve performance, rather than random variations (Holland, 2006). This characteristic is especially of importance when exposing a system to shocks or perturbations implying a certain level of uncertainty.

Cities can be defined as [physical manifestation of the networks with large numbers of interactions between the elements/ agents in a relatively small area. Cities as systems are based on a set of functional actions, processes, operations that must perform in order to achieve addressed outputs] (Batica et al., 2013). Cities can be broken down into urban

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[100] Parts of this chapter have been published and submitted as the authors contribution to the report 4.2 of the FP7 Project SMARTesT, Manojlovic, N., Nauman T., Schinke R., Spekkers M., Toumazis A., Giangola-Murzyn A., Deroubaix J-F, Barocca, B., Moulin E. (2012) Flood reislience Tools, Report 4.2, SMARTeST

functions and services. Urban functions of a city are defined as components that urban system need to provide as basic needs to residents such as housing, work, or education. Whereby the functions have a spatial extent, the services provide the connectivity between the physical components (e.g. transportation network connects two buildings) (Batica et al., 2013). Some basic services are given as transportation network, water and energy supply or telecommunications.

Many processes in the cities are not centrally steered, but self-organised. Therefore, system behaviour at macro level cannot be regarded as a mere aggregation of the elements at micro level. This is often regarded as emergent phenomenon at larger scales (Chavalarias et al., 2009, taken from Salagnac et al., 2013). The processes at different scales are interrelated and interconnected. Putting the system analysis of the cities in the context of natural hazards such as floods, it is possible to analyse in which way they can influence the main processes in an urban system.

Natural phenomena such as floods, that are results of specific hydro-meteorological conditions and events, have an impact on society and urban environment starting from dwellers up to the governance structures. They can influence both, the functions and services of a city. At the same time, the extent of floods can be influenced by utilising appropriate technology e.g. dikes or walls, that is designed and operated by humans and can have an impact on natural processes and conditions (e.g. river morphology).

Consequently, the extent and impacts of floods as natural phenomena can hardly be studied by separating social and technical processes (i.e., parts) and designing them in isolation. In that sense [they are to be regarded within the sociotechnical system] (Vojinovic& Abbott, 2012).

Due to high complexity, interconnections and interrelatedness of the single domains and their elements, a holistic approach[101] is required to study urban systems in the context of flood management (Vojinovic& Abbott, 2012). It should regard urban systems as CAS and focus not only on the elements, but also on their interactions (Vojinovic, 2015).

Following the holistic approach as introduced by Vojinovic& Abbott, 2012 and further developed in Vojinovic, 2015, an urban system in the context of flood risk can be defined as depicted in Figure 3-1. In that system, dwellers and built environment can also be defined as the constitutive elements.

Dwellers, as an element of the society, interact and are interrelated with the other elements including the built environment, which provides them with housing. It that sense it is possible to analyse how the interaction between those two elements can contribute to the dynamics of risk of the overall system as well as in which way the risk can be mitigated.

[101] Holism (gr. ὅλος *holos*, "*whole*" in opposite to the *reductionism,* is the idea that the elements of a system are determined by their interactions. The terms used in the contemporary science dates back to Jan Cristiaan Smuts' work published in "Holism and Evolution" in 1926 (taken from Pasche& Jeorgakopulos, 2008). Holism as the idea has its roots in the antic philosophy (e.g. Aristotle (384 BC – 322 BC) and his view that „ The whole is more than the sum of its parts. "), but it also to be found in the philosophic work of Kant (1724-1804), Hegel (1770-1831) or in the *Gestalt* psychology e.g. Wertheimer (1880-1943) (Vojinovic& Abbott, 2012)

Consequently, when introducing the concept of resilience as a property of the system (e.g. Zevenbergen et al., 2008) it has to include the understanding of both, the systems' elements and their interactions and interrelations.

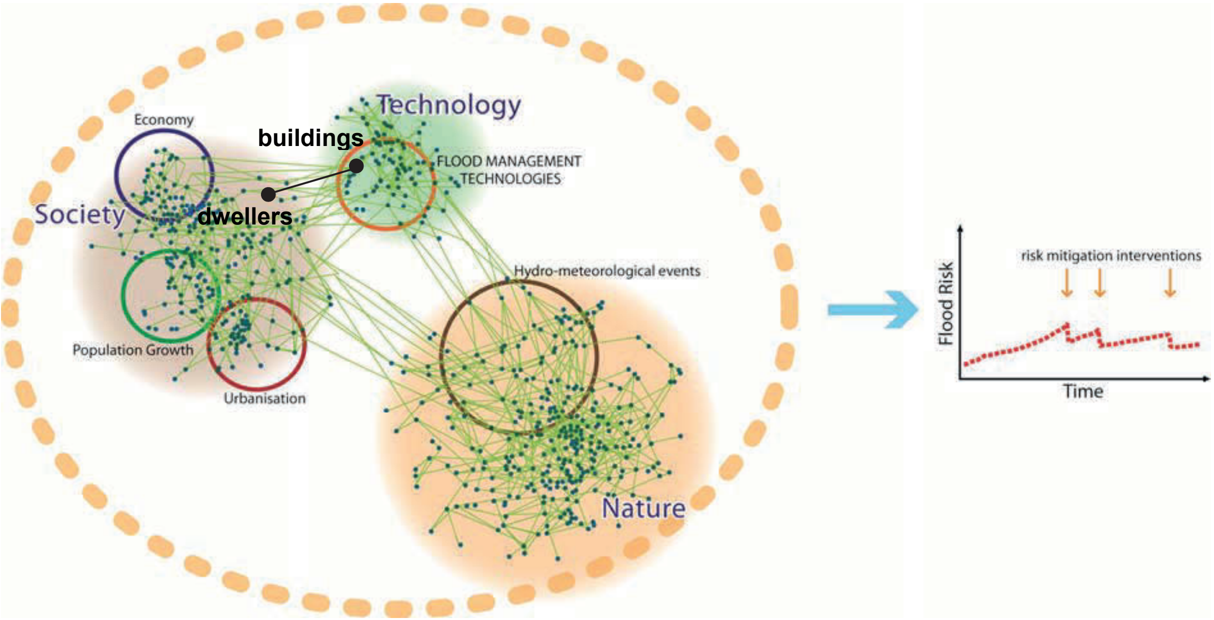

Figure 3-1 Formation and propagation of risk is a result from the coevolutionary nonlinear process between the ever changing social, technical and natural processes. Dots represent sub-processes and activities and lines represent their interactions. The main elements that are in the focus of this work being dwellers and buildings are highlighted (Vojinovic, 2015)

3.1.2 Characterisation of flood resilience in urban systems

Urban systems are exposed to a wide range of external and internal perturbations causing changes or even shocks. Within the process of adaptation and evolution, urban systems such as CAS should develop capacity to manage the ambiguities of current and future perturbations by increasing the level of urban resilience (e.g. Zevenbergen et al., 2008). In the heart of urban resilience is its response to impacts (such as natural hazards) but it goes beyond it; it encompasses the capacity of a society to adjust to uncertainties and surprises and [capitalise on positive opportunities the future may bring] (cited in Resilience Alliance, 2007).

Urban resilience represents a system characteristic and can be considered as [the degree to which cities are able to tolerate alterations before reorganising around a new set of structures and processes] (Resilience Alliance, 2007). It can be observed for the system as a whole and is then referred to as general resilience. According to Resilience Alliance, 2007 general resilience involves features such as diversity, openness, reserves, modularity and "apparent" redundancy. This approach to general resilience is based on non linearity and multi domains (basins) of attraction (Gallopin, 2006[102]) where resilience is a measure of their topology.

[102] See section 2.1 which introduces the basic terms regarding different resilience approaches.

This approach of general resilience does not consider any particular kind of perturbation or any particular aspect of the system that might be affected (Walker et al., 2004). Further, resilience to a specific disturbance or event (*"resilience of what to what*") is referred to as specified resilience. Specific resilience capacities are not independent, but represent a complex network of different capacities, in which elements can influence each other. In that sense, increasing one specific resilience can lead to the decreasing of another (e.g. increasing resilience of the built environment to floods can decrease its resilience to other hazards such as avalanches). Those aspects usually cannot be captured when merely analysing general resilience. Therefore, the resilience approach calls for assessing both specified and general resilience (Walker, 2009). As this work focuses on flood resilience, the distinguishing features which must be considered when assessing the general resilience system will be discussed. For the scope of this research the definition proposed by the United Nations' International Strategy for Disaster Reduction (UNISDR, 2007[103]) has been taken as a basis and is given as:

> *Def. 1: "Resilience is the capacity of a system, community or society potentially exposed to hazards to* ***adapt****, by* ***resisting*** *or* ***changing*** *in order to reach and maintain an acceptable level of functioning and structure."(UNISDR, 2013).*

Transferring this approach to the holistic representation of the urban systems as given in Figure 3-1 the mechanisms are to be identified or created that can improve the resilience of the overall system in order to assess or create the possibilities of flood risk mitigation. Having floods as a focus of this work, the following subsystems could be identified for the main urban flood typologies being riverine, coastal and pluvial and are given in Figure 3-2 (see also section 2.1)[104]:

(a) an urban system exposed to a riverine or a coastal flood including lake flooding protected by a conventional flood defence structure
(b) an urban system exposed to a riverine or a coastal flood including lake flooding with a naturally elevated flood plain
(c) an urban system exposed to a pluvial flood.

Here urban system is given as a sociotechnical system with its functions and services as introduced in section 3.1.1.

Different flood types can also be combined and occur either in coincidence or as conjoint events. One of the frequent combinations in urban areas is the joint occurrence of pluvial and riverine floods and is typical for small urban catchments (Pasche et al., 2008).

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[103] http://www.unisdr.org/we/inform/terminology#letter-r (last accessed: January, 2015)

[104] All those flood types can be combined with the groundwater (GW) flooding. Within this work the GW flooding will not be explicitly regarded. Also, the extreme waves or Tsunamis that are results of geo-physical processes have been beyond the scope of this work.

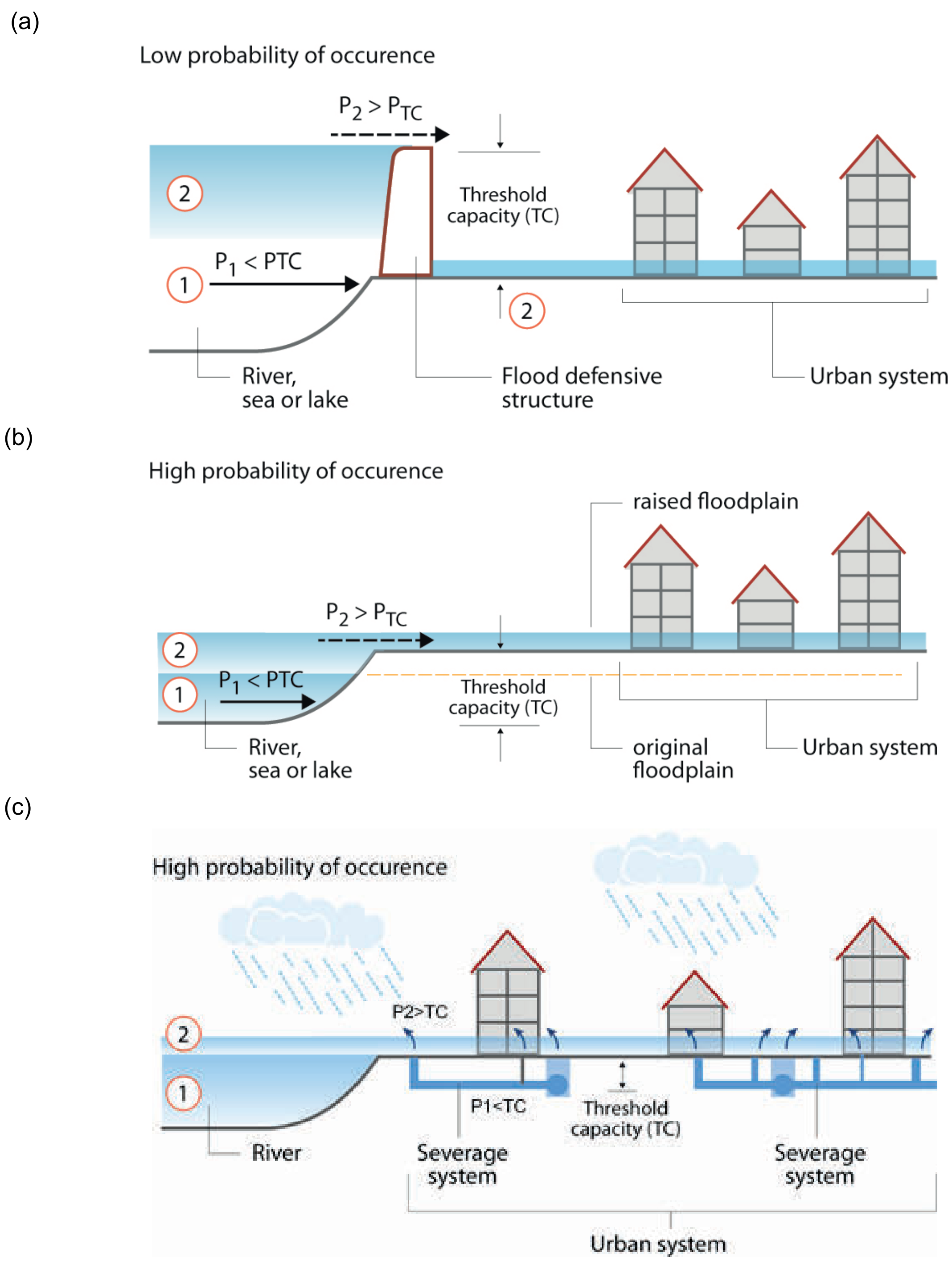


Figure 3-2 Definition of the system: An urban system exposed to a flood event below (1) and beyond (2) the threshold capacity

In all the defined systems, the existing capacity to manage floods of urban systems is a reflection of the extent of past events, i.e. the configuration and coping mechanisms of the existing urban systems are derived from the response to events which have occurred in the past for different flood typologies (e.g. Pasche et al., 2008). This capacity is either an intrinsic property of the system or it can originate from manmade structures, whose purpose is to resist floods by not allowing flood water to reach the urban environment. This intrinsic property of the system is referred to as threshold capacity (TC), by which it is withstanding flood perturbation (i.e. events $P1<P_{TC}$ (1)). Up to this level the perturbation does not reach the urban system, but it is configured in a way to *resist* floods.

When being exposed to an event beyond the threshold capacity or the design level ($P2> P_{TC}$ (2)), the existing configuration of an urban system is not sufficient to protect the urban system from flood, but it has to mobilise other capacities to manage the extremes.

Following the adopted definition of resilience (Def.1) and considering the mechanisms that are to be developed in different flood systems as given in Figure 3-2, the system mobilises its resilient capacities that are given as (Gersonius et al., 2010, Francis& Bakera, 2014):

- Resistance – the system's intrinsic threshold capacity
- Restorative - the system's ability to *cope* and *recover* from an impact of short-term perturbations
- Adaptive - the system's ability to adaptively adjust to the long-term changing conditions

3.1.2.1 Resistance (threshold) capacity

The resistance capacity describes the ability of the system to withstand perturbation (e.g. Gersonius et al., 2010)

The system (a) protected by a conventional flood defence structure has a threshold capacity determined by the protection level (probability of occurrence) of the structure. Up to this designed level, the system *resists* flood hazard (1) i.e. disabling it to reach the urban system behind it. When the threshold capacity of the defence structure has been exceeded, the urban system has to mobilise its resilience capacity to manage this disturbance. The probability of occurrence usually corresponds to 1:100, in extreme cases reaching 1:10000 (main dikes in the Netherlands), indicating a rather low probability that the urban system will be affected by flood.

The system (b) is exposed to a riverine or coastal flood without any conventional flood defence structures. Such a system has a threshold capacity determined by the elevation of the flood plain (1). Exceeding this capacity, the urban system is exposed to flood and has to cope with floods mobilising its resilience capacity (2). Such a system's configuration corresponds to an area with the probability of occurrence which can be found in urban systems close to water bodies, which are affected by floods usually at higher probabilities < 1:100.

For the case of pluvial floods the system reacts as given in case (c). The flood events below the threshold level ($P1< P_{TC}$) can be managed by the existing sewerage system (1). Exceeding this level ($P2> P_{TC}$), flood water reaches urban fabric, which then has to activate its restorative capacity to cope with this perturbation (2).

3.1.2.2 Restorative capacity

The restorative capacity describes the system's ability to *cope* and *recover* from an impact of short-term perturbations after being exposed to an extreme event that goes beyond the threshold value (e.g. Gersonius et al., 2010). Consequently the restorative resilience is composed of coping and recovery capacity. Coping capacity refers to the capacity of a system to minimise impacts in the case of a disturbance, whereby recovery capacity addresses the ability of the system to quickly and efficiently reach an equilibrium state after being exposed to an extreme event (e.g. Gersonius et al., 2010). Although their timing is different (during and before an extreme event) those capacities have the same bottom line which is managing extreme flood events exceeding the threshold value without addressing the uncertainty aspect and long term development, and as such their merging into one bounding capacity, termed "restorative", is reasonable[105].

The urban systems depicted in Figure 3-2 activate their resilience capacity after exceeding the system's threshold level. Note that at this point the system is being observed in the actual moment, addressing the short term disturbances.
Addressing the short term disturbances, the main coping and recovery mechanisms of an urban system exposed to a flood event beyond the threshold level are classified here as (Figure 3-3, adapted from Gersonius et al., 2010, Ashley et al., 2008):

1. fast recovery; the system reacts fast and returns to the initial state after being exposed to an unexpected flood hazard in a foreseeable time period
2. slow recovery; the system returns to the initial state within a longer period of time
3. recovery reaching new equilibrium: a certain adjustment of the system to the perturbation occurs; the system establishes an alternative equilibrium state equivalent to the state of at least acceptable level of functioning.
4. no recovery; after exceeding the threshold value (design flood) the trajectory of development abruptly drops and the system cannot recover to at least an acceptable level of functioning.

[105] Merging those capacities has been performed by various authors such as De Graaf, 2007 or Gersonius et al., 2010)

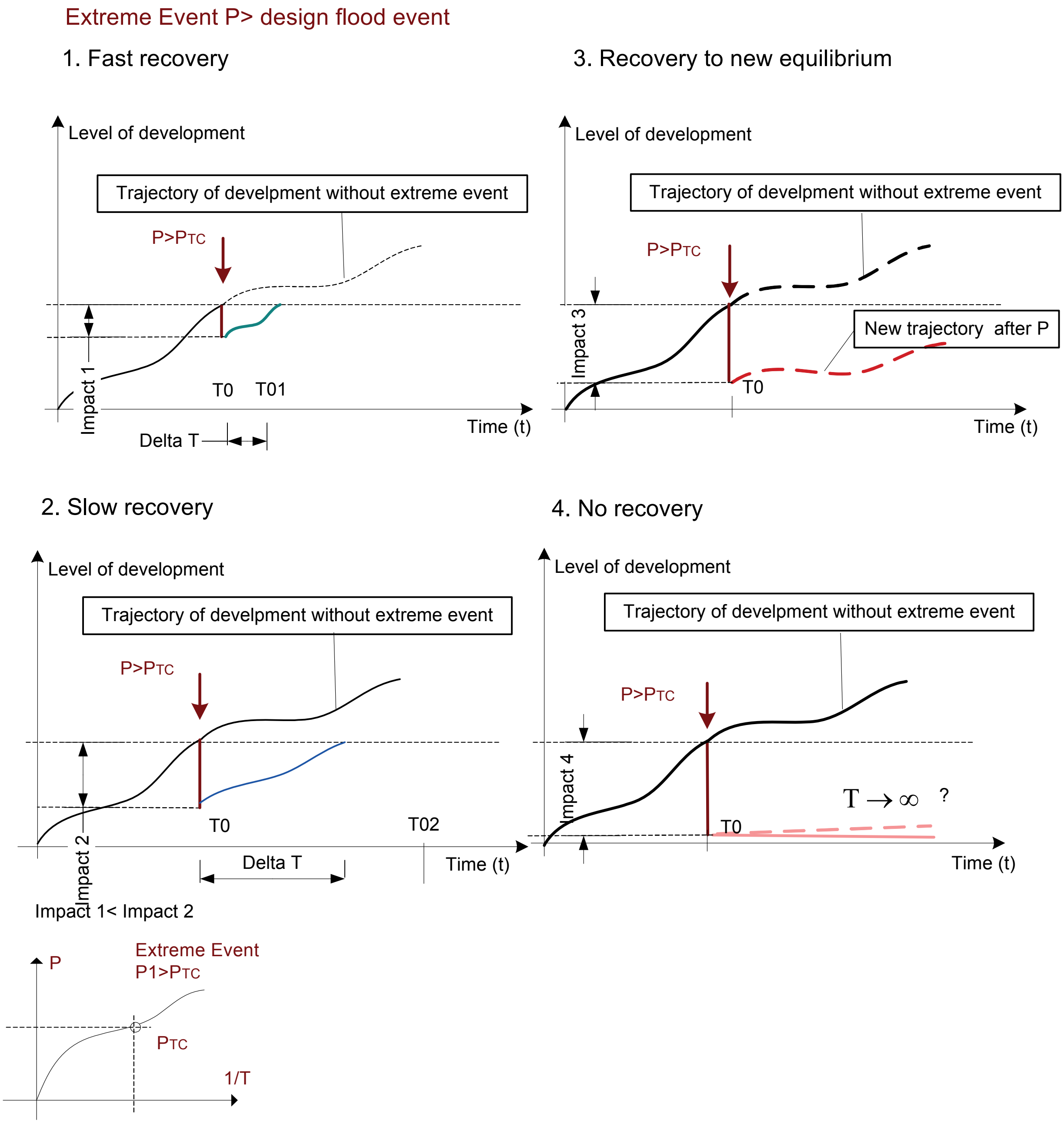


Figure 3-3 Restorative mechanisms of an urban system for an extreme event P > design level or the threshold capacity P_{TC} (adapted from Gersonius et al., 2010, Ashley et al., 2008)

Finding an optimal ratio between different capacities, i.e. setting the threshold value, is a complex problem and cannot be *a priori* given. It must be mentioned that the threshold levels of the present systems are determined based on the experiences from past disasters (De Graaf et al., 2007). However, future decision making has to consider the uncertainties caused by future developments such as climate change or economic growth, increasing its complexity. Due to those uncertainties it is difficult or even impossible to predict the future behaviour of the system and as such the optimal threshold value. As a consequence, the probability of occurrence of flood in the urban system can vary and if the required availability of resilient capacity is not provided for the required span of variations, the system can retreat.

In that sense, for defining a resilient strategy it is necessary to analyse both the short and long term perspective of resilience, i.e. restorative and adaptive capacities.

3.1.2.3 Adaptive capacity

Adaptive capacity refers to the capacity of an urban system (as CAS) to adaptively adjust to future changing conditions, both external (e.g. climate change) and internal (e.g. urban infill) (De Graaf et al., 2007). Other than restorative resilience, in which the time horizon is instantaneous, i.e. during and right after an extreme event, adaptive resilience gives a temporal dimension to the resilience capacity of an urban system and represents the system's behaviour in the long term perspective.

The urban systems presented in Figure 3-2 should develop an adaptive capacity to cope with the uncertainties of future development and the implied range of perturbations (P) values (Pi, Pj) and maintain their functionality, rather than consider only one design event P as in the case of the perturbations in the short term perspective. They can cope with future uncertainties in the long term perspective either by increasing the threshold capacity crucial for its functioning or increasing the restorative capacity, enabling the system to restore its functionality in case of being exposed to a range of magnitudes of perturbation and stresses.

For example, increasing the threshold capacity of the defence structure (by raising dikes) in system (a) is not necessarily sufficient to increase the adaptive capacity of the overall system, as due to uncertainties the required threshold level cannot be a priori known and can lead to its under- or overestimation. At the same time, the restorative capacity has to be managed in such a way as to contain the potential for adaptation for a range of values (external and internal variables).

By mobilising adaptive resilience, the mechanisms depicted in Figure 3-3 are given a temporal component. In this way the measures are enabled to be resilient for a range of scenarios of future development. In this way the *no regret strategies* (Ashley et al., 2008) can be avoided.

Flood resilience as a system characteristic, in both the short and long term aspects, can be improved by the application of corresponding strategies given as ***flood resilience strategies.***

In order to assess to which extent the given resilience strategy improved the resilience level, resilience metrics has to be developed. This is given in section 3.2.3.

3.1.2.4 Adopted definition of (flood) resilient cities in the context of urban flood risk

(Flood) resilient cities as urban systems inherit their main characteristics, i.e. being *inter alia* complex adaptive systems as introduced in section 3.1. In the context of flood risk management they are observed in their ability to enhance resilience.

Box 1 summarises the characteristics that have been assessed as decisive for the definition of (flood) resilient cities based on the adopted and presented methods in sections 3.1.1 and 3.1.2.

Box1:
Main characteristics adopted for the description of a flood resilient city:

- *It is a complex adaptive system (e.g. Holland, 2006)*
- *It is a sociotechnical system, where e.g. dwellers and their houses can be considered as its elements (Vojinovic, 2015; Vojinovic&Abbott, 2012)*
- *It exhibits a certain level of resilience through different resilient capacities (resistance, restorative, adaptive) which can be analysed at different scales (multi scale approach) and in different time scales - i.e. short and long term perspective (e.g. Gersonius et al., 2010)*
- *Its resilience level can be improved by application of different resilience strategies at different scales. Those interventions should encompass actions in social, technical and natural environment and should be consistent*

3.1.3 Flood Resilience Strategies

A ***set of strategies*** can be defined that can improve the flood resilience level of an urban system and are referred to as flood resilience strategies (2007/60/EC, Crue EraNet, 2005, FloodSite 2005, FIAC 2007). They are defined as a notion or idea on how to combine different measures in order improve the resilience level of the analysed system in a way that it is conform to the given context i.e. flood typology and local conditions. There is not a single combination of measures that fulfils this requirement. In that sense, developing flood risk mitigation strategies becomes a “wicked” problem (Lach et al., 2005). According to Rittel& Webber, 1973 these problems have multiple and conflicting criteria for defining solutions, the solutions can create problems for others, and no rules can be applied for determining when problems can be considered to be solved. In order to overcome this problem, the following steps are required to create a basis for the development of flood resilient strategies:

1. to scope the measures that can be used for development of resilience strategies (Scope and inventory)
2. to assess the measures in their potential to improve the resilience level when combined into strategies in a form of a context based storage and access of the collected measures (Knowledgebase)

Scope and inventory:

In order to address the whole span of measures that can be part of resilience strategies, the model of risk will be applied, bringing the resilience and management of urban systems into the context of flood risk management.

Summarising the paradigm shift from traditional to more integrative, flood **risk** becomes the central concept to be regarded, replacing the traditional paradigm of flood hazard management (2007/60/EC). Risk as a notion [describes the actual exposure of something of human value to a hazard and is often regarded as the combination of probability and loss]

(Smith, 1996 cited in Samuels et al., 2007). In the context of natural hazards, risk refers to the probability of harmful consequences, or expected losses resulting from interactions between natural hazards and vulnerable conditions (UNISDR, 2013). For the purpose of quantitative risk analysis, the **risk** of flooding is expressed as the product of the probability, intensity and vulnerability of flooding which is in the sense of 2007/60/EC and is given as:

$$Risk = probability \times intensity \times vulnerability \quad \text{(Eq. 3-1)}$$

$$Risk = hazard \times vulnerability \quad \text{(Eq. 3-2)}$$

$$Risk = probability \times consequence \quad \text{(Eq. 3-3)}$$

Where:

$Hazard = probability \times intensity$,

$Consequence = intensity \times vulnerability$, where[106]

Probability is the estimated likelihood of a flood event e.g. (1 in 100 years) (FloodSite- Language of Risk, 2008)

Intensity quantifies the extent of the hazard.

Vulnerability is a characteristic of a system that describes its potential to be harmed. This can be considered as a combination of susceptibility and value. (FloodSite- Language of Risk, 2008)

Hazard is a specific natural event, such as a flood, with the potential to cause damage characterised by a certain probability of occurrence and intensity (FloodSite- Language of Risk, 2008)

Consequence represents an impact such as economic, social or environmental damage or improvement of the elements at risk, and may be expressed quantitatively (e.g. monetary value), by category (e.g. high, medium, low) or descriptively (adapted from HR Wallingford, 2002).

Different types of measures can be identified that either reduce the probability of floods or minimise their possible consequences to an urban system by minimising impacts or reducing vulnerabilities. An overview of the possible measures is given in Figure 3-4. A more detailed presentation of the measures is given in Appendix 3.1

The measures that reduce the probability of floods act as physical barriers or temporary storage of floodwater preventing it to reach urban environment and to cause damage. Those measures encompass the traditional flood protection structures for different flood typologies such as dikes and walls, or Sustainable Drainage Systems (SUDS) such as green roofs or swales that can be described as [small-scale source-control structures with a limited capacity] (Butler & Davies, 2011). The main idea of those measures is to retain the stormwater as close as possible at the source (i.e., source-control) and to make the use of small scale structures.

Those measures improve the threshold capacity of the system and in that way contribute to the overall resilience level of an urban system.

[106] In the international publications there is a considerable heterogeneity in definitions of those terms. The presented definitions are adopted for the scope of this work

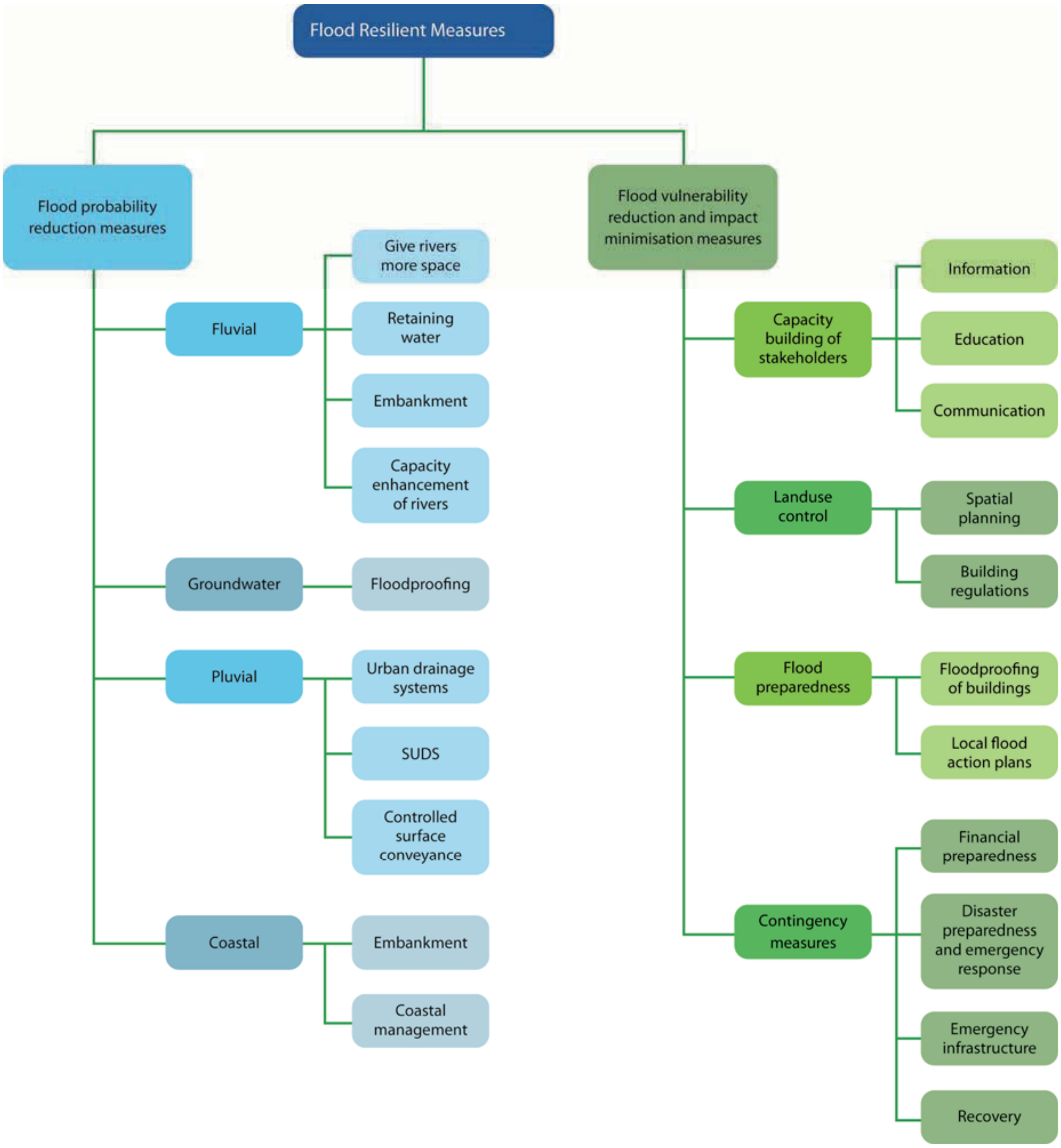


Figure 3-4 An overview of the possible measures to mitigate flood risk (adapted from Pasche et al., 2008, Vojinovic& Huang, 2014, Batica et al., 2012); a more detailed presentation of the measures is given in Appendix 3.1.

The measures that minimise impacts or reduce vulnerability of an urban system imply modification of the urban environment and address both, its social and technical dimensions. They reduce the vulnerability of the system by empowering the key stakeholders to efficiently contribute to flood risk management while practicing their role (preparedness) or by preventing damages by performing flood risk adapted landuse planning and restricting further urbanisation if this contributes to increase the damage potential (prevention). Minimising impacts of floods in an acute case is performed by the contingency measures which encompasses all activities and resources available in the case of a hazard event that include:

emergency response, emergency infrastructure, financial preparedness and recovery. Also the reduction of vulnerability can be performed by flood alleviation measures of the built environment. As such measures strongly depend on the residents' behaviour and their capacity to apply them; they are only effective if residents are aware of the imminent hazard. Those measures will be discussed in more detail in section 3.2. Those measures can also be summarised in the ***4 A's*** of the safety chain of flood resilience given as (1) **A**wareness, (2) **A**voidance, (3) **A**lleviation and (4) **A**ssistance (FIAC, 2007, Ashley et al., 2007).

For the development of resilience strategies the decisive question in which way those measures are to be combined in order to improve the resilience level of a system. This decision should be based on the *meta information*[107] that is to be provided in a form of a knowledgebase.

Knowledgebase of measures (KB of M):

Knowledgebase contains data and information at a higher level of abstraction about the data (meta information) (Brodie, 1984). In the context of flood risk management, a knowledgebase should be understood as a comprehensive repository of the resilience measures and strategies. Going beyond the conventional databases the knowledge base also contains so called "business logic" on the applicability of the measures i.e. a set of "rules" which define the potential of the measures to mitigate flood risk for the given contexts (i.e. flood typology and description of the urban environment) including their resilience performance as shown in Figure 3-5. In that sense, a specification of parameters decisive for the selection of measures& strategies should be delivered which describes those measures and give the information about their implementation aspects and best practices, if available.

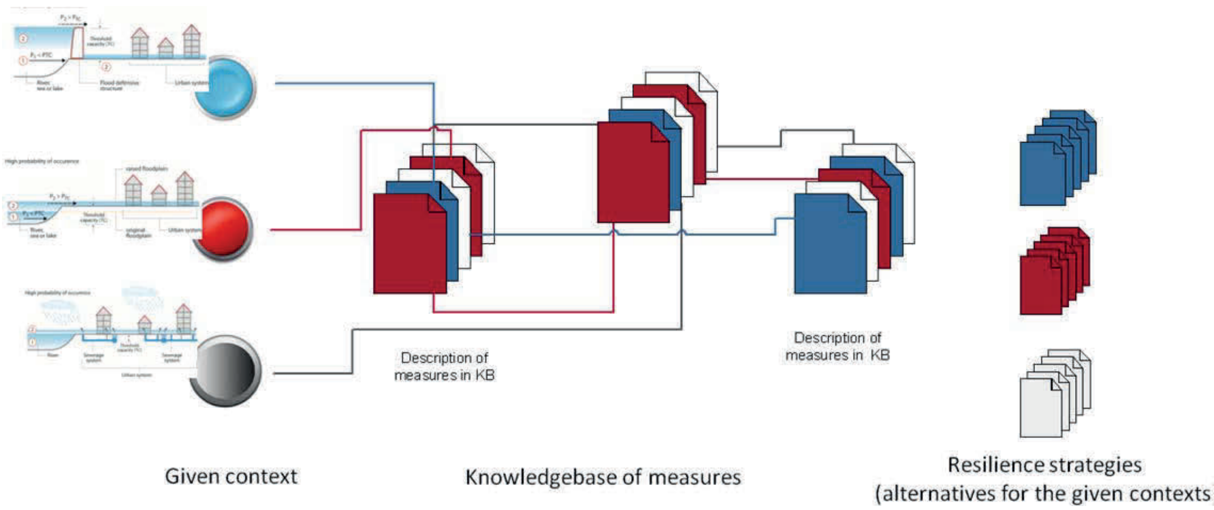


Figure 3-5 The role of the knowledge base in the development of the flood resilient strategies

[107] Information *about* information (www.freedictionary.com) In this case, it means the specific information about the measures

The following structure of a knowledge base of resilience measures and strategies has been developed and is given in Table 3-1.

Table 3-1 Structure of the knowledgebase of measures

Type of Info	Parameter	Type
I) General Description	1. Definition+ Scope (scale)	Description
	2. Technical Description	Description+ Images
II) Implementation aspects	3. Design criteria for the relevant flood typology	Description+ Figures
	4. Already Practiced/ Emergent	1. Practiced 2. Implemented as a pilot 3. Emergent
	5. Characteristics (rules) relevant for combination with other measures	A list of rules
	6. Resilience potential for the given scale and contexts	Description 1. resistance 2. restorative 3. adaptive
	7. Multi criteria (multi benefits) including costs	List (MCA) + Unit costs (figures)
	8. Responsibility	Description
	9.Implications (Stakeholders, Institutional, Legislative)	Description
III) Best practices	10. Examples from implemented cases and evaluation	Description+ Images

Based on those parameters, the measures can be combined into strategies, which ***resilience performance*** i.e. change of the overall resilience level of the system can be assessed.

According to 2007/60/EC flood risk management planning and the resilience strategies to be developed should address all aspects of flood risk management focusing on prevention, protection, and preparedness (Article 7). It means that a combination of all resilience capacities (resistance, restorative, adaptive) should be considered in order to practice flood risk management in the sense of 2007/60/EC. The traditional strategies are based on the mere building of dikes or levies are constructed for a “designed flood”, i.e. threshold capacity, up to which their performance is mostly predictable enhancing the *resistance* capacity of a system. Exceeding that level, their performance cannot be guaranteed and the protected urban system (e.g. areas behind the dikes) remains unprotected. Such concepts should be extended with the other resilience capacities applying the corresponding measures. The meta information about the measures contained in the knowledge base can contribute to better understanding on which measures and in which way to apply in order to extend the traditional strategies towards holistic flood risk management.

Figure 3-4 shows a range of measures that can be combined into resilience strategies and applied to the sociotechnical system depicted in Figure 3-1 by making use of the meta information about the measures stored in the knowledge base. It also means that measures to improve the resilience of built environment have to be observed in a broader, sociotechnical, context analysing the potential of individual measures for combining into a strategy as well as the prerequisites posed on the stakeholders to accept and implement them.

Flood resilient systems implement flood resilience strategies. The relevant strategies for the scope of this work related to the flood resilience of properties and dwellers will be explained in more detail in section 3.2 when the strategies and measures for resilient built environment will be introduced[108].

3.1.4 Engagement of Dwellers towards Flood Resilient Cities

The development and implementation of resilient strategies involves different elements of the urban systems at different scales and has decisive implications on stakeholders' involvement including the participation of dwellers. This transition from traditional methods to (holistic) flood risk management and flood resilient cities is a long-term process (Ashley et al., 2008) that cannot be intrinsically initiated, but should be triggered and governed throughout the process. A framework for engaging stakeholders should deliver the roadmap for reaching flood resilient cities, covering the implementation of different resilient strategies of the coordinating multilevel decision making and the managing interests of various stakeholder groups (Manojlovic et al., 2012). The bottom up approach enables active involvement of all stakeholders in the sense of the 2007/60/EC, where each key stakeholder group, including dwellers, is being involved in the decision making process from an early stage. It implies that each stakeholder group, including dwellers is being involved in the decision making process within their role in the development of resilient cities.

A framework for engaging key stakeholder groups has been developed, taking dwellers as one of the key stakeholder groups and supporting them in performing their role, as depicted in Figure 3-6.

This is an iterative process composed of the 4 main phases given as:

1. *Scoping*- the key stakeholders of flood resilient cities are assessed by means of stakeholder analysis
2. *Understanding*- the scoped stakeholder groups acquire the required knowledge and skills for participation in the decision making process
3. *Experimenting*- based on the flood resilience measures (4As), different resilience plans are developed by all stakeholders

[108] Development of flood resilient systems for the whole sociotechnical system has been beyond the scope of this work, which focuses on flood resilience of properties and dwellers.

4. *Evaluation and final decision making*- the resilience plan with the lowest conflict potential is to be adopted. Its resilience level is evaluated. Based on the result, the final decision is made.

Depending on the result, the process can be repeated, finally reaching the consensus among the stakeholders on how to manage urban systems towards flood resilient cities. Defined in this way, this concept extends the approach of Ashley et al., 2008 by introducing two processes that are underlying the process of stakeholder involvement, which are **capacity building** and the **decision making process**. Those two are coupled in the sense that capacity building should enable stakeholders to perform the decision making processes. Although those two are continuous processes, their intensity varies throughout the governance process. As the concept and implementation of flood resilient cities is still in emergence and usually associated with reluctance and scepticism as well as changes in existing practices (e.g. Ashley et al., 2008), the stakeholders should first become aware of the concept and understand what it implies. Also, the stakeholders should acquire knowledge and skills relevant to making concrete decisions and as such capacity building is triggering the governance process and dominating its initial phases (1,2). Capacity building should be tailored to the role of a specific stakeholder group. In the latter phases (3,4) the stakeholders should develop resilient plans and make the final decision, which has to be evaluated at the end of the process. In those phases the dominant process is decision making.

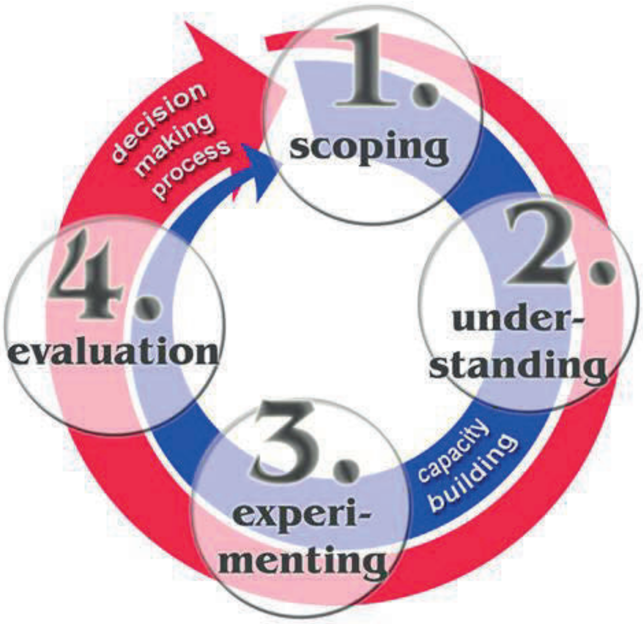


Figure 3-6 Framework for stakeholder engagement towards flood resilient cities (adapted from Ashley et al., 2008, Manojlovic et al., 2012)

The focus of this work is the participation of dwellers in the engagement process and their interaction with the built environment. The basic role of dwellers in flood risk management addressed in this work is to be proactive through the protection of their own properties. This role has been summarised in Table 3-2.

Table 3-2 Role of private stakeholder in flood risk management

	Role of private stakeholders- protection of own properties:
1	⇒ Understanding the necessity for action
2	⇒ Acquiring relevant information for understanding own role
3	⇒ Acquiring relevant knowledge for practicing the assigned role
4	⇒ Accepting the role and taking action (protect own properties)

The protection of the properties, i.e. the built environment, is based on the technology of flood resilient buildings. Although those measures are well established, the decision making process of defining an appropriate resilient strategy for the built environment is a problem of a difficult nature, as there is no a priori solution and each of the situations has to be treated separately (Manojlovic et al., 2009). It also causes an important implication for the dwellers that are facing new technologies and approaches which they are expected to efficiently apply. Also, flood resilient strategies for buildings can have an impact on the lifestyle of dwellers, demanding their empowerment to change their attitudes and behaviour. Such a complex decision making process should be applied by decision support tools that contain the required expertise and are flexible and adaptable to integrate newly acquired knowledge.

This specific knowledge, which is relevant for their empowerment, has to be transmitted to them in an adequate way within the capacity building process, accompanying the decision making process.

In order to enable dwellers to efficiently practice their role, the main requirements on expertise and instruments to be developed and made available are summarised as:

- Understanding resilience in the context of the built environment and how to improve its level
- Decision support tool for the resilient built environment
- Capacity building of dwellers

3.2 Understanding resilience in the context of the built environment[109]

3.2.1 System Approach- a multi scale analysis of urban systems

Applying the holistic approach (Vojinovic, 2015) for analysing the flood risk management processes, the built environment can be regarded based on its characteristics and its interrelations with the other domains such as nature and society (Figure 3-1), representing it as a complex adaptive system (CAS). As the processes in such a sociotechnical system take place at different scales, a multi scale approach becomes the key principle or urban resilience (e.g. Folke et al., 2010), stating that [deliberate transformational change can be initiated at multiple scales. Transformational changes at lower scales, in a sequential way, can lead to feedback effects at the catchment scale, which is a learning process, and facilitate eventual catchment scale transformational change]. This process is carried by different actors and organisations that can bridge the scales (dwellers, local communities).

Applying the system approach for better understanding of the dynamics of complex systems regarding their resilience and sustainability (Fiksel, 2006), the cities can be represented as multi-level interacting systems (Zevenbergen et al., 2008).

The single elements of that system can be decomposed into smaller heterogenic elements that are behaving as input-output units. Its further decomposition ends up in the definition of the smallest spatial elements such as buildings or roads. As input, the flood hazard is defined. The output is the impact caused by the flood hazard. Single spatial elements interact with each other crossing scales (e.g. building is an element of a city) and types of agents (e.g. people residing in built environment). Each element has its own dynamics and processes (e.g. aging). This system approach is generic and can be applied to any of the elements of urban systems and their interactions.

In that sense, the **built environment** and its interactions in a sociotechnical system as given in Figure 3-1 can be represented as a hierarchical set of subsystems, starting from the built environment of the city level and downscaling it to the property level, as shown in Figure 3-7.

At each of the levels, the input and output values can be determined as well as their interactions with the other components of urban systems. Each of those systems has a certain level of resilience. Those systems can be composed of different types of urban environments (e.g. built and social environment), where the interactions with the remaining elements have to be indicated.

Improving the resilience of those levels or elements can lead to the improvement of the overall resilience of the system. However, as introduced in section 3.1.3 resilience of the whole is not a simple sum of the parts (see also Walker et al., 2004). Applying the concept of multi scale resilience as introduced in section 3.1.3, the improvements at smaller scales (in

[109] Parts of this section have been published and submitted as the authors contribution to the report 3.2 of the FP7 Project SMARTesT, Salagnac, J-L., Schertzer, D., Tchiguirinskaia, I., Manojlovic, N., Hunter, K., Garvin, S. (2013): Guidance for Flood Resilient Systems, FP7 Project SMARTeST Report 3.2

this case building) lead to feedback effects at the larger scales scale, which is a learning process and should contribute to the overall improvement of the system resilience at larger scales. Therefore, it is important to analyse the resilience level at different scales and assess in which way they can interact and mutually improve.

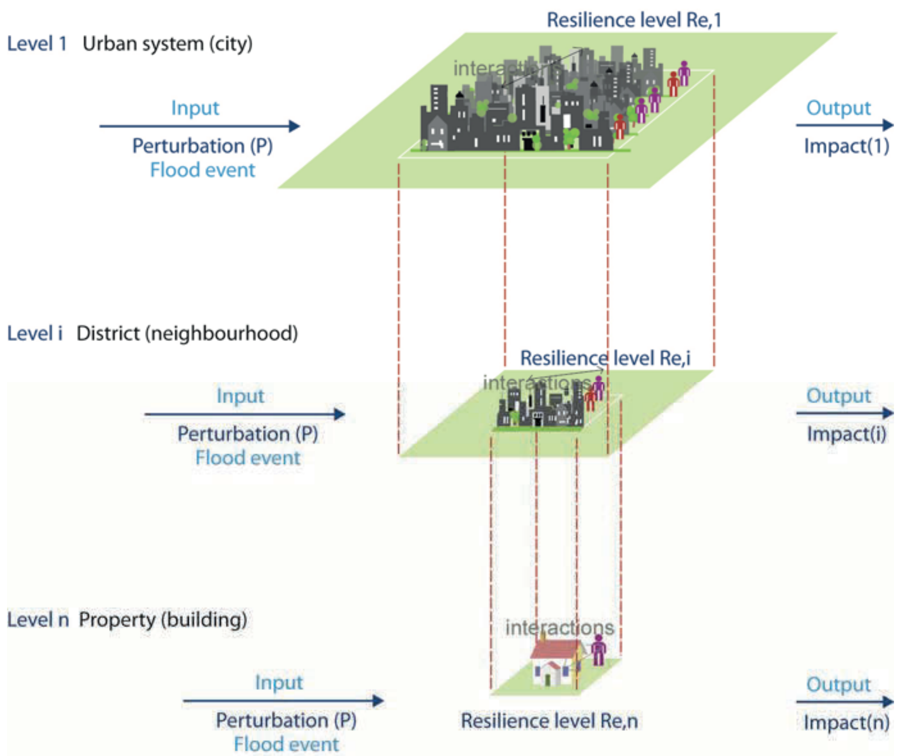


Figure 3-7 Left: Multi scale approach- Spatial decomposition of an urban system applying the system approach

Although the system approach does not fully cover the complexity of the resilience problem (e.g. Zevenbergen et al., 2010) it offers a framework to make the interactions between different processes visible in spatial and temporal dimensions, which can serve as a basis for the holistic approach and analysis of (flood) resilient cities.

3.2.2 Knowledgebase of measures for flood resilient built environment

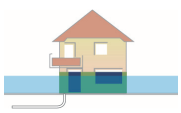
Section 3.1.3 introduced a set of different measures that are to be combined into resilience strategies on different scales. The main criteria for combining the measures into systems should be provided in a form of “rules” or meta information. This information is structured in a form of a knowledge base as presented in Table 3-1. For the purpose of the implementation of the resilient strategies on different scales in a multilevel system, the concept of Flood resilient systems as defined within the FP7 Project SMAREST has been made use of, given as:

A flood resilient system (FReS) is a system that contains a set of measures combined to a *whole* in a way to increase flood resilience of the given system i.e. the system will continue to work in the case of exceptional events or be able to return to the least level of functioning or to the initial state (SMARTEST Glossary, 2010). FReS development tries to [encompass a multi-scale territory and to create favourable conditions for a co-construction of acceptable decisions for the concerned stakeholders] (Salagnac et al., 2013). It requires consideration of a complex range of factors, which need to be explored and analysed in cooperation with involved stakeholders, and to take into account local socioeconomic and psycho-environmental context at different scales (Salagnac et al., 2012, definition adopted for the FP7 project SMARTEST).

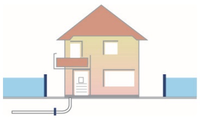
Following this definition, flood resilient systems for the built environment have been defined utilising the measures of flood alleviation as a basis, which are referred to as flood resilient technology (FRe technology). The main types of FRe technology can be summarised as dryproofing, wetproofing, relocation and elevation of the building, amphibious and floating homes (see also Ch. 2). While the first four strategies can be applied to the existing buildings (retrofitting), the latter two are applicable only for the new housing (fitting). For the decision on which measure to combine in a FReS, they have to be described in a way that their potential and rules for the combination into a resilient system are clearly indicated. Such description of measures can follow the structure of a knowledge base given in Table 3-1.

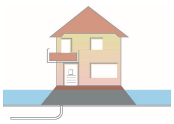
An overview of the general characteristics of the measures as defined in Table 3-1 (I) is given in in Table 3-3[110]. The scope of the measures (Column *Measures* in Table 3-1) has been adopted from the FP7 Project SMARTEST.

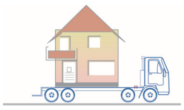
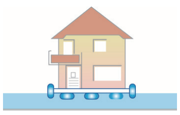
Table 3-3 Flood alleviation measures- Flood resilience technology- General description and Implementation aspects as an input to the knowledge base

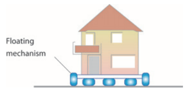
I) General Description				**II) Implementation aspects**
Measures		**Definition &Scope (scale)**	**Technical description**	**Characteristics (refer to Table 3-1)**
Dry Proofing	Sealing 	The building is sealed i.e. the external walls are used to hold back the flood water Building scale	Water resistant concrete “Weiße Wanne”, polymer bituminous seal “Schwarze Wanne“) combined with the additional sealing against non-pressurised water Protection (sealing) of the openings	**Design criteria:** acceptable level of risk **Practice:** in general- practiced, however flood barriers are mostly emergent **Characteristics relevant for combination with other measures:** - the homes are kept dry - the occupancy of the building is not affected - stability of the building can be jeopardized (limited applicability above 1m of flood depth) - logistic requirements can be rather high

[110] Within this work FRe technology has been used to define different flood resilient systems (i.e. no new systems or products have been developed). An overview of different technologies and a short description are given.

			Installing non-return valves within the private sewage system as a protection from the sewerage backflow	**Resilience aspect at the property scale**: resistance (improving threshold capacity) **MCA:** - cost intensive solution **Responsibility**:- homeowners for the measures on their property **Main implications for stakeholders:** logistic requirements
	Shielding 	The floodwater does not reach the building itself. Barriers are installed at some distance from the building or a group of properties Building to neighbour hood scale	- flood barriers with partially permanent structures - flood barriers without permanent structures - manually operated structures - automatically operated structures - flood products	
Wet-proofing 	Applying waterproof materials to building fabric and contents	The floodwater reach the building but damage potential of a building is reduced by applying water resistant materials and changes in the occupancy Building scale	e.g. water resistant paints and coating, lime based plaster, plasters of synthetic resin, mineral fibre, insulation tiles, oil based paints	Design criteria: acceptable level of risk for elevating the inventory, for waterproof materials- no threshold value Practice: in general- practiced, however new flood proof materials are not established on the market Characteristics relevant for combination with other measures: - cost effective solution - as people face floodwater in their homes, risk awareness is kept alive - materials used are not fully water resistant - limited occupancy of the building parts reached by the floodwater - logistic requirements can be rather high (e.g. pumps) Resilience aspect at the property scale:
	Adapting the occupancy of the building		raising the inventory, heating tanks and electrical appliances above the expected flood level	

	Elevating the inventory	Using easily removable pieces of inventory in lover parts of the building Building scale	e.g. removable furniture (e.g. with wheels), rugs rather than fitted carpets	restorative and adaptive resilience MCA: - cost intensive solution - Material can be well integrated into the building exterior/ interior Responsibility:- homeowners for the measures on their property Main implications for stakeholders: logistic requirements
Elevation		Vertical translation and the temporary placement of the structure on cribbing while a new foundation is built underneath. Building scale	- elevation of the building on piles - elevation of the building on new solid foundation	**Design criteria:** acceptable level of risk usually the highest historic flood event **Practice:** in general- practiced **Characteristics relevant for combination with other measures:** - not applicable to all types of buildings (e.g. solid brickwork or historic buildings) - can be technically demanding - logistics requirements in the case of emergency (incl. evacuation) can still be high - the building can be elevated above the threshold and kept dry **Resilience aspect at the property scale**: increasing threshold capacity **MCA:** - cost intensive solution **Responsibility**:- to be discussed for the given case **Main implications for stakeholders:** logistic requirements

Relocation/		Moving the building to a flood safe zone. Building scale	- disassembling and then reassembling - transporting it as a whole	**Design criteria:** acceptable level of risk **Practice:** in general- practiced **Characteristics relevant for combination with other measures:-** the building is removed from the flood prone area and therefore not exposed to any floods **-** not applicable to all types of buildings - can be technically demanding **Resilience aspect at the property scale**: restorative and adaptive **MCA:** - cost be cost demanding **Responsibility**:- to be discussed for the given case **Main implications for stakeholders:** changing location
Floating homes		The building is not supported by a firm foundation, but floats on water. Building scale		**Design criteria:** no thresholds **Practice:** some examples exist, however can be considered as emergent **Characteristics relevant for combination with other measures:-** the building floats on water **Resilience aspect at the property scale**: restorative and adaptive **MCA:** - cost be cost demanding, considerable changes in lifestyle **Responsibility**:- to be discussed for the given case **Main implications for stakeholders:** considerable changes in lifestyle

Amphibious homes		erecting the building structure on a float Building scale	- concrete floats (e.g. DURAVERMEER) - HDPE floats (e.g. BATIFLO) - Plastic floats (e.g. the Buoyant foundation- USA)	**Design criteria:** acceptable level of risk **Practice:** some examples exist, however can be considered as emergent **Characteristics relevant for combination with other measures:-** the building floats on water after a threshold has been reached **Resilience aspect at the property scale**: resistance, restorative and adaptive **MCA:** - cost be cost demanding, considerable changes in lifestyle **Responsibility**:- to be discussed for the given case **Main implications for stakeholders:** considerable changes in lifestyle

Within those groups of measures there is a large variety of techniques and materials used. A special group of measures that receives a special attention and is being rapidly developed is related to flood barriers (e.g. researched within FP7 projects SMARTEST and FloodProbe[111]). An overview of different techniques is given in Figure 3-8. The diversity of measures indicates the necessity to study their specific performance for different conditions (i.e. flood typology or given urban environment) when deciding on which of them to use for a flood resilient system. Those characteristics are to be stored in the knowledge base.

Further to the general description of the measures, it is necessary to analyse their implementation aspects. They are here presented in a generalised way (see Table 3-3). A more detailed description as a part of the knowledge base is given in the FLORETO Knowledge base.

The knowledge base should contain the best practices i.e. selected examples of the applied measures where their benefits could be seen in practice.

[111] http://www.floodprobe.eu/ (last accessed: January, 2015)

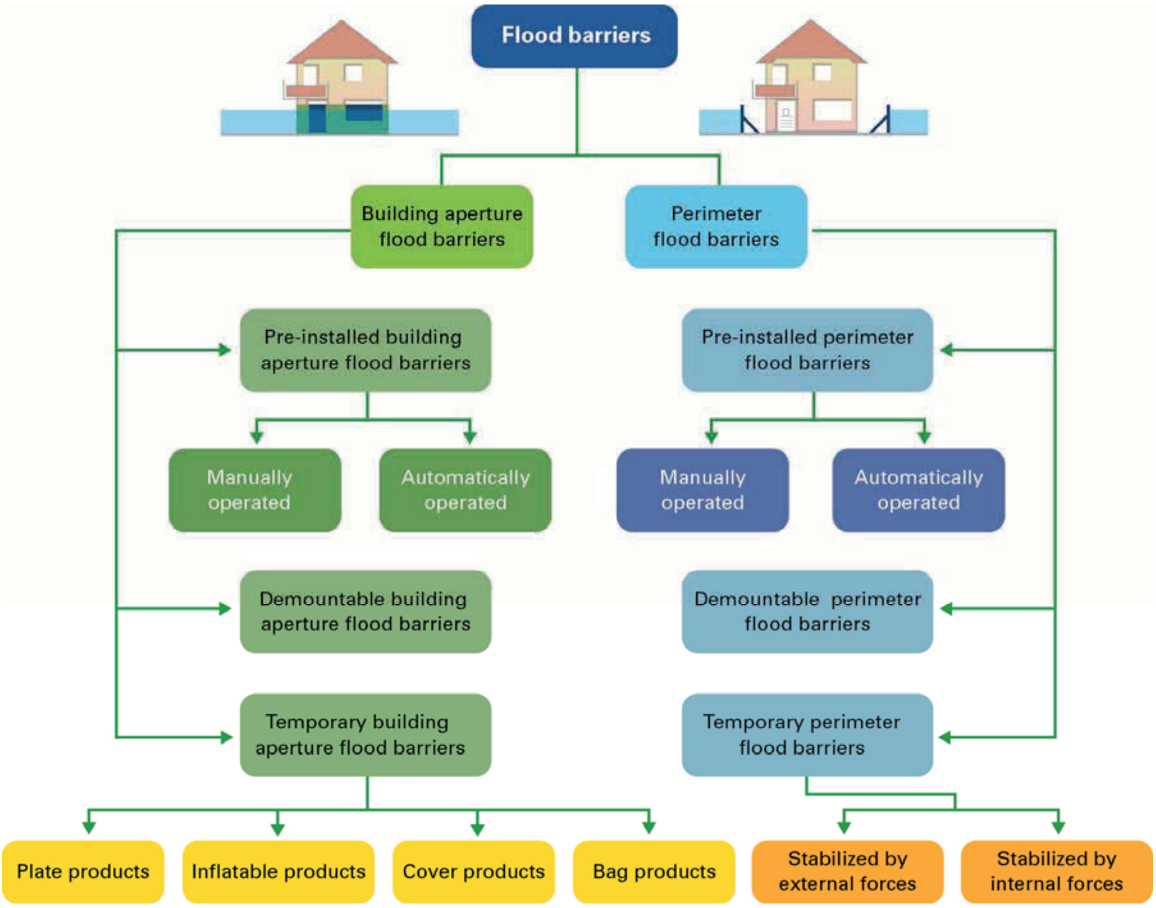


Figure 3-8 Classification of flood barriers (After Garvin et al., 2011)

Examples of different flood alleviation measures are given in Figure 3-9- Figure 3-11.

III) Best practices/Examples

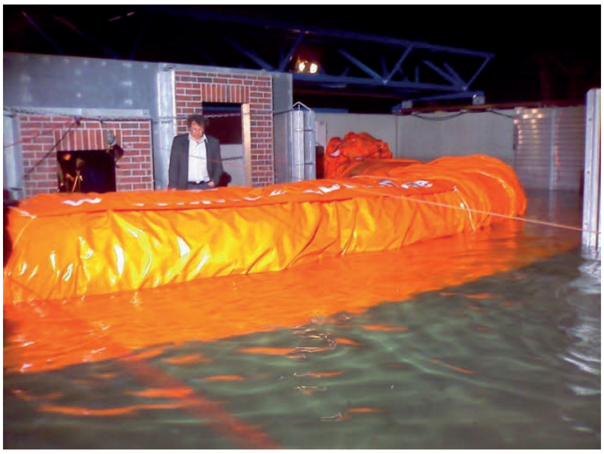


Figure 3-9 Manually operated demountable perimeter flood barrier in urban floodplain along Elbe

Figure 3-10 Left: Wetproofing of building fabric in a storm surge prone area in Hamburg, Germany; right: adapting the building occupancy& elevation of the inventory, Lake Lucerne (source: NSV)

Figure 3-11 left: Floating homes in Vancouver, Canada; right: House on piles in New Orleans, USA

A more detailed description of the measures is given in the FLORETO- Knowledge base (password protected: http://floreto.wb.tu-harburg.de/loginlogout/)

3.2.3 Flood resilient systems on the property[112] scale

Applying the system approach as shown in Figure 3-7, the property (building) is represented as an element of the built environment. It has a spatial extent determining its size and location, while its dynamic nature is characterised by internal processes such as aging of the building stock. Its location and spatial relation with the other buildings defines the configuration or topology of the built environment on larger scales. The social environment influences the silhouette of the built environment through lifestyle and culture. The quality and technical performance of the building fabric is determined by the level of technologic development. The building is constructed following certain regulations and codes.

[112] Within this work, the terms property and building level are used interchangeably.

Being exposed to flood perturbation i.e. a natural hazard such as floods, the property/building activates its resilience capacity. The threshold capacity is an intrinsic property of a building enabling it to cope with the events up to a certain (usually design) level. When exceeding this threshold capacity by an extreme flood event, the system at the property scale mobilises the capacities of restorative and adaptive resilience. The overall resilience capacity of a building is given as Re (see Figure 3-7). This process has been illustrated in Figure 3-12.

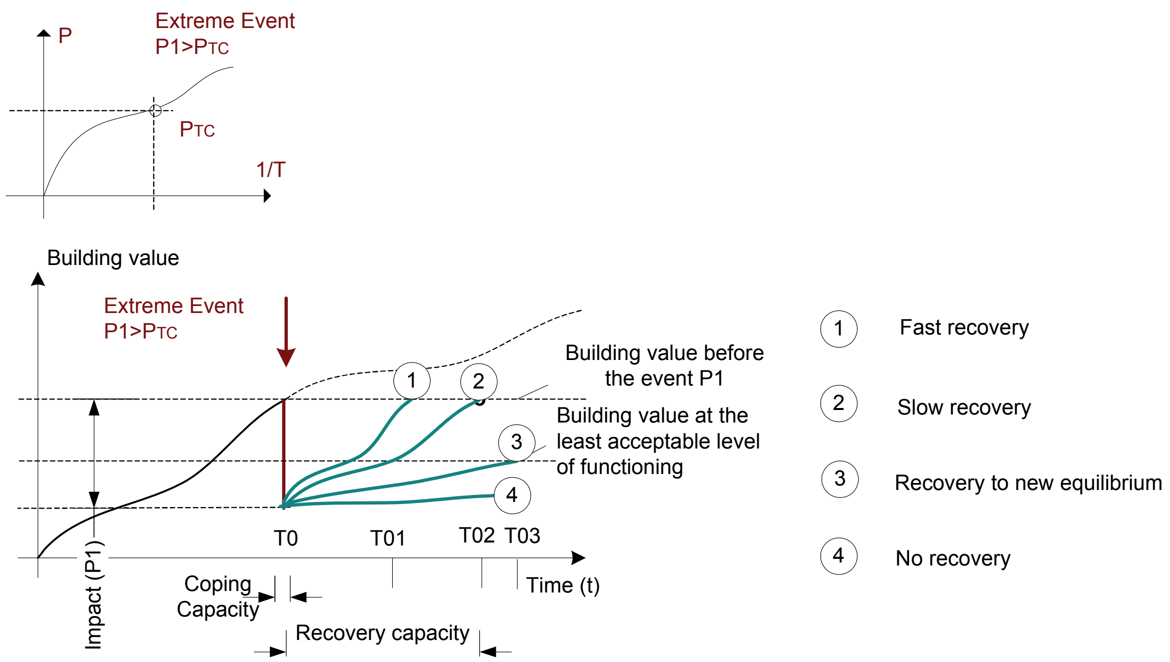


Figure 3-12 Restorative mechanism of the built environment (activation of coping and recovery capacity in the case of an extreme event after the threshold capacity has been exceeded)

Applying the resilience mechanisms given in Figure 3-3 to the case of the property level systems, the following cases are delivered:

1. fast recovery- after being exposed to an extreme event the building returns to the initial state within the maximal period of several weeks
2. slow recovery- after being exposed to an extreme event the building returns to the initial state within at least a period of several months
3. least acceptable level of functioning- after being exposed to a flood the building reaches the level of functionality than enables “normal” functioning. This means that a certain amount of damage remains (e.g. gaps& cracks) and as such the living quality has been reduced. However if it is possible to live in the building (main functions of the building available[113] and no potential threat to health excluded) the building comes to a habitable state.
4. no recovery- the building reaches and remains in the inhabitable state

[113] The main functions of the building are analysed in section 3.3.1.

Additionally the aspect of recovery- betterment as defined by Mens et al., 2011 can be considered. It describes the situation when the building is not only brought to the initial state but the flood event has been used as an opportunity to improve the initial building conditions.

In a dynamic environment with unknown development pathways, a system on the property level mobilises its adaptive capacity to manage disturbances in the long term perspective (see section 3.1.2.3). It means that the system defined at the property level can keep its resilience level for a range of flood parameters, coping with the uncertainty in this way. For each resilient system, its adaptation pathway has to be defined, which indicates the possibility of the system to adaptively change to a range of conditions i.e. anticipating future development and defining a range of possible scenarios.

Resilience Metrics

In a FReS the single FRe technologies are to be combined in a way to increase the resilience level of the building/property as a whole. The extent to which the observed FReS has contributed to the overall resilience characteristics of a building can hardly be directly assessed. Resilience surrogates or proxy indicators, which are [measurable resilience attributes of a system] (Bennett et al., 2005) are to be defined, describing the characteristics of all resilience capacities as given in previous sub section. For the scope of this work, the proxies have been identified and defined for the resilience capacities that describe the functionality of a building after being exposed to an extreme event as well as the availability of the main services relevant for a building (energy, electricity, telecommunication, traffic, water supply and drainage). For the main functions of a building, the ones outlined in Table 3-7 have been taken as a basis. The developed set of proxies and the assessed resilience level can be used as an input for the resilience matrix at larger scales such as the flood resilience index of an urban system (Batica et al., 2013).

Resistance:

Resistance of a building is defined by the threshold value up to which the building is not exposed to floods and preserves all its functions and has access to all the services. It can be naturally created (e.g. the building is located on an elevated terrain) or by manmade structures (e.g. building on piles). It can be measured by the P_{TC} i.e. the threshold value taken as a basis for the design.

Restorative resilience:

Recovery capacity is characterised by the time required to reach equilibrium (T01, T02, T03 in Figure 3-12) as well as the effort needed to reach it. Both equilibriums are considered: returning to the initial state and reaching the least acceptable functioning state. The least acceptable functioning state is defined by the least restored building functions as listed in Table 3-7.

Damage evolution (also called graduality in Zevenbergen et al., 2008, De Brujin, 2005) has been introduced to describe the resilience capacity of the system and its sensitivity to an increase of the magnitude.

Four main cases have been distinguished: (1) the damage is gradually increasing until it reaches its maximal value. For lower magnitudes, the damage rate is lower, getting a steeper gradient with the increasing magnitude. (2) the damage is gradually increasing until it reaches its maximal value. For lower magnitudes, the damage rate is higher, getting lower with the increasing magnitude. (3) damage rate is rather constant until reaching a certain magnitude value (threshold), when the gradient abruptly increases. For a certain magnitude value, the damage reaches its maximum and is kept constant for the increasing magnitude. (4) the damage level is kept low with the increasing magnitude.

The coping capacity of a property/ building is characterised by its ability to perform during a flood event, which also includes the accessibility of the key services. It implies the flexibility of the contingency measures (evacuation) and continual availability of the services during a flood event. Also, the sensitivity to any malfunctioning of the system is to be assessed indicating the weak points and flexibility of the system to perform in case of the failure of its elements. The systems with distributed risks are likely to perform better than the ones with a concentrated risk, which tend to create bottle necks in the system.

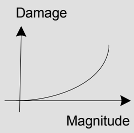
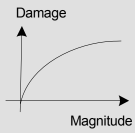
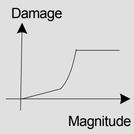
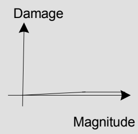
Adaptive resilience:

Adaptive resilience is being characterised by adaptation pathways (stepwise presentation of the intermediate states of the system) and the corresponding effort one system has to undertake to adapt to a range of scenarios.

The main proxy indicators are summarised in Table 3-4.

Table 3-4 Proxy indicators developed for describing flood resilient systems at the property scale

Nr	Proxies	Value
		Resistance:
I	Threshold value of the design flood* (* the values has been taken in accordance with 2007/60/EC)	high (extreme events) < 100 years medium- likely return period ≥ 100 years low (frequent events)
	Restorative resilience:	
Recovery Capacity:		
I	Time to equilibrium (return to the acceptable state): a) Time needed to return to initial state b) Time needed to reach the least acceptable functioning state	1. fast: less than weeks/month(s) 2. medium: months/year(s) 3. slow: years 4. retreat (no recovery)

II	Resources and effort needed for reaching the equilibrium	1. low- reduced to cleaning and drying of the building fabric (opt: returning the inventory to the initial state) 2. medium- 1+ minor (esthetical) repairs required 3. high- repairs of building fabric needed
III	Level of permanency and impact of the (tangible) damage occurred	1. no damage 2. minor damage that can be repaired without considerable costs. 3. in combination with other measures (e.g. financial incentives) damage can be recovered 4. even with other measures damage can hardly be recovered
IV	Damage evolution (adapted from Zevenbergen et al., 2008)	(1)  (2)  (3)  (4) 
Coping capacity:		
V	Flexibility of the contingency measures (vertical and horizontal evacuation of the people is enabled (intangible damage)	1. yes 2. no 3. not required/ applicable
VI	Continuous supply of the services (gas, electricity, communication) is enabled	1. yes 2. yes with considerable effort 3. no
VII	Sensitivity to malfunctioning (criticality)- failure analysis considering the following main aspects: - Controllability of the seepage water - Logistics... - Controllability of the impact to the local drainage system	Low- the risk is distributed over a range of elements High- the system depends on one factor, which in case of failure, causes the failure of the overall system
Adaptive Resilience:		
VIII	Transformability of the system to respond to a range of perturbations (adaptation pathways) and the corresponding effort	The criteria 1-5 are to be fulfilled for a range of flood conditions The effort to adapt and improve the resilience level over time (adaptation pathway)

Development of flood resilient systems

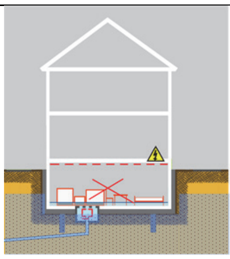
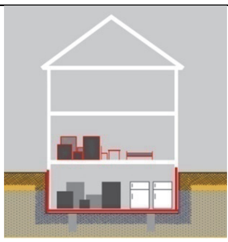
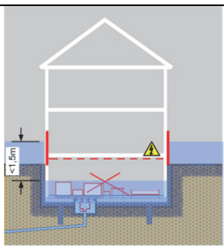
Criteria/Rules:

The main resilient systems at the property scale (P-RS) have been developed by combining different flood resilient technology based on the descriptions given in the knowledge base with the objective to improve at least one of the resilience capacities following the criteria and assumptions given as:

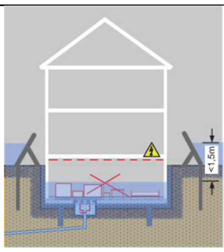
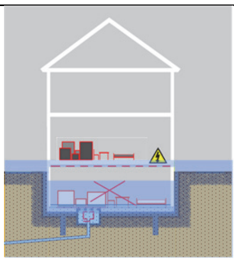
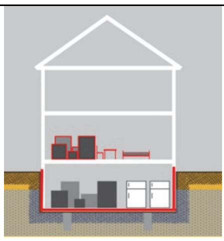
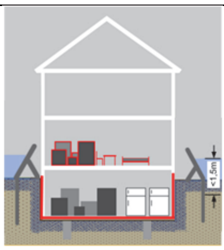
- The focus is put on the combination of mere flood resilient technology, not considering the other resilient measures such as early warning systems. The possible ways on how these measures interact and can create a 'resilient system' with the measures of raising risk awareness are discussed and in section 3.4., where the developed measures and methods are introduced and discussed.
- The resilient systems are defined to consider the building as a whole i.e. that all its parts are to be protected (if a building has both, a basement and a ground floor, both those building levels are to be considered). Those systems that protect only a part of a building such as mere protection of openings can in general be considered as an improvement of the resilience of the building but are here regarded as "intermediate systems", as not all potential have been exploited for their realisation (protection of building fabric etc.).
- Generic or abstract FReS have been developed that target the "ideal case" of performance i.e. when all included elements perform as planned. The real performance of the systems is to be assessed for different flood typologies and built environment characteristics
- The measures are combined in a way to support or extend the performance of each other and not to impede it or to overlap (e.g. protection of openings and shielding of the building overlap in their function).
- The improvement of the resilient performance of a building is to be evaluated utilising the proxies as given in Table 3-4.

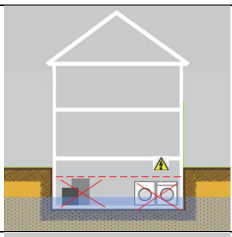
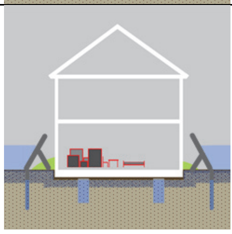
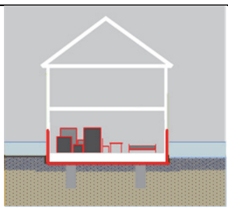
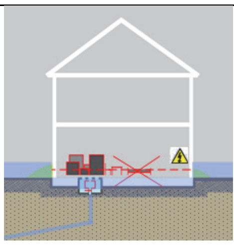
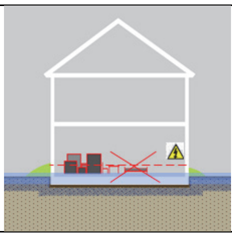
  The developed FReS have been outlined in Table 3-5.

Table 3-5 Developed flood resilient systems on the property level (P-RS)[114]

	Resilient system	General information		
		Dry proofing	Wet proofing	Building contents& occupancy
P-RS 1	Controlled flooding of basement 	- horizontal sealing of the walls in ground floor to prevent capillary rise from the basement - protection from the backwater effect	-application of water resistant materials for walls, floors, ceiling, staircases - elevation (encapsulation) of services - installation of a pump in a sump with sensors	-change of occupancy of the basement with permanent elevation of inventory items - temporary elevation of the inventory
P-RS 2	Sealing of basement 	- sealing of walls, floors, ceiling, staircases either by application of waterproof concrete or polymer bituminous seal - dry proofing of services (e.g. encapsulation of wiring) - closure of openings - protection from the backwater effect	-none	-none
P-RS 3	Controlled flooding of basement and sealing of the above ground floor(s) 	- sealing (horiz+vertical) of walls, floors, ceiling, staircases either by application of waterproof concrete or polymer bituminous seal - dry proofing of services (e.g. encapsulation of wiring) - closure of openings - protection from the backwater effect	-application of water resistant materials for walls, floors, ceiling, staircases - elevation (encapsulation) of services - installation of a pump in a sump with sensors	-change of occupancy of the basement with permanent elevation of inventory items - temporary elevation of the inventory

[114] A more detailed description including the implementation aspects and examples of the developed FReS-PS is given in the FLORETO knowledge base (password protected: http://floreto.wb.tu-harburg.de/loginlogout/) and is summarised in Appendix 3.2.

P-RS 4	Controlled flooding of basement and shielding of the above ground floor(s) 	- horizontal sealing of the walls in ground floor to prevent capillary rise from the basement - shielding of the building applying temporary barriers - protection from the backwater effect	-application of water resistant materials for walls, floors, ceiling, staircases - elevation (encapsulation) of services - installation of a pump in a sump with sensors	-change of occupancy of the basement with permanent elevation of inventory items - temporary elevation of the inventory
P-RS 5	Controlled flooding of basement and wetproofing of the above ground floor(s) 	- protection from the backwater effect	-application of water resistant materials for walls, floors, ceiling, staircases - elevation (encapsulation) of services - installation of a pump in a sump with sensors	- change of occupancy of the basement with permanent elevation of inventory items - temporary elevation of the inventory
P-RS 6	Sealing of the basement and sealing of the above ground floor(s) 	- sealing of walls, floors, ceiling, staircases either by application of waterproof concrete or polymer bituminous seal - dry proofing of services (e.g. encapsulation of wiring) - closure of openings - protection from the backwater effect		- no changes
P-RS 7	Sealing of the basement and shielding of the ground floor 	- sealing of walls, floors, ceiling, staircases either by application of waterproof concrete or polymer bituminous seal - dry proofing of services (e.g. encapsulation of wiring) - closure of openings - protection from the backwater effect - shielding of the building applying temporary barriers		- no changes

P-RS 8	Wet proofing of basement		- horizontal sealing of the walls in ground floor to prevent capillary rise from the basement - protection from the backwater effect	-application of water resistant materials for walls, floors, ceiling, staircases - elevation (encapsulation) of services	- change of occupancy of the basement with permanent elevation of inventory items - temporary elevation of the inventory
P-RS 9	Shielding of the building		- shielding of the building applying temporary barriers - protection from the backwater effect	- no wet proofing elements used	- no changes
P-RS 10	Sealing of the above ground floor(s)		sealing (horiz+vertical) of walls, floors, ceiling, staircases either by application of waterproof concrete or polymer bituminous seal - dry proofing of services (e.g. encapsulation of wiring) - closure of openings - protection from the backwater effect	- no wet proofing elements used	- no changes
P-RS 11	Controlled flooding of the above ground floor(s)		- protection from the backwater effect	-application of water resistant materials for walls, floors, ceiling, staircases - elevation (encapsulation) of services - installation of a pump in a sump with sensors	- change of occupancy of the ground floor with permanent elevation of inventory items - temporary elevation of the inventory
P-RS 12	Wet proofing of the above ground floor(s)		- protection from the backwater effect	-application of water resistant materials for walls, floors, ceiling, staircases - elevation (encapsulation) of services	-change of occupancy of the ground floor with permanent elevation of inventory items - temporary elevation of the inventory
P-RS 13	Elevation/ Relocation	The building is relocated from the existing position	- no dryproofing elements used either by elevation or removal to other area.	- no wet proofing elements used	- no changes

A more detailed description of the defined resilient systems at the property scale and the analysis in terms of their resilience performance following the criteria given in Table 3-4 is given in Appendix 3.2.

3.2.4 Flood resilient systems on the neighbourhood to district level

Applying the system approach, (Figure 3-7) and the multi scale resilience approach the system on the neighbourhood/district scale can be defined as an integration of the elements on the property level, with which they interact and convey feedbacks. Such a system is given in Figure 3-13. Systems on the neighbourhood/district level define boundary conditions for the resilient systems defined at the property level. It means that the strategies defined on the higher levels influence which resilient system will be defined/ selected on the property scale.

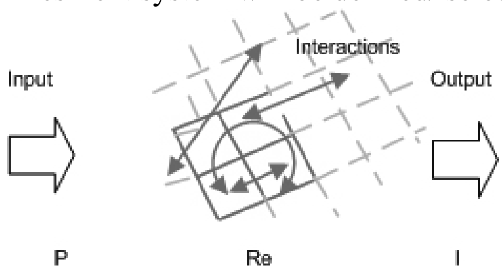


Figure 3-13 System analysis of the built environment on the district level

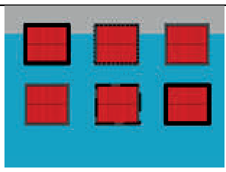
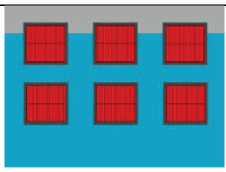
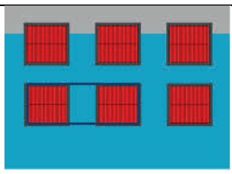
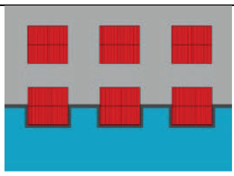
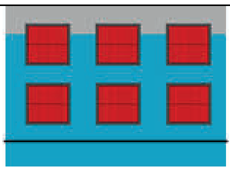
The five main resilient systems are defined being (Manojlovic& Pasche, 2008):

- Protection of single properties separately with different protection level
- Protection of single properties separately considering a uniform protection level
- Clustering of the adjacent buildings (neighbourhoods)
- Connecting buildings to a resilience frontline
- Combination of conventional and resilience measures

Within this work the scales neighbourhood- city level are summarised in one section as the focus of this work is set to the property level and the others are considered as higher levels in the system approach. The FReS at this scale have only been introduced in order to analyse how the systems at the property scale feedback into the system on higher levels and vice versa. The criteria for their development and implementation are not discussed in detail in this work.

Table 3-6 Resilient systems on the neighbourhood- district level

	Resilient system	**Description**	**Elements of resilient system**		
			Flood alleviation	***Contingency response***	***Landuse***

D-RS 1	Protection of single properties separately with non-uniform design flood level		Each property is protected as a standalone unit for different design flood events, depending on the level of acceptable risk	- resilient buildings (resilient systems on the property level as given in 3.2.3)	- Flood forecasting and warning - Financial incentives - Insurance - Assistance in implementation	adapted landuse, building codes
D-RS 2	Protection of single properties separately with uniform design flood level		Each property is protected as a standalone unit for uniform design level.	- resilient buildings (resilient systems on the property level	- Flood forecasting and warning - Insurance	adapted landuse, building codes
D-RS 3	Clustering of the adjacent buildings (neighbour hoods)		Clustering the neighbourhoods with the aim to develop synergetic effect, i.e. reducing costs and improving the efficiency of the flood adaptation.	- resilient buildings (resilient systems on the property level)	- Flood forecasting and warning - Insurance - mountable barriers	-
D-RS 4	Connecting buildings to resilience frontline		Closing the front to the watercourse. The gaps between the buildings are closed either by permanent constructions or temp containment structures, or both.	- resilient buildings (resilient systems on the property level)	- Flood forecasting and warning - Insurance - temp containment structures	-
D-RS 5	Combination of conventional and resilience measures		The resilience measures bear the uncertainty of the future development (unpredictable flood event), the structural measures are made used of.	- resilient buildings (resilient systems on the property level) - resilient infrastructure	- Flood forecasting and warning - Insurance - temp containment structures	adapted landuse

3.2.5 Multi scale analysis (integration)

As already introduced, the flood resilient systems (FReS) at different scales are not independent. Also, a resilient system at a larger scale is more than a mere aggregation of the resilient systems at smaller scales (Schertzer& Tchiguirinskaia, 2011).
The FReS at smaller scales can create feedback to the systems at larger scales as illustrated in Figure 3-14.

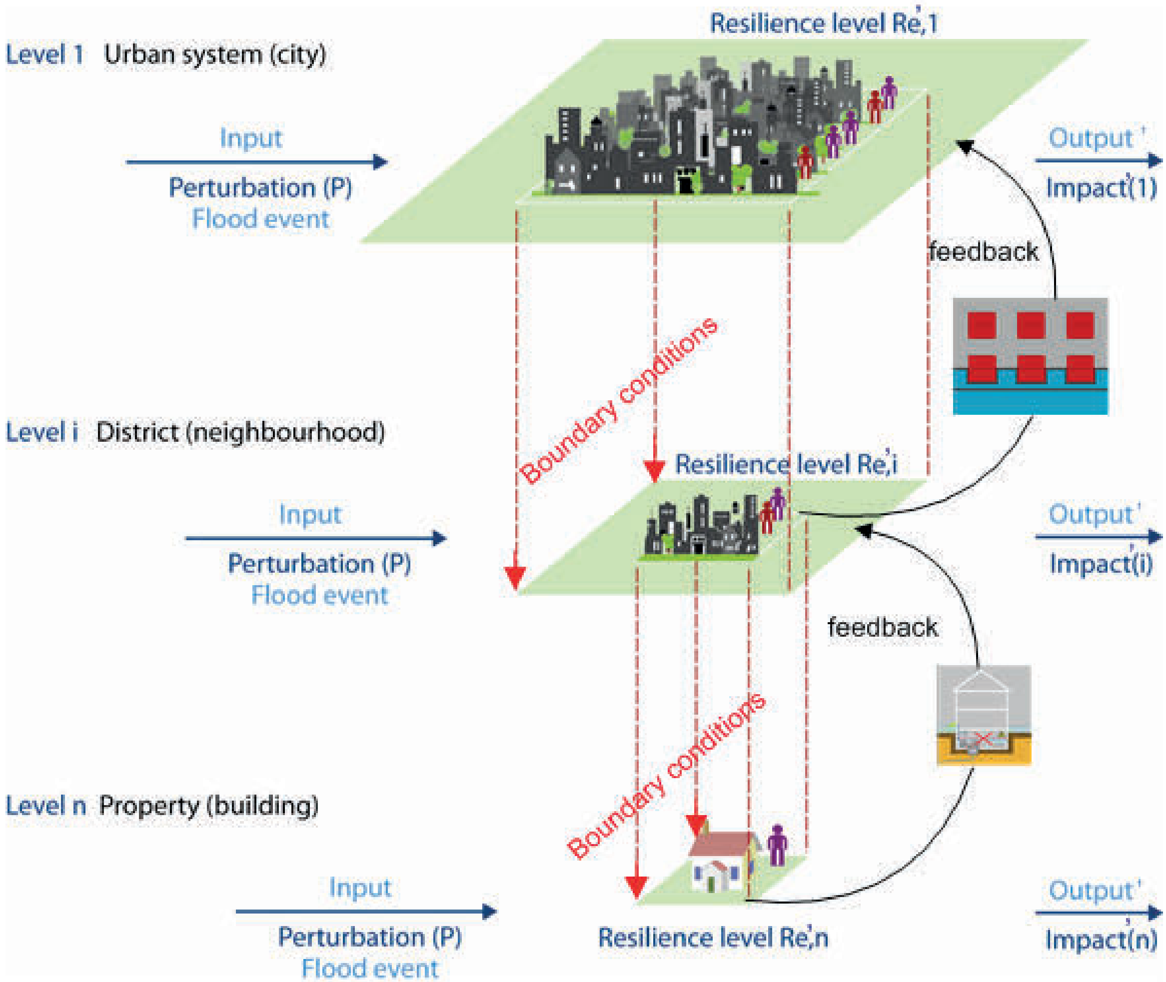


Figure 3-14 Multiscale approach

In that sense, the property scale resilient systems deliver feedback to the neighbourhood systems. At the same time, the systems at larger scales create the boundary conditions for planning. This work focuses on the analysis and the resilient metrics at the property level, which will be an input for the analysis at larger scales.

3.3 Decision support tool for the resilient built environment

Defining an appropriate strategy or the resilient system for the resilient built environment by selection of resilient systems is a complex task that can hardly be generalised (Manojlovic et al., 2009). The resilient systems that fit best for the given conditions are not a priori known and are to be analysed for each case separately. Thus, the process of decision making is very knowledge intensive and requires a high level of expertise. A decision making process for resilient built environment encompassing all the facets of flood risk management as defined in the 2007/60/EC has been developed and is depicted in Figure 3-15.

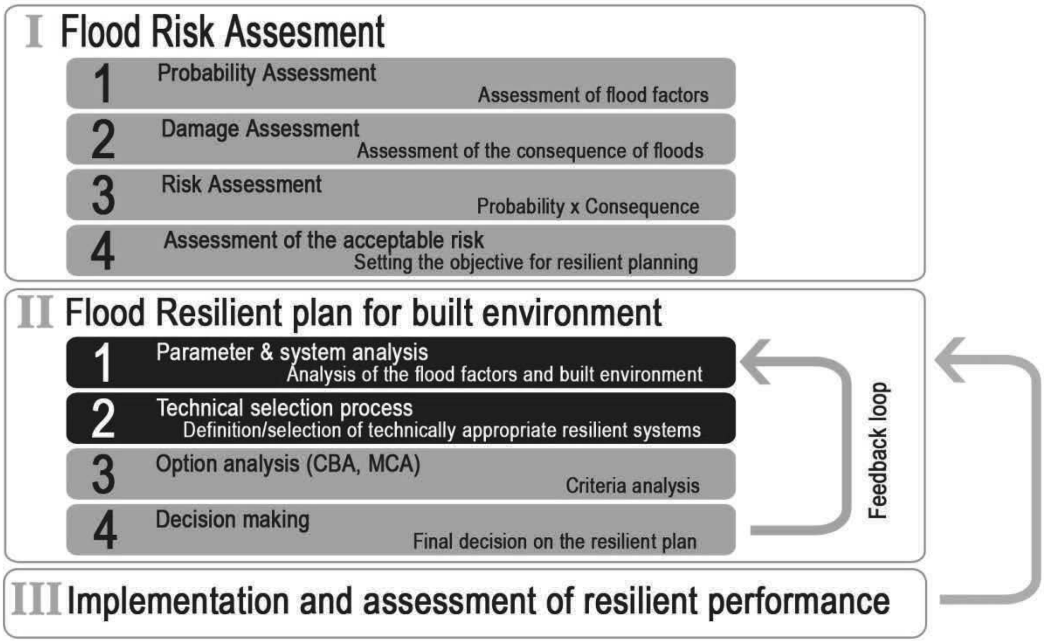


Figure 3-15 Decision making process for the resilient built environment. After the process has been completed (after step III), the feedback to larger scale systems is delivered.

This process encompasses the *(flood) risk assessment* and *(flood) resilience plan for built environment*. Within the risk assessment step, the probability of flooding and its consequences are analysed, determining the risk of the studied building/area. In the final instance, the acceptable risk i.e. objective for the resilient plan is defined.

For definition of a resilience plan for the built environment, the parameters describing the flood situation and built environment are analysed. The technical selection process is the key process, as within this step the decision is made, which systems are applicable for the given flood conditions, built environment and the estimated potential damage. Different options are analysed and evaluated considering economic, social, ecological and reliability criteria within cost benefit or multi criteria analysis. After the decision has been made, the implemented measures are reviewed. The results from the review process are fed back in the process, improving the decision making. After the process has been completed, the feedback to larger scale systems is delivered. In sections 3.3.1- 3.3.3 the single steps will be presented in more details.

3.3.1 Flood Risk Assessment

Flood risk assessment is a step of the risk management that describes [the process of evaluating adverse effects caused by flooding] (FloodSite- Language of Risk, 2008). Focusing on the built environment on the property level, the risk to flooding can be assessed by analysing the individual elements of risk.

As a first step of the decision making process as depicted in Figure 3-15 the flood probability assessment is performed (1) determining flood factors (e.g. water depth or flood duration). Those factors can be given for single flood events or statistic floods (e.g. 100 year floods). A physically based approach is then applied in order to assess the vulnerability of the building elements for the given intensity of floods. These are given monetary values and expressed as rebuilding (refurbishing) costs (2). The assessed damage is then combined with the probability of the occurrence of flood events determining the risk to floods (3). As a final result of this phase, the acceptable level of risk is defined either in form of the flood factors threshold (e.g. for 20 cm water depth) or for the acceptable damage level. The single steps of the flood risk assessment are given in the following text.

3.3.1.1 Flood probability assessment

The objective of the probability assessment is to determine the inundation areas (boundaries of flooding and the flood parameters such as water depth and flow velocity, Pasche, 2006) for different flood typologies and frequencies and the corresponding flood parameters. Determination of the inundation areas (flood analysis) must include a hydrological and a hydraulic analysis. The first one gives the design hydrographs and its probability of occurrence. The second one determines the flooded areas for these design hydrographs (Pasche, 2007). The flood analysis of riverine or coastal floods must cover the whole river basins, sub-basins and coastal reach. In general, recorded discharges and water stages at river gauging stations are not available in a sufficient resolution to derive on this basis the inundation areas for given probability and along the whole river and its tributaries. Thus mathematical models need to be applied. Due to the wide range of modelling instruments the selection of the right one needs expertise (Pasche, 2006). In order to simulate the complexity of the flood processes in urban areas (surface runoff, overland flood and pluvial floods) and their interactions, floods are usually modelled by coupling different models (Djordjevic, 2010 in Zevenbergen et al., 2010). For simulating urban surface (major system) and buried pipe network (minor system) so called dual drainage models are used (Djordjevic, 2010). Whereby the pipe network is modelled using the 1D[115] (one- dimensional) models, the surface flood flow can be modelled either as a network of 1D open channels and ponds or as a 2D computation al flow domain. Those modelling procedures are referred to as 1D/1D and 1D/2D respectively (Djordjevic, 2010 in Zevenbergen et al., 2010). In the case of the coastal floods, 2D models are applied as [the modelling domain is a basin rather that a channel] (Djordjevic, 2010 in Zevenbergen et al., 2010). The selection of the models and their preparation was beyond the scope of this work. The results of the flood probability

[115] A detailed description of different models and terms (e.g. flood frequency) has been beyond the scope of this work. More detailed description can be found in e.g. Pasche, 2007 or Zevenbergen et al., 2010

assessment that are the flood parameters for different return periods are used for the damage assessment. The way it is implemented in given in Chapter 4.

3.3.1.2 Flood damage (consequences) assessment

Within the flood damage assessment step, the potential damage of the built environment exposed to flood water is assessed. This is given the monetary value and used as an input for the multi criteria or cost benefit analysis.

For the damage assessment at the building scale, the following main starting points have been set:

- The focus is put on direct tangible damage
- The synthetic *ex-ante* method based on the physical approach has been adopted to derive potential damage to the built environment analysing the physical process in the building elements and materials (see also the discussion in chapter 2, sections 2.2.2.1 and 2.4)
- The damage model also encompasses the damage perception of dwellers. In this way the interactions between the built environment and dwellers as shown in Figure 3-1 can be captured.

Definition of damage in the context of built environment at the building scale

Following the physically based approach, the alteration of the characteristics of the built environment can be described by the physical, chemical and biological processes caused by presence of water in the building fabric and contents. This change and the extent to which built environment altered its original qualities can be described and quantified by the means of the physical or chemical laws. The following definition has been developed within this work to define the scope of damage at the building level:

> *Def. 2: Damage is referred to as "changes in overall functions of a building, which consequently affects the quality of living of the affected dwellers."*

In that sense, any restriction of performing those functions due to floodwater is defined as damage to buildings. For that purpose, it is necessary to assess the basic functions of a building and analyse in which way they can be reduced due to floods. The assessment of the basic functions has been performed based on the CIB W 092 1997 and are given in Table 3-7.

Table 3-7 Functions of a building (adapted from CIB W 092 1997)

Function	Description
Provide adapted spaces to carry out activities	This is the service provided by the building that allows users to have at their disposal suitable spaces with regard to activities which are to be carried out.
Protect occupants and goods	This is the service provided by the building that protects users and goods against natural (climatic, seismic …), accidental (industrial gas emission, fire ...) or voluntary (aggression, theft ...) events.
Allow access and use of goods and tools	This is the service provided by the building that allows occupants to use tools required by their activities and to take advantage of their goods.
Provide an adapted ambiance	This is the service provided by the building that allows the user to adapt indoor ambiance according to outdoor ambiance e.g. temperature and humidity, odour in the building
Control relations between occupants indoor/outdoor	This is the service provided by the building that allows the occupants to control (choose, favour, avoid ...) their relations with others as well as with the environment.
Environmental "friendship"	This is the service provided by the building that allows occupants to live without impacting the environment
Semiotics	This is the service provided by the building that reflects the quality of life of the occupants and creates the appropriation e.g. aesthetics

Following this assessment, it can be concluded that a building has both, functional role which is reflected in protection or provision of certain services to dwellers, but also the aesthetical aspect should be considered which is reflected in semiotic qualities of a building.

Therefore, two main groups of damage types and the corresponding damaging functions for the assessment of the direct tangible damage can be defined:

1. *objective (functional)*- damage to the built environment when the basis function of the building element cannot be performed or it affects the human health (e.g. moulding of the fabric);
2. *subjective (aesthetical)* - assessing whether the semiotic qualities and adapted ambiance have been reduced
   - semiotic optic; i.e. visual defects
   - provision of an adapted ambiance (humidity, odour) unless they are not affecting the human health

Those functions differ in the way to be assessed. Whereby the objective or functional damage can be measured using physical instruments or calculation methods (e.g. changes in stability or deterioration of the insulation performance), the aesthetics and the living quality are subjective and depend on the dwellers' perception and can be significantly different amongst dwellers. In that sense, the definition of damage strongly depends on the dwellers and their lifestyle (e.g. Mayer& Messner, 2005, Penning Rowsell et al., 2003).[116]

As different building elements perform a certain function as a system (e.g. wall has the insulation or stability role), it is necessary to analyse not only the building function as a whole, but the specific functions of the building elements, their role, and how the flood water can impede their proper functioning.[117]. Table 3-8 depicts the building elements considered for this work and the requirements for their functioning and which way the alterations of the functionality are considered for the damage assessment.

In terms of the subjective assessment of the damage, the main criteria taken for the assessment is that this damage does not influence the primary function of the building element, but compromises its aesthetical qualities. They are related to changes in colouring, stains, minor cracks or spelling of the finishes.

Table 3-8 The requirements on the building elements and the corresponding criteria for the damage assessment taking into the consideration Table 3-6

Building element	Requirements on performance of the building elements (adapted from RWE, 1984 and based on CIB W 092 1997)	Objective	Subjective
Foundations/ building as a whole	Static/stability function	Collapse Cracks Deformations due to the consolidation	

[116] This differentiation can also be analysed in the context of the resilience of the built environment as introduced in Figure 3-12 when describing the recovery mechanism of the built environment. As a criteria for the state 3, has been defined that non functional damage to the built environment is acceptable. The new equilibrium characterise the state where only minor semiotic damages are acceptable.

[117] It is also to mention that the type of damage differs depending on the point in time when it is assessed. Directly after a flood event the damage processes are related to the moisture penetration, mechanical deterioration or contamination, whereby after a certain period of time (more than six months) the damage is related to the long term presence of the moisture in the building fabric such as cracks formation due to the frost/thaw, deformations due to the soil consolidation or moulding of the building fabric (Thieken et al., 2009).

Walls	- Shelter/protection role - Static/stability function - Insulation (heat, moisture, acoustic)	Reduced (measurable) performance of the insulation elements Cracks that endanger the stability of the walls Increased moisture in the elements that can cause health problems	Changes in colour, stains, minor cracks
Floors	- insulation (heat, moisture, acoustic) - Stability	Reduced (measurable) performance of the insulation elements Cracks that endanger the stability of the floors	
Ceiling	- insulation (heat, moisture, acoustic) - Stability	Reduced (measurable) performance of the insulation elements Cracks that endanger the stability of the floors	
Staircases	- Access to goods and space - Stability	Cracks that endanger the stability of the staircases	
Openings	- Connection between the indoor and outdoor space - Protection from natural events and conditions (frost, rain, heat) or voluntary (aggression, theft ...) - Aesthetical element (design feature of a façade)	Cracks that endanger the	Spelling of the paint
Services	- Continuous supply of the services such water, electricity, heating, ventilation…	Interruption in the continuous supply	Changes in colour, stains
Inventory	Specific function		

In order to assess the damage of a building considering the potential damage to different building elements and applying the physically based approach, the three- step method as depicted in Table 3-25 has been developed and is given in Figure 3-16.

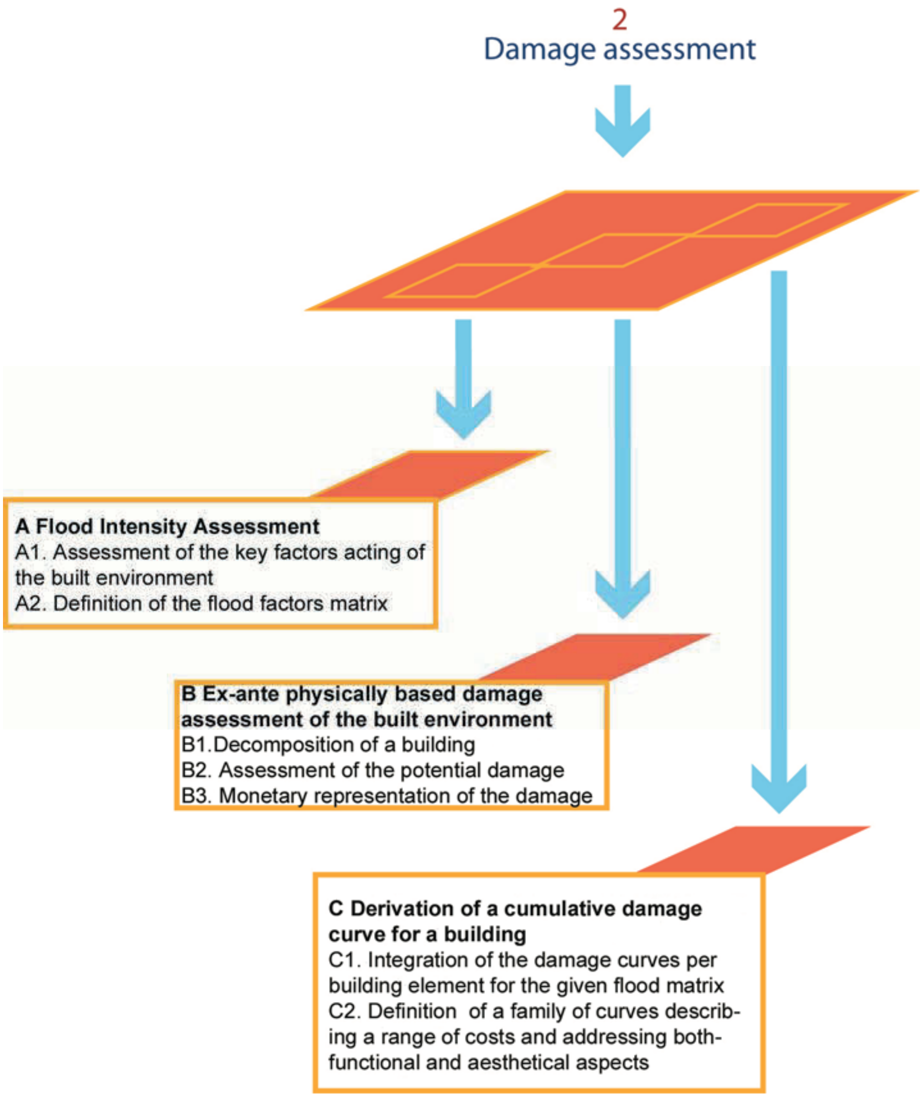


Figure 3-16 Methodology for damage assessment developed in this work

A. Flood intensity assessment (description of the flood and its parameterisation)

Flood intensity assessment encompasses the assessment of flood parameters relevant for the damage assessment. They are results of the flood probability assessment, which precedes the damage assessment process. In the first step, all relevant parameters are assessed and analysed (A1). Out of the analysed parameters a matrix of the adopted values is defined (A2).

A1 Assessment of the key factors acting on the built environment

There is a number of important flood characteristics, which are relevant to understand how flood can damage a building. The main flood parameters can be summarised under the three main groups (e.g. Garvin& Kelly 2004):

I) Physical
II) Chemical
III) Biological

In reality, flood conditions for a specific case are determined by the combination of these features.

Physical factors describe static and dynamic actions on the building fabric, the main ones being (e.g. Garvin& Kelly 2004):

- water depth
- flow velocity
- duration of exposure to (flood)water
- rate of flood rise
- debris potential of the landscape

Chemical factors are given as:

- Concentration of acids
- Concentration of bases
- Concentration of salts
- Organic contamination (oil)
- Temperature

Biological factors:

- Concentration of micro-organisms

Additionally other physical parameters are relevant for the assessment of the potential damage such as the temperature of the air and the floodwater.

The result of the assessment of flood intensity delivers the matrix $[X_{ij}]$ of flood factors, where the X represents the flood parameter i, given for different flood conditions j.

A detailed description of the single factors and their impact to the built environment is given in Appendix 3.3a.

A2 Definition of the flood factors matrix (intensity of floods)

The flood factors matrix describing the flood intensity $F=[X_{ij}]$, has been reduced to the following parameters:

$$F=[X_{ij}]=[h_j, D_j, v_j, c_{oil}] \quad \text{Eq. 3-4}$$

or in a developed form as given in Table 3-9. The threshold values adopted are based on the values taken from the relevant literature and following the generally accepted practice. The velocity threshold is based on the work performed by Kelman& Spence, 2004 and Merz et al., 2004. The results indicated that the velocities below 2m/s did not have any decisive influence on the overall damage. As a thorough static analysis of the buildings is beyond the scope of this work, the cases above 2m/s will not be analyses in detail, but assumed that the building is subjected to total damage (*worst case scenario*).

The duration thresholds are based on the definition of flood resilient material introduced by FEMA, which states that ["Flood-resistant material can be defined as any building material capable of withstanding direct and prolonged contact with floodwaters without sustaining significant damage. The term "prolonged contact" means at least 72 hours, and the term "significant damage" means any damage requiring more than low-cost cosmetic repair (FEMA, 2002)]. The value of 24h has been taken as the experiential values of the material behaviour are available for this duration. Also, the pluvial floods often last less than one day (Pasche et al., 2008).

Table 3-9 Developed flood factors matrix adopted for the scope of this work

Flood factor	Values
Water depth h_j [m]	Real number
Velocity v_j	<2m/s *>2m/s (not systematically considered)*
Duration d_j [h]	<24h <24h<d<3days 3days<d<max
Oil content c_{oil} [g/m^3]	is simplified to y/n function and derived indirectly based on the presence of an oil tank in the building Yes No

For further considerations, the damage will be given in dependence of the water depth for a combination of the other parameters creating families of damaging functions (also called damage curves).

B. Ex-ante physically based damage assessment of the built environment

In the first step, the building is decomposed to building elements to enable capturing all functionalities and the impact of flood water to their performance (B1). Further, the potential damage to those elements caused by the flood parameters assessed in step A is identified and quantified based on the susceptibility of the building materials and the defined structure of the building elements (B2). In order to define the alterations in functionality of the components of the built environment, physical processes that lead to those changes have to be understood. For the scope of this work, a desk study has been performed considering the following sources:

- The state of the art literature in the physics of materials and construction
- The available literature on experiences on the damage assessed to buildings and their elements after flood events
- The available literature on resilient repair (provided by the construction and insurance industry)

- Personal communication with the loss adjustors and the experts on resilient repair
- Available literature and experiences from the testing procedure of different building materials and elements when exposed to flood water (e.g. results from the FP 7 project SMARTEST, 2012)

The study focused on the processes in building fabric defined at a general level (e.g. concrete, wood, brickwork). Additionally, the regional specific features have been taken focusing on German constructions styles. If available, Swiss and English construction types and materials have been considered.

In the final step, the assessed alteration of the built environment is given a monetary value (B3).

Step B has been illustrated in Figure 3-17.

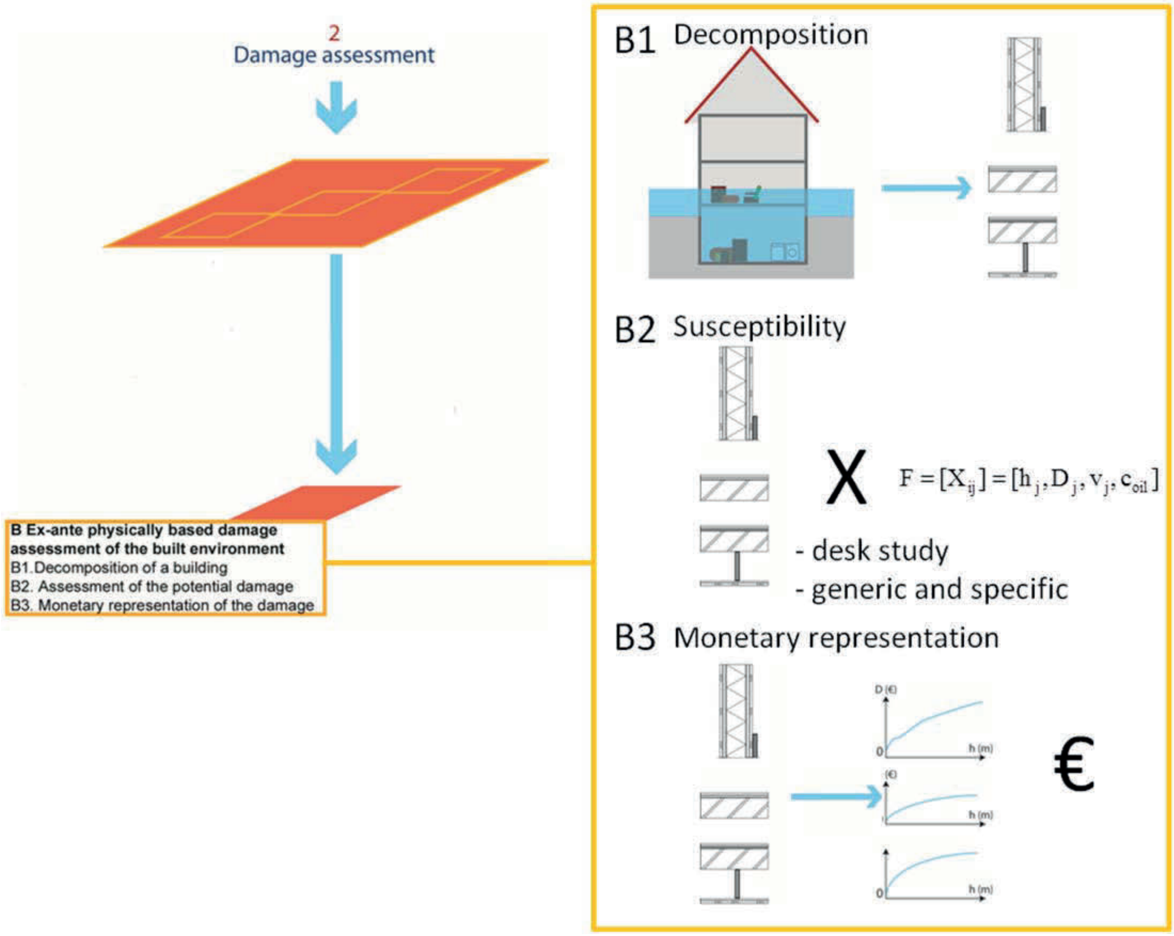


Figure 3-17 Step B in the damage assessment procedure

The individual steps of the damage assessment procedure are given in more details as follows:

B1. Decomposition of a building to the building elements and the associated physical processes

The main building elements with their functions and the considered damage are depicted in Table 3-8. For each of those elements, the dominating physical, chemical and biological processes are assessed based on the results from the desk study as summarised in Table 3-10.

Table 3-10 Building elements and processes considered for assessment of potential damage

Building element	**Processes**	
	Physio- chemical **[h_j, D_j, v_j, c_{oil}]**	**Biological** **(not explicitly considered)**
Building as a whole Foundation	Buoyancy Lateral pressure	Decaying/moulding
Walls	Lateral pressure Capillary rise Diffusion Sorption Heat conductivity Efflorescence Acidic attack	Decaying/moulding
Floors	Buoyancy Diffusion Sorption Heat conductivity Efflorescence Acidic attack	Decaying/moulding
Ceiling	Buoyancy Diffusion Sorption Heat conductivity Efflorescence Acidic attack	Decaying/moulding
Fenestration	Lateral pressure Heat conductivity Diffusion Sorption Acidic attack	Decaying/moulding
Inventory	Buoyancy Diffusion Sorption Acidic attack	Decaying/moulding
Services	Buoyancy Corrosion	Decaying/moulding

B2. Assessment of the potential damage to the building elements

Damage assessment of the building elements starts with a systematic analysis of the defined elements and their parameterisation. Within this process it is crucial to capture all relevant characteristics of a building element that are exposed and potentially susceptible to the adopted flood parameters. Depending on the building element, apart from the materials, it is required to assess further parameters decisive for the assessment of the damage potential such as its location, distribution in a building or its composition. For the defined building elements, the impact of flood factors for the given flood typology is described and the potential damage assessed based on the desk study results.

For each defined building element, the following sub-steps are performed:

I) systematic analysis and parameterisation (of the building elements)

II) description of the damage potential for the relevant flood factors per building element

In the following text, the procedure for the derivation of damage curves (both functional and aesthetical) for the elements and processed defined in Table 3-10 is given. If no information is provided for the aesthetical functions, that it takes the values of the functional damage curves. The physical and chemical processes relevant for the susceptibility assessment, studied literature and experience are given in Appendix 3.3b.

In order to describe the level of susceptibility for of the building elements to different flood factors and/or their combinations, a damage scale has been defined as given in Table 3-11.

Table 3-11 The damage scale describing the level of affect for different flood matrices

Level	Type	Activities required
0	No susceptibility/ damage	No activities required
1	Low	The repairs/refurbishment is limited to drying and cleaning
2	Medium	Repairs and replacements take place in addition to drying and cleaning
3	High	Substantial changes and repairs of the construction required
4	Very high	The building has to be abandoned (total damage)

Building as a whole

System analysis and parameterisation:

Building as a whole is described by its type, presence of the elements beneath the surface (such as basement), age and the foundation type as shown in Table 3-12.

Table 3-12 Classification of the buildings

Parameter	Type/Value	
Building type	1.Detached 2.Semi-detached/terraced 3.Multi-storey	
Presence of a basement	a) Yes b) No	
Age/ condition of the building fabric	I) New II) Old-refurbished III) Old	
Type of Foundations	Type : (a) Shallow: foundation blocks (individual footing), strip slab (b) Deep: piles	Material: solid concrete reinforced concrete masonry loam
Presence of any flood resilient measures (FRe Technology)	a) Yes b) No	

Each building can be described utilising those parameters. For example a new detached building without basement with striped foundations can be described as 1.a) I)(a)-striped.

Additionally those buildings can differ in usage i.e. whether they are main or adjoining building, residential, commercial or mixed, but those characteristics have not been regarded as explicit parameters, but implicitly included in the building description (e.g. through the inventory description).

Description of the damage potential for the relevant flood factors per building element

Building as a whole is exposed to the stability problems (buoyancy and lateral pressure) as well as moulding and decaying as given in the classification Table 3-10. As a thorough static analysis of the buildings has been beyond the scope of this work, as a rule, it has been taken that a more massive building, possesses the better stability (Schmidt-Döhl, 2013). Also, old, non refurbished buildings are considered to be susceptible to structural damage at any condition. The aesthetic (subjective) damage is assigned to the specific building elements.

The main considerations for the assessment of the potential damage for different building types and the flood intensity parameters are given in Table 3-13.

Table 3-13 The damage level and the corresponding description considered for the building as a whole for different flood intensity parameters

Type of the Building based on Table 3-12	Flood intensity	Damage level and description
Detached and semi-detached houses with basement and strip foundation (old, new, old refurbished)	h<0,5m v<2m/s	2-3 - Drying and cleaning - Repair of cracks and gaps
Detached and semi-detached buildings with basement and strip foundation, when exposed to 1 m of flood water are subjected	h<1 m v<2m/s	3- - Drying and cleaning - Repair of cracks and gaps
Old buildings of any type	Any condition	3-4 - Drying and cleaning - Repair of cracks and gaps - Replacement of the
All types	d>15 days	2 - removal of moulds (decontamination)
All types	Any condition C_{oil}>0 (Y)	3- 4 - drying and cleaning (including decontamination) - removal of inventory
All types	v>2m/s	4-5

Walls

System analysis and parameterisation:

The walls are one of the main building elements having different roles mainly related to the stability of the building (static) and its proper insulation against a range of perils (e.g. moisture, temperature, wind, rainfall).

In terms of their static performance, one differentiates between supporting, partition (not supporting) or stiffening walls. The protective role of a wall element is related to its thermal insulation, acoustics and fire protection, protection against moisture, hydrostatic pressure or rainfall (Rongen& Hestermann, 2010).

The walls should also fulfil semiotic requirements, which are individual and set by the dwellers. In the case of walls, the changes are possible in colour, stains, minor cracks as given in Table 3-8.

For purpose of the assessment of their susceptibility to floods, the walls can be distinguished by their location, function and the composition. Those parameters with the corresponding values have been summarised in Table 3-14.

Table 3-14 System analysis and parameterisation of the building element- walls

Parameter	Type	
Location	1. Outside 2. Inside	
Function	a) supporting wall b) partition wall c) stiffening wall	
Composition	The main element determining the type of the wall is the wall base element that are given as:	(1) Masonry (single and double leaf) (2) Timber (3) Prefabricated elements (4) Concrete (5) Steel

Each wall element can be represented by a matrix containing those parameters. For example an exterior masonry wall would be described as (1, a), (1)).

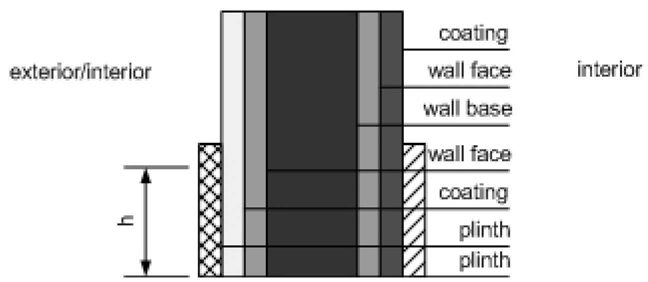


Figure 3-18 Wall system

Composition of the wall element will be decisive for further discussions on damaging functions. As depicted in Figure 3-18, a wall composed of the following elements:

Wall base, that defines the type of wall, is the main parameter for classification of the damaging functions for walls.
Wall face defines materials rendering the wall face (e.g. plaster)
Coating is the final element of the wall system, serving usually for esthetical purposes.
Plinth walls are a course of brick or stone, often a projecting one, along the base of a wall. Plinth walls are short walls that are usually integral with the foundations (usually strip footings) and serve the twin purpose of stiffening up the footings and also of retaining any material (hardcore, etc.) within the buildings.

Wall base:
Three main type of wall base have been considered that are:

- masonry

- loam
- concrete
- timber
- prefabricated walls

Wall face:
As wall face different materials can be used, which characteristics mainly depend on their location (outside or inside).
For the outside walls facing, the following materials are used:

- o Rendered without rear ventilation (nowadays not often used, (Rongen& Hestermann, 2010))
- o Rendered with rear ventilation facade including the following materials and elements:
  - o Plaster (gypsum plaster, mineral plaster i.e. lime and cement, hydraulic lime)
  - o Boards (gypsum boards, gypsum plasterboards)
  - o Mortar

For the inside walls facing, the following materials are used:

- o Plaster (gypsum plaster, mineral plaster i.e. lime and cement, hydraulic lime)
- o Boards (gypsum boards, gypsum plasterboards)
- o Mortar

Wall coverings, coatings and finishes:
Considered materials are given as:

- o Paint coatings (mineral paint coating, lime-based paint coating, water emulsion paint coating, oil and synthetic paint coating, cement paint coating)
- o Elements fixed by mortar e.g. ceramic tiles
- o Wallpapers (including ingrain wallpapers)- internal walls
- o Wood

Description of the damage potential for the relevant flood factors per building element
For the scope of the work, the following processes have been considered for the susceptibility assessment of the wall elements:

- Physical actions: lateral pressure, water absorption (capillary uptake) and heat conductivity.
- Chemical actions: efflorescence, acidic attack and organic (oil) contamination.
- Biological Actions: (moulding of the walls only in exceptional cases as the damage assessment within this work considered the short term damage...

The main considerations for the damage curves both functional and aesthetical are given in Table 3-15 and Table 3-16 resp.

Table 3-15 The damage level and the corresponding description considered for the building element-wall for different flood intensity parameters (functional damage)

Type of the wall based on Table 3-14	Flood intensity	Damage level and description of the required activities for damage repair
Brick masonry (all sub types)	d> 3days v<2m/s	3 - drying and cleaning (for the non plastered walls 2 weeks, for plastered walls 3 weeks, (Bodzak et al.,1998) - filling gaps and cracks - repair of the wall element up to the level of h+0,5m (due to the capillary rise)
Brick masonry (all sub types)	d< 1day v<2m/s	3 - filling gaps and cracks, up to the level h+0,1m (Nowak et al., 1998) - cleaning and drying -replacement of thermal insulation (except closed cell plastic or hydrophobised insulation)
Partition walls (wooden, gypsum)	At any condition	4 Replacement
Double shell masonry of sand-lime bricks with heat insulation and air space		
Loam wall base	At any condition	3-4 The wall element has to be replaced
Concrete wall base (plastered)	d<3days	2-3 - Drying and cleaning (3 weeks) - Repair of the wall element up to h+0.1m
Concrete wall base (plastered)	d>>3days	2-3 - Drying and cleaning (4 weeks) - Repair of the wall element up to h+0.5m - Anti fungi treatments
Timber walls	d<3days	3 - Drying and cleaning (3 weeks) - Repair of the whole wall element - Anti fungi treatments
Timber walls	d>>3days	3-4 - Drying and cleaning (4 weeks) - Repair of the whole wall element - Anti fungi treatments
Loose fill insulation, mineral wool	At any condition of h,d	4 - Replacement of the whole element

Closed cells plastics types of insulation (boards)	At any condition of h,d	2 - Drying and cleaning
Polyurethane foam of Styrofoam insulation	At any condition of h,d	2 - Drying and cleaning
Hydrophobised insulation	At any condition of h,d	2 - Drying and cleaning
Mortar on masonry	At any condition of h,d	3 - Drying and cleaning - Replacement of the damaged elements
Lime or cement lime plasters (internal)	At any condition of h,d	2-3 - Drying and cleaning including decontamination (bacteria), efflorescence removal - Deformed elements are exchanged
Gypsum plaster (on any type of the wall base)	At any condition of h,d	4 Replaced
Lime based plaster if installed over a water resistant render	At any condition of h,d	2 - Drying and cleaning
Hydraulic lime	At any condition of h,d	2 - Drying and cleaning (no need to remove it, the wall element can dry out, Garvin and Kelly, 2004)
Plasterboard on solid masonry, cavity walls, timber frames	At any condition of h,d	4 - Drying and cleaning of the wall element - Replacement
Paint coatings (any type), coating-lining systems, wall papers on any type of the wall base	At any condition of h,d, c,v	4 - Drying and cleaning of the wall element - Replacement
Ceramic tiles on any type of the wall base	h<< d< 24h	2 - Drying and cleaning of the wall element
Ceramic tiles on any type of the wall base	h d< 24h	3 - Drying and cleaning of the wall element - Replacement of tiles to allow the wall element dries out
Wooden panels	At any condition	4 - Replacement

Table 3-16 The damage level and the corresponding description considered for the building element-wall for different flood intensity parameters (aesthetical damage)

Type of the wall based on Table 3-14	Flood intensity	Damage level and description of the required activities for damage repair
All types of walls	Even for h<< Any d v<2m/s c<0	2 - All wall coverings will be replaced for the whole wall element (colour, stains, minor cracks, including removal of efflorescence)

Floors/ Ceiling[118]

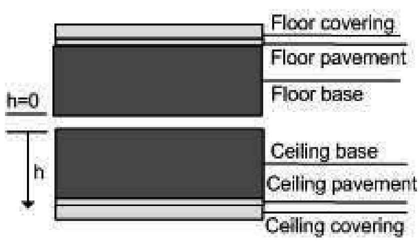
System analysis and parameterisation:

Floors are building components with the function to support the imposed load of people and building contents (stability role), to exclude the passage of water and water vapour from the exterior of the building and to disable heat loss (insulation) as given in Table 3-8. Apart from this functionality, floors and ceilings have to fulfil the esthetical criteria as they are usually visible. Those criteria imply no cracks, no changes in colour and no permanent stains. Each flood/ceiling element can be distinguished by its location and composition as summarised in Table 3-17.

Table 3-17 System analysis and parameterisation of the building element- floors and ceilings

Parameter	Type
Location	a) basement b) basement-ground floor c) ground floor-first floor d) between upper floors
Composition	Specific combination of base material-pavement-covering (see Figure 3-19) and Table 3-18

The system defined for floors and ceiling is composed of a base, pavement and covering as depicted in Figure 3-19.



Functions:
- Stability
- Insulation (thermal, moisture)

Esthetical
- optic (no stains, cracks and changes in colour)

Figure 3-19 Floor and ceiling system

[118] As floor and ceiling elements have similar configuration (see Figure 3-19), they are presented here in one subchapter. However, they are implemented separately (refer to Chapter 4)

The floors and ceilings are assessed based on the base material and covers. The types of floor base, pavement and coverings that have been considered for the analysis are given in Table 3-18.

Table 3-18 Considered materials of different elements of the floor/ceiling system

FLOOR BASE	FLOOR PAVEMENT	FLOOR COVERING
Solid concrete floor	Joints mortar	PVC, ceramic tiles
Suspended concrete floor	Tiles glue	parquet, laminate, wood,
Loam	Insulation	natural stone, fitted carpet
Wood		rug, coating, novilon,
Masonry	Acoustic insulation	roofing cardboard, linoleum,
Timber suspended floor	(Floor heating)	terrazzo

Description of the damage potential for the relevant flood factors per building element

The main considerations for the damage curves both functional and aesthetical are given in Table 3-19 and Table 3-20 resp. For all cases it has been considered that if the water level reaches the floor covering (h=0,01 cm) the floor is regarded as fully exposed to flood.

Table 3-19 The damage level and the corresponding description considered for the building element-floor for different flood intensity parameters (functional damage)

Type of the floor/ceiling based on Table 3-17	**Flood intensity**	**Damage level and description of the required activities for damage repair**
Timber suspended floor base	At any condition	4 - Replacement of the floor element including the pavement and covering e.g. Nowak et al., 1998, Golz, 2012
Solid concrete floor base	At any h, d	2-3 - Drying and cleaning (Drying time is set to 3 weeks for all durations) - Floor covering has to be replaced if carpet, parquet, wood
Suspended concrete floor base	At any h,d,v	3-4 - Replacement together with the pavement and covering
Loam floor base	At any h,d,v	3-4 - Replacement
Masonry floor base	h<1m at any d	2-3 - Drying and cleaning - Repair of minor gaps and cracks - Replacement of the floor covering and pavement
Any floor type	At any h, d	3

	C>0 (Y)	- Drying and cleaning including decontamination - Repair of gaps and cracks - Replacement of the floor covering and pavement
Carpets on any floor base	At any condition	4 - Replacement
Granulated floor insulation	At any condition	4 - Replacement
Any ceiling	$h=h_{celiling}$ Any d,	3-4 - Drying and cleaning - Repair of gaps and cracks - Replacement of the wall covering and pavement

Table 3-20 The damage level and the corresponding description considered for the building element-floor/ceiling for different flood intensity parameters (aesthetical damage)

Type of the floor/ceiling based on Table 3-17	**Flood intensity**	**Damage level and description of the required activities for damage repair**
All types of floors	Even for h<< Any d v<2m/s c<0	2 - All floor coverings (including tiles) will be replaced for the whole wall element (including removal of efflorescence)

Staircases

System analysis and parameterisation:

The staircases are distinguished by their location (inside/ outside), by the building levels they are connecting (doorstep – basement - ground floor - upper floors) as well as by their composition. The value h_{sc} indicated its height. Table 3-21 outlines the main characteristics of a staircase system.

Table 3-21 System analysis and parameterisation of the building element- staircases

Parameter	Type
Location	Inside/outside
Connecting building levels	a) doorstep b) basement-ground floor c) ground floor-first floor d) between upper floors
Composition	Specific combination of base material-pavement-covering (see Figure 3-20 and Table 3-22

The staircase system is composed of a base, pavement and covering as depicted in Figure 3-20.

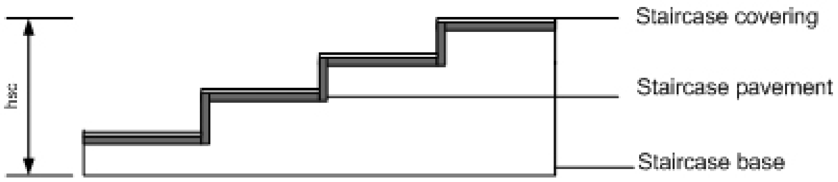


Figure 3-20 Defined staircase system

Table 3-22 summarises the main materials considered for those main elements of staircases.

Table 3-22 Considered materials of different elements of the staircase system

BASE	(HANDRAIL)	PAVEMENT	COVERING
Concrete	Wood	Joints mortar, Tiles glue	PVC, ceramic tiles
Metal	Metal	Insulation	parquet, laminate, wood,
Wood	Plastic	Acoustic insulation	natural stone, fitted carpet
Masonry			coating

Description of the damage potential for the relevant flood factors per building element

The main consideration for the staircase element, for both functional and aesthetical functions is given in Table 3-23 and Table 3-24 resp.

Table 3-23 The damage level and the corresponding description considered for the building element-staircase for different flood intensity parameters (functional damage)

Type of the staircases based on Table 3-21	Flood intensity	Damage level and description of the required activities for damage repair
Wooden floors	At any h, d	4 - Replacement
Concrete staircase base	At any h, d	2-3 - Drying and cleaning - Replacement of the covering/pavement of the affected steps and the handrails
Masonry staircase base	At any h, d	2-3 - Drying and cleaning - Replacement of the covering/pavement of the affected steps and the handrails
Carpets on any staircase base	At any condition	4 - Replacement
Concrete, masonry, metal	c>0, at any h, d	4

staircase base		- Drying and cleaning (including decontamination) - Replacement of the pavement and covering and the handrails - Repairing gaps and cracks

Table 3-24 The damage level and the corresponding description considered for the building element- staircase for different flood intensity parameters (aesthetical damage)

Type of the staircases based on Table 3-21	**Flood intensity**	**Damage level and description of the required activities for damage repair**
Any type of staircase base and handrails	At any h, d	2-3 - Drying and cleaning - Replacement of the covering/pavement of all steps

Openings

System analysis and parameterisation:

The main openings in the building are doors and windows. Additionally the ventilation openings are regarded but have not been considered in detail. The openings can be distinguished by their location, material, and topology/distribution, as given in Table 3-25.

Table 3-25 System analysis and parameterisation of the building element- openings

Parameter	Type
Type/Function	1. Doors 2. Window 3. Others
Location	a) outside b) inside
Material	I) wood- chipboard w/o paint coating II) massive wood III) stainless steel IV) galvanised steel IV) aluminium V) synthetic materials VI) glass (single and double glazing)
Topology (Figure 3-22)	(1) at a certain distance from (h) from the ground are connected with wall (2) directly on the ground and as such are connected and interact with floor and wall elements

The topology (1) corresponds in the general case to doors, whereby the type (2) is typical for windows. The other openings such as ventilation openings can belong to both groups.

Each opening element can be represented by a matrix containing those parameters. For example a wooden exterior door would be (1, a), I), (1)).

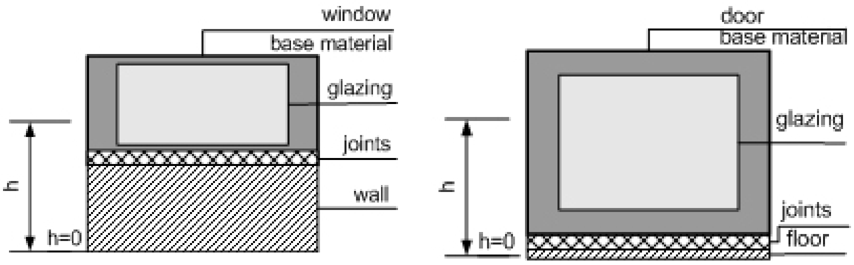


Figure 3-21 Defined systems for the openings a) at a distance from the ground b) directly on the ground

Apart from base material of the openings, the additional element that is considered for the damage assessment is the frames (timber, metal).

Description of the damage potential for the relevant flood factors per building element

The main considerations for the openings for both functional and aesthetical functions are given in Table 3-26 and Table 3-27 resp.

Table 3-26 The damage level and the corresponding description considered for the building element-openings for different flood intensity parameters (functional damage)

Type of the openings based on Table 3-25	**Flood intensity**	**Damage level and description of the required activities for damage repair**
Massive wood openings	$h=>h_{opening}$ d<3d, v<2m/s	2-3 - Drying and cleaning - Repainting
Wooden openings	$h=>h_{opening}$ d>3d, v<2m/s	4 - Replacement
Metal openings	$h=>h_{opening}$ d<3d, v<2m/s	2-3 - Cleaning and anti-corrosion treatment
Metal openings	$h=>h_{opening}$ d>3d, v<2m/s	4 - Replacement
Wooden openings	c>0, v<2m/s at any h,d	4 - Replacement
Synthetic materials	$h=>h_{opening}$ v<2m/s, any d	2-3 - Drying and cleaning - Repainting
Single glazing	$h=>h_{opening}$ at any v, d	4 - Replacement
Double glazing	$h=>h_{opening}$	4

	v>2m/s, d	- Replacement
All types of openings	c>0 (Y)	4 - Replacement
All types of doors	v>2m/s	4 - Replacement

Table 3-27 The damage level and the corresponding description considered for the building element- staircase for different flood intensity parameters (aesthetical damage)

Type of the openings based on Table 3-25	**Flood intensity**	**Damage level and description of the required activities for damage repair**
Any type of openings	At any h, d, v	4 - Replacement

Building Services

System analysis and parameterisation:

Building services are utilities supplied to and used within a building[119]. They are given as heating, electricity, water supplying and sewerage system. Due to their heterogeneity in terms of materials, elements or roles, they have been parameterised separately as given in Table 3-28.

Table 3-28 System analysis and parameterisation of the building element- building services

Type	Basic Function	Subtype	Main elements
Water supply	Supplying potable water		Pipes, sanitary equipment, boiler
Sewerage system	Collecting and conveying waste water	Storm water Waste water Combined	Pipes, sanitary equipment, non return valve (y/n)
Heating system	Supplying heating	Oil District Electricity Gas	Oil tank
Electricity	Supplying electricity	Fuse boxes Wiring	Level base cut-out (y/n) Wiring (encapsulated y/n), sockets
Telecommunications	Providing telecommunication service	Telephone Internet	Wiring, sockets Auxiliary devices, wiring, sockets

[119] http://www.dictionaryofconstruction.com/ (last accessed: January, 2015)

Description of the damage potential for the relevant flood factors

The main consideration for the building services for both functional and aesthetical functions are given in Table 3-29, and Table 3-30 resp.

Table 3-29 The damage level and the corresponding description considered for the building element-building services for different flood intensity parameters (functional damage)

Type of the services based on Table 3-28	**Flood intensity**	**Damage level and description of the required activities for damage repair**
Pipes	At any h, d, v<2m/s	2 - Cleaning
Sanitary fittings	h<1,2m at any d	2 - Cleaning (disinfection)
Boilers	At any condition	4 - Replacement
Electrical wiring	At the h reaching the lowest socket fuse, at any d,v	4 - Replacement
Oil tanks (not anchored)	At h>0,5m	4 - Replacement - Drying and cleaning+ Oil decontamination
Storage heaters and gas furnaces	At any h,d,v	4 - Replacement
Telecommunication network	At the h reaching the lowest point, any d, v	4 - Replacement

Table 3-30 The damage level and the corresponding description considered for the building element-building services for different flood intensity parameters (aesthetical damage)

Type of the services based on Table 3-28	**Flood intensity**	**Damage level and description of the required activities for damage repair**
Sanitary fittings and equipment	At any condition	4 - Replacement

Inventory

System analysis and parameterisation:

The inventory elements can be distinguished by their specific functions, connection to the building fabric, materials they are made of and the topology/distribution in the building as summarised in Table 3-31.

Table 3-31 System analysis and parameterisation of the building element- inventory

Parameter	Type
Function	1. Furniture 2. E appliances 3. E appliances- hobby 4. Hobby 5. Personal items and utensils
	a) permanently fixed to building (e.g. built in closet) b) movable (e.g. chair)
Material	I) wood II) metal III) canvas IV) synthetic materials V) paper
Topology (Figure 3-22)	(1) directly on the floor with rather evenly distributed volume over the space (e.g. wardrobe, kitchen units) (2) at a certain distance h from the floor hanging at a wall element (e.g. painting) (3) combined (1) and (2)- the substantial part is at a certain distance h from the floor) (e.g. table).

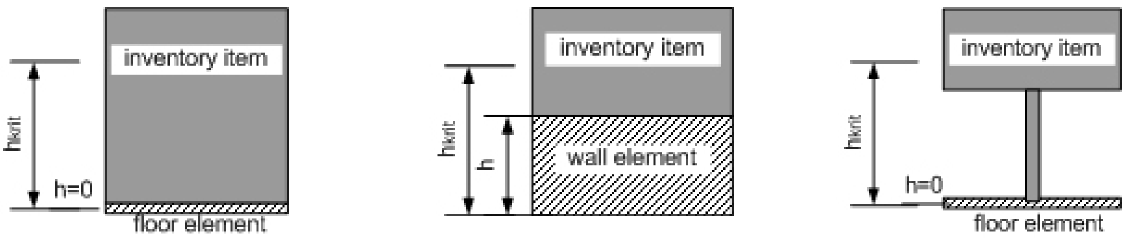


Figure 3-22 Defined cases of the topology/distribution of the inventory elements (1) directly on the floor, (2) at a certain distance h from the floor (3) combined- the substantial part is at a certain distance h from the floor

For all the cases depicted in Figure 3-22, the height h_{krit} has been defined, which marks the flood depth at which the inventory item cannot perform its original function (e.g. for a washing machine this is the level at which the engine is positioned). This parameter is optional, depending on the type of inventory and its function. All inventory elements can be attached or detached to the ground or walls and depending on the attachment level they can be displaced due to buoyancy or lateral force of the flood water. In that sense, the h_{krit} value represents the initial height before the inventory element gets in touch with the flood water.

Each inventory element can be represented by a matrix containing those parameters. For example a table would be (1, b), I), (3)). For the h_{krit}, the height of the table board is taken.

Description of the damage potential for the relevant flood factors

The main considerations for the inventory for both functional and aesthetical functions are given in Table 3-32 and Table 3-33 resp.

Table 3-32 The damage level and the corresponding description considered for the building element-inventory for different flood intensity parameters (functional damage)

Type of the inventory based on Table 3-31	**Flood intensity**	**Damage level and description of the required activities for damage repair**
For h_{crit} irrelevant e.g. books, CDs, photos, decoration, canvas	At any condition	4 - Replacement
For h_{crit} relevant e.g. electrical appliances, kitchen units	$h=>h_{crit}$ At any d, c	4 - Replacement
For h_{crit} relevant e.g. electrical appliances, kitchen units	$h<h_{crit}$ d<3d	3 - Drying and cleaning
Pieces of furniture where h_{crit} relevant	$h<h_{crit}$ d<3d	3 - Drying and cleaning
Pieces of furniture where h_{crit} relevant	$h>h_{crit}$ At any d, c	4 - Replacement

Table 3-33 The damage level and the corresponding description considered for the building element-inventory for different flood intensity parameters (aesthetical damage)

Type of the inventory based on Table 3-31	**Flood intensity**	**Damage level and description of the required activities for damage repair**
All inventory items	At any condition	4 - Replacement

From the damage matrix to the damage curves

Based on the assumptions for the damage calculations for each building element given in the tables above, damage curves are derived.

The full set of functions is stored in the FLORETO database (see also section 4- the section introducing the database and the way the damage functions are stored there). Also, they are given at the link: http://floreto.wb.tu-harburg.de/loginlogout (password protected). In the following text, some examples are given.

In the case of a wall element with a brickwork base, the damage is calculated based on the assumptions stated in Table 3-15. Due to the capillary rise, the wall element has to be refurbished up to 0,5m in addition to the flood level for the flood events with the d>3days in order to calculate the functional damage. The required surface is to be multiplied with the unit repair costs. The corresponding function for one wall element can be expressed as:

$$D = (\mathbf{h}+0.5\text{m}) \times \mathbf{b} \times \mathbf{C_k}$$

Where,

h- estimated water depth in a building [m]

b- with of the wall element [m]

C_k – unit costs of repair [€] as given in the subsection B3

In the case of the inventory elements, the functions can be expressed by the relative portion of the inventory value that is to be recovered for the given flood conditions. Those are to be multiplied by the unit costs of the analysed inventory item. Table 3-23 illustrates the case of the derivation of the damage curves (functional and aesthetical) for a kitchen unit. The assumptions considered are given in Table 3-32.

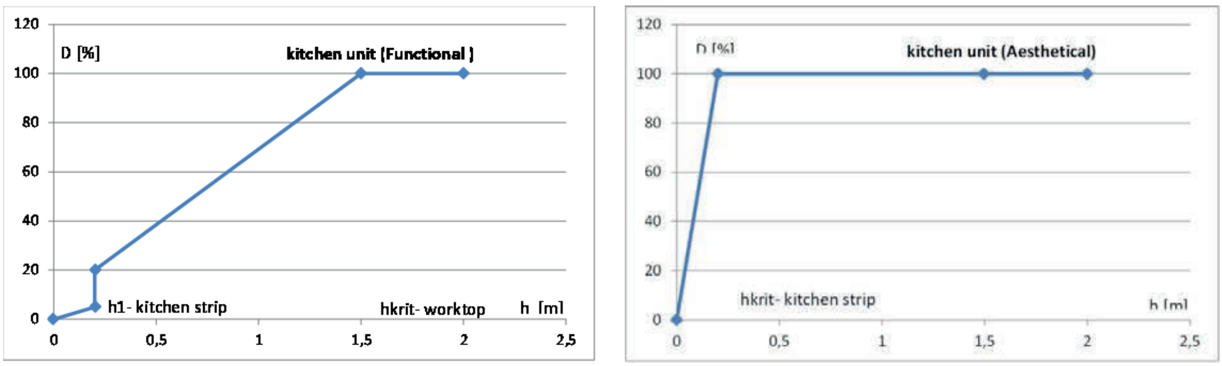


Figure 3-23 Damage curves for the inventory element- kitchen unit a) functional b) aesthetical

B3. Monetary representation of the damage potential of the building elements

Based on the assessed susceptibility level of the building elements and the required activities to repair them for different flood conditions, the associated costs for their rebuilt are assessed. For the scope of this work, the approach has been adopted where the damage assessed in monetary terms expresses the rebuilding (refurbishing, replacing, repairing) costs in order to bring those elements to their initial state. Consequently, the damage is calculated as the effort (in terms of money, resources) to rebuilt the damaged element and bring it to the initial state. This rebuilding effort considered is composed of:

1. Replacement costs (for single material or items)
2. Improvement of the existing material or item
3. Manpower costs to refurbish/repair the building element
4. Energy required (in terms of clean water, electricity)

5. Drying and cleaning (including decontamination, anticorrosive treatments, odour control) – energy and manpower

The total damage of a building assessed for a given matrix of flood parameters $FP = [x_{ij}]$, where, Xij-flood parameters i (water depth, duration, velocity, contamination) for given conditions/values j, is given as:

$$D_{Building}(X_{ij}) = \sum_{k=1}^{m}(V(BE_k, X_{ij}) \times n_{BE_k} \times C_k) \ [€] \qquad \text{Eq. 3-5}$$

Where $V(BE_k, X_{i,j})$ is the susceptibility of the building element item BE_k (out of m), for the given set of flood parameters Xij and C_k, which are refurbishment costs of the considered BE_k. The overall costs- Ck are given as an interval ($C_{k,min}$,$C_{k,max}$) defining a range of values $D_{Building}$ The costs are taken as market prices available in the standardised books and documents (e.g. Baukostenindex in Germany). Additionally, the market values of certain products are surveyed (e.g. cost of the building contents).

In order to apply this method in other regions, for which the BKI cannot be directly applied, a cost conversion factor is to be applied.

C. Derivation of a cumulative damage curve for a building

The final damage function for a given building is derived as an accumulative function, which sums up the damage curves derived for the elements for both, functional and aesthetical damage.

C1. Integration of the damage curves per building element for the given flood matrix

The damage of the whole building is given as the sum of the single building elements contributing to the damage for which the assessment has been performed. Additionally, the potential damage assigned to the building as a whole, mainly related to the indoor climate (see also Table 3-10) is added to the overall damage for a building.

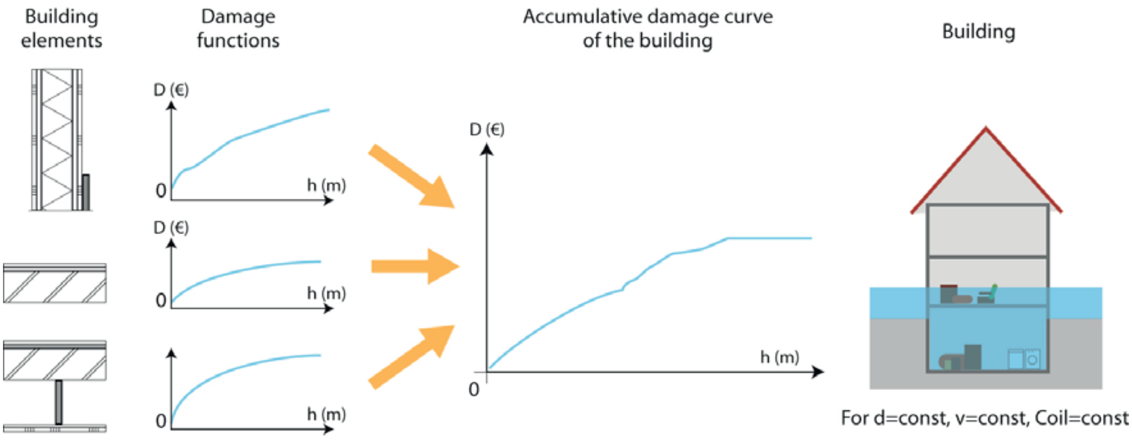


Figure 3-24 Cumulative damage cure for a building given for a defined set of flood parameters and for the given costs (C_{kmin} or $C_{k,max}$). As the final result, a family of curves is created covering a range of costs (C_{kmin}-$C_{k,max}$) (see also section C2). Here one of those curves (C_{kmin},$C_{k,max}$)is presented

C2. Definition of a family of curves describing a range of costs and addressing both-functional and aesthetical aspects

As a final result, a family of damage curves for a building is derived. They vary in costs (C_{kmin}-$C_{k,max}$) and on the type of the functions considered.

Risk Assessment

Risk assessment combines the flood probability assessment results (1) with the potential damage assessed in (2) following the definition given in the equations Eq 3-1 till Eq 3-3. In practical terms, the risk is expressed as a product of the return period of a certain flood event and the corresponding consequences (i.e. assessed damage). For the risk assessment expressed in monetary terms (quantitative) and for the option analysis (such as the cost-benefit analysis) the damage is expressed as expected annual damage (EAD) as given in section 3.3.2.3 where the option analysis is introduced.

3.3.1.3 Assessment of acceptable risk

The level of the acceptable risk sets the basis for the resilient planning. Although the decision is made based on the figures and facts (e.g. assessed damage for the given flood conditions for a defined return period) the acceptable risk is more a social issue than a “hard fact” derived by the hydrodynamic models (see also Pasche et al., 2010). It can be performed by enabling the end-users tools to create “if-then” scenarios, which can help them to decide for the acceptable risk. For the scope of this work, the acceptable level of risk is set to reducing the damage to the maximal extent that is achievable utilising the existing resilient systems.

3.3.2 Resilience plan for built the environment

The development of a resilience plan for the built environment has the objective of delivering the optimal[120] resilient system for the given conditions and considering a set of defined criteria that can be technical, economic and social& aesthetic ones. This process is composed of the main phases being (Figure 3-15):

(1) Parameter& system analysis
(2) Definition/selection of technically appropriate resilient systems
(3) Option analysis
(4) Decision making

[120] The term *optimal* will be defined in the course of the chapter- section 3.3.2.2.

In phase (1), the relevant parameters are analysed. They describe flood typology and the built environment together with its interactions with the other elements of an urban system, defining the given conditions for decision making. Based on the given conditions and the assessed flood risk, technically appropriate resilient systems are assessed in phase (2). Technically appropriate systems are referred to as resilient systems applicable from the technical point of view considering given flood conditions and the system characteristics. In phase (3) the selected, technically appropriate flood resilient systems are assessed against socio-economic and aesthetic criteria utilising a multi criteria analysis (MCA). Alternatively, a simplified version is applied dealing only with the economic criteria performing a cost-benefit analysis. In the phase (4) the final decision on resilient system to be applied is made.

Described in this way, this process is generic and can be applied to any of the scale. For the scope of this work, the **decision making process at the property scale** as of relevance for the dwellers has been considered as described in section 3.2.

3.3.2.1 Parameter& System analysis

The decision making process for the built environment at the property scale developed in this work, starts with a parameter and system analysis. As introduced in section 3.1.1 on the holistic approach, the built environment is interlinked and interrelated with the other elements of the socio technical system and consequently any alterations of its quality will have an impact on the other elements such as urban landscape or lifestyle. Also, those alterations are a function of other elements such as flood extent and typology, dwellers' awareness or the available technology.

In terms of its resilience performance, the resilience systems behave as depicted in Figure 3-7. A system at the property scale is exposed to a perturbation (P), which represents a flood event of a certain typology. Applying the system approach, the built environment can be decomposed in a way that smaller units interact with each other and with the other elements of an urban system as given in section 3.2.1. The flood resilience level and response of this system are to be improved by the application of flood resilience systems.

Consequently, which flood resilient systems at the property scale are to be applied depends on a range of characteristics that can be summarised in the following key parameters referring to the sociotechnical system (see also Figure 3-1):

I) Nature: flood typology and parameters; For the scope of this work, the flood types as given in section 2.1 and Figure 3-2 have been considered (pluvial, riverine, lake, storm surge) together with a defined set of their physical, chemical and biological characteristics (such as water depth, duration, velocity or oil content).

II) Technology: (system description at the property scale):

1. built environment (definition of parameters (such as type of building, description of walls, floor or inventory).

2. interactions of buildings with the other elements of the built environment (built environment at larger scales, adjacent built environment-topology)
3. technological development in relation to the flood resilient technology (existing measures of dry and wetproofing, flood resilience measures)

III) Society: interactions with dwellers (e.g. experience with floods, acceptance of own responsibility, readiness to apply FReT, behaviour, lifestyle) governance networks at different scales (district, cities, national and beyond), legal frameworks, different stakeholder groups

The main parameters of groups I and II) have been summarised in Table 3-9 and Table 3-34. The parameters describing the Technology domain (group II) are summarised in Table 3-34.

Table 3-34 II) Technology: System description at the property scale and the corresponding parameters

P. Type II-1 (Technology)	Parameter group	Parameters- values/ examples
Built environment (at the property scale)	Type of building	single house, terrace, multi storey building
	Building condition	New, old, old-refurbished
	Building profile	(e.g. dwelling house, adjoining building)
	Type of Foundation	e.g. (strip, piles)
	Basement	(y/n)
	Occupancy of the building level	(intensive, low, not used)
	Period (Year) of construction	Given as a year or a period
	Building condition	e.g. new, new bad, old, old refurbished
	Walls	wall type, outside face, inside face, covering
	Floors	floor type, floor covering
	Ceiling	ceiling type, ceiling covering
	Staircases	type, covering
	Openings	windows, doors (elevations, materials)
	Services and Fittings	Electro (e.g. encapsulated wiring y/n) heating system (e.g. type, location) sewerage system water supply
	Inventory	movable assets (e.g. location) fixtures (e.g. location)

P. Type II-2 (Technology)	Parameter group	Parameters- values/examples
Relation to	Location/ Terrain configuration	e.g. flat, steep, riverside, hillside

adjacent built environment and topology	Distance to adjacent objects/ buildings	e.g. short, medium, long
	Pathways of the flood water	e.g. walls, openings, airbricks
P. Type II-3	Parameter group	Parameters- values/examples
Relation to technology	Already existing FRe Technology in/on the building	Yes/no Type of technology and location
Adequate technology	Availability of the adequate technology	Yes/No

P. Type III (Society)	Parameter group	Parameters- values/examples
Relation between dwellers and buildings	Flood related: Experience with floods Flood risk awareness Acceptance of own responsibility Readiness to apply FReT Non flood related: Behaviour Lifestyle	 Yes/no Yes/no Yes/no Yes/no Descriptive Descriptive
Governance networks	Neighbourhood District Urban system	Relevant stakeholder groups Relevant stakeholder groups Relevant stakeholder groups
Legal frameworks	Legislation, water laws Building codes	List of the applicable laws List of the applicable documents

Within this analysis, the focus will be set to the I) and II) parameters. The aspects summarised under III) Society will be addressed in section 3.4 mainly via addressing the links between dwellers and the built environment via the capacity building of stakeholders to support this alteration.

Additionally, the protection goal defined in the previous step (see section 3.3.1.3) is to be considered as a parameter for decision making. For the scope of this work, as introduced in the section 3.3.1 the protection goal will be set to the maximal protection level, i.e. the no structural damage occurs; the rebuilding costs are reduced to drying and cleaning (see also section acceptable level of risk).

Both, parameters and system descriptions will be referred to as an *input parameter* or *given conditions* in the following text.

3.3.2.2 Definition/selection of technically appropriate resilient systems

The number and diversity of the relevant parameters indicate the complexity of the decision making process. In general cases, different combinations of the parameters lead to a different set of possible resilient systems. The key problem to be solved in this phase is how to find the most appropriate resilient systems based on the given conditions (input parameters).

This is a knowledge intensive process and for solving the means of a Computational Intelligence (CI) have been used.

Computational intelligence (CI) (*also Artificial intelligence- AI*) is defined as [a branch of computer science concerned with the study of the design of intelligent agents[121] (Poole et al., 2007).

Transferred into the language of CI, the problem of finding technically appropriate resilient systems can be seen as a problem of finding the *mapping function* that would match the input parameters to the technically appropriate solutions.

This mapping function is given as the following:

$$y = M(X): \quad y \in Y, \quad X \in X^{\infty} \qquad \text{Eq. 3-6}$$

Where

- X set of all relevant input parameters
- Y set of all possible flood resilient systems (FReS)

The input parameters consist of vectors of categorical and/or numerical attributes, composed of the parameters describing flood typology and the system at the property/building level. An example of a categorical attribute is *wall type (*given with values such as masonry, timber, concrete), whereby numerical attributes are *water depth* or *flood duration (*expressed in real numbers). The input parameters are further represented as X, with the complete set of all possible design criteria represented as X^{∞}, and the cardinality $|X|$ being the number of attributes of the input parameters.

The class parameter is made up of the technically applicable flood resilient systems that are needed to protect the property in the event of a flood. The set Y constitutes a categorical enumeration of all possible resilient systems.

Potentially, there are many possible matching functions M, the challenge is to find a $M_{optimal}$, which returns the most appropriate flood resilient systems.

This mapping process has been illustrated in Figure 3-25.

For defining criteria for the derivation of this function it is important to understand the domain and the nature of the problem. Flood resilient planning is a parameter intensive

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[121] An agent could be anything that acts in an environment. [An intelligent agent acts "intelligently", which means: what it does is appropriate for its goal and circumstances and it should learn from experiences and makes appropriate choice given perpetual limitations and finite computation]. (Poole et al., 2007).

domain as presented in 3.3.2.1. The knowledge that contains the patterns (rules) for decision making is being eliciting and elucidated from the experts and used for predicting the $M_{optimal}$ for a given case.

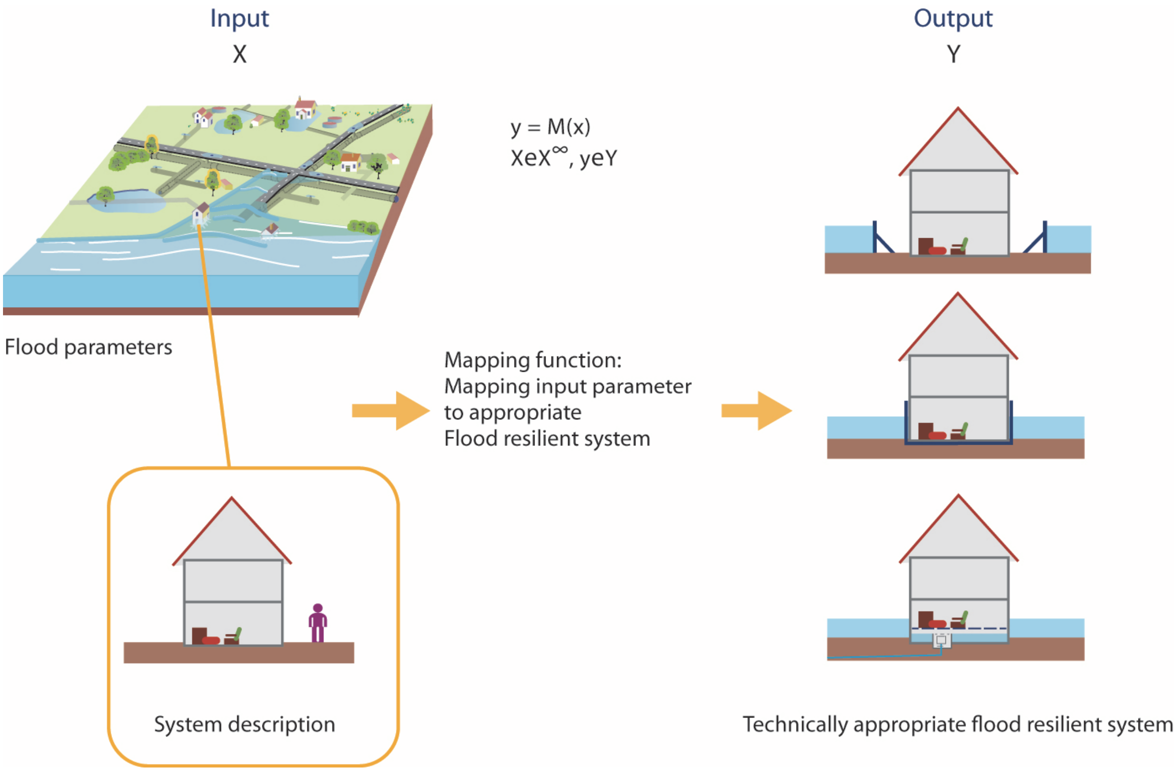

Figure 3-25 Mapping parameters to flood resilient systems for the built environment on a property scale

However, this knowledge mapping process faces some drawbacks, mostly in the forms of a knowledge acquisition bottleneck and a robust learning limitation bottleneck (Welbank, 1983, Owotoki, 2007).

The knowledge acquisition bottleneck is the well-known bottleneck of rule based knowledge bases. It consists of the *knowledge elicitation problem* and the *knowledge representation problem* (defined in Welbank, 1983 as):

The knowledge elicitation problem is related to the inability of experts to easily, accurately and explicitly express their implicit knowledge as rules for a machine. Also, sometimes experts have conflicting opinions about aspects of their knowledge, which relates the accuracy of the rules defined in the knowledge base.

The knowledge representation problem is related to the problem of the translation of the knowledge elicited from the experts into a form that can be stored in and understood by the machine. This process is inherently uncertain due to the leak of knowledge in the transcription from experts to machine form. There is no guarantee that the knowledge elicited is exactly the same as that transferred into the system.

The robust learning limitation bottleneck is related to the limitations of the improvements and the inflexibility of the existing knowledge base created, based on the "experts" knowledge. Such a created set of rules has no way of learning new concepts by itself. In order to update its knowledge base the same experts, or where they are not available new experts, must be approached; the latest knowledge of the experts must be elicited again and transcribed into the machine. Every time the process is confronted with the knowledge elicitation bottleneck. This is a considerable disadvantage in a domain where the initial knowledge is incomplete or the knowledge turnover is high (introduced in Owotoki, 2007).

Those drawbacks can be overcome by introducing the learning effect to the initial knowledge stored in the knowledge base. In that way, the knowledge of experts is supplemented with more objective knowledge extracted from new examples stored in the database.

This effect can be achieved by the utilisation of computational intelligence (CI) in the knowledge discovery (KDD) or data mining (DM) process.

This approach incorporates the knowledge of experts in the constructed CI model but overcomes the knowledge acquisition bottleneck by supplementing any available expert knowledge with more objective knowledge extracted from databases (Owotoki, Manojlovic et al., 2006). This process of knowledge discovery/data mining from databases with the use of CI models also overcomes the robust learning problem, as the models are able to autonomously learn new concepts and patterns when presented with new datasets containing the design criteria of the properties and measures that were used in previous flood events (Owotoki, Manojlovic et al., 2006).

The Data Mining (DM) and Computational Intelligence (CI) Models Based System for finding the matching function for input parameters to appropriate resilient system(s)

Data mining (DM)[122] or knowledge discovery (KDD) is a [computer assisted process of discovering meaningful new correlation, patterns and trends by digging into (mining) large amount of data stored in the warehouse] (Sumathi& Sivanandam, 2006). The relationships found could be used to predict future behaviour. During the data mining process the previously unknown, valid and actionable information is being extracted, utilising different techniques originating from statistical, machine learning, computational intelligence and data visualisation techniques. Results of the data mining process can be rules, insights or predictive models.

Applying the data mining approach to this matching problem is enabled through the *learning theory.*

The learning theory (Zimermann et al, 2002 cited in (Owotoki, Manojlovic, et al., 2006) presupposes that by training a CI model with a representative sample of the input space $X^{representa\ tive} \subset X^{\infty}$, so that it becomes the $M_{optimal}$ to realize the function (Eq. 3-6), the model

[122] Data mining is usually considered as one step in the KDD process. Here it is referred to the general paradigm of extracting knowledge of databases. The difference between those two as well as the phases of the KDD process will be introduced later in the text.

will be able to generalize the unseen members of the input space $X^{unseen} = X^{\infty} - X^{representa\ tive}$ and still perform optimally at predicting the appropriate measures, delivering the following statements:

$$\begin{aligned} &if\ M = M^{optimal} for\ y = M(X^{representative}) \\ &then\ M = M^{optimal} for\ y = M(X^{unseen}) \end{aligned} \qquad \text{Eq. 3-7}$$

This assumption in equation Eq. 3-7 is the core principle of building intelligent models with training data in the data mining process and later validating them with test sets which were previously unseen by the models. The performance of the trained models on the test set is then extrapolated to real life scenarios which are also input parameters that were previously unseen by the models (Owotoki, Manojlovic, et al., 2006). The main data mining techniques are given as predictive and descriptive as depicted in Figure 3-26 (Dunham, 2003).

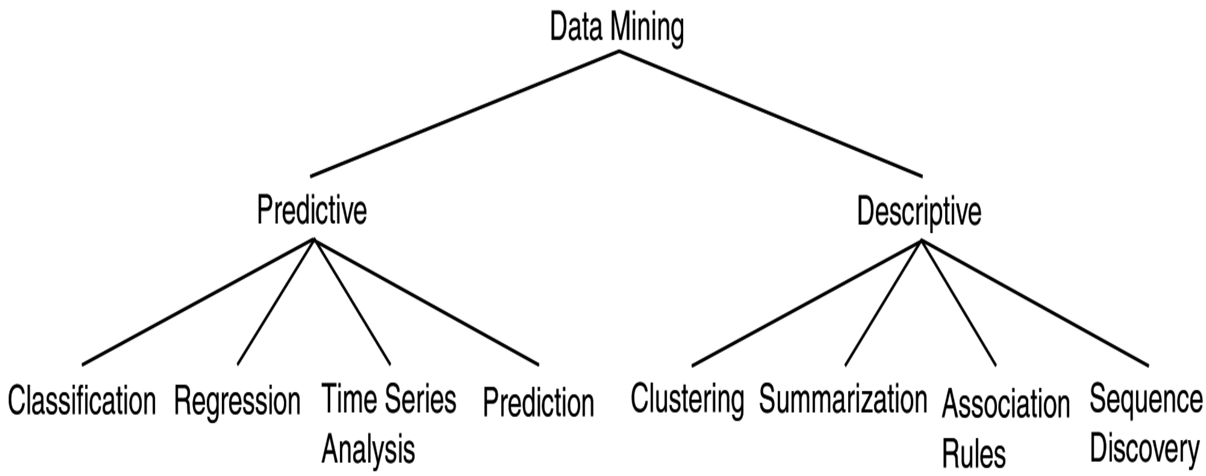

Figure 3-26 Data mining techniques (Dunham, 2003)

However, the most frequently used techniques/principles of data mining are *classification*, *clustering* and *association* (Sumathi& Sivanandam, 2006):

Classification means assigning records to one label out of a group of labels. The labels usually come from a pre-defined set. Classification can formally be defined as the learning of a target function M that maps each attribute set X to one of the class labels Y. The most common classification tools are decision trees, k-nearest neighbours, and neural networks. (Sumathi& Sivanandam, 2006). In the case of resilient systems, classifying means labelling new, unseen input parameters (system description) based on the resilient systems examples defined by the experts for the existing cases (predefined classes).

Clustering is a technique used to place data elements (instances) into related groups without advanced knowledge of the group definitions. The goal of clustering is to distribute instances into groups, so that the degree of association is strong between members of the same cluster and weak between members of different clusters. Common methods for clustering are K-means, hierarchical clustering, DBSCAN (Density-Based Spatial Clustering of Applications with Noise) or CLARANS (Ng at al., 1994). In the case of the resilient systems application domain, clustering would identify and group objects described with input parameters with a similar behaviour without labelling (defining a resilient system).

Association deals with finding patterns where one event is connected to another event. It proceeds by elucidating this association in terms or rules. An association rule pertains to relationships between two disjoint item sets X and Y and can be given as: $X \Rightarrow Y$ (when X occurs, Y also occurs). One distinguishes between one-dimensional, multi-dimensional, multi-level and constraint-based association. Association is usually done using methods such as Apriori and Tertius (Flach& Lachiche, 2001). In the case of the resilient system application domain, association would assess the features (parameters) of the built environment that lead to the selection of a certain resilient system.

Depending on the domain and concrete problems, those techniques can be combined. Also some authors consider clustering as one technique of classification. An example is the k-nearest neighbour method (Brent, 1995), which will be introduced further in this work.

Regarding the learning process, data mining applications can be classified in two main areas (Hady, 2010) being:

- Unsupervised learning (Automated discovery of a previously unknown pattern)

In this case, the learning algorithm is given a collection of unlabelled data (no previous knowledge) and has to organise data following certain rules. This can be achieved by clustering data points, called examples, into natural groups based on a set of observable features.

- Supervised learning (Automated prediction)

In this case, the learning algorithm gets a collection of labelled instances and has to construct a model that can predict the output for any new example, based on a set of features that describe it.

In general, unsupervised learning describes the learning process for a clustering method, while supervised learning is related to classification.

As the problem of matching resilient systems can be understood as labelling different systems for a new set of parameters based on the existing (expert) knowledge, the classification methods/supervised learning have been selected as a basis for the mapping function given in Eq. 3-6.

<u>Data Mining Classification Methods</u>

Classification [involves the ordering of a set of objects described by high-dimensional data into small units, or classes that give a better understanding, control, interpretation and retrieval of the data. The main goal of classification is to assign an instance to a class depending on the values of the descriptive features] (Owotoki, Manojlovic et al., 2006).

Definition 1 (Classification): Given a finite set of training examples $(X_i, y_i)_{i=1}^{m}$, $X_i \subseteq X^{\infty}, y_i \in Y$ where X is the feature space, i.e. the set of all possible design criteria (key parameters), and $Y = \{y_1, y_2, ..., y_m\}$ is the set of the possible classes, Find a function

$$M : X^{\infty} \rightarrow Y$$
$$X \mapsto y = M(x)$$

with low approximation error on the training data as well as on the unseen examples (Owotoki, Manojlovic et al., 2006, Kemloh, 2008).

Classification can formally be defined as the learning of a target function M that maps each attribute set X to one of the class labels Y. The so built target function is known as the Classification Model. It can be used as a descriptive model that is an explanatory tool, to distinguish between different objects. It can also be used to predict the class label of unknown records. It is called a predictive model in the latter case. If the prediction of the class of new examples is more accurate than random guessing, the system has learned how to perform the classification task to some extent (Owotoki, Manojlovic et al., 2006).

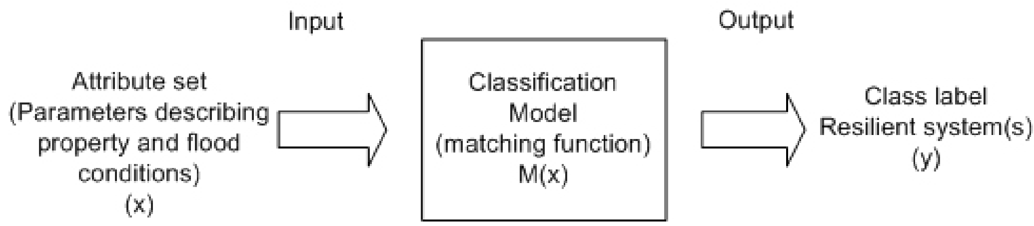

Figure 3-27 Classification in data mining

Deciding on which classification model to use is a major technical challenge (i.e. the model selection problem) which is still being studied in the machine learning[123] and the computational intelligence community. A wide range of classifiers is available, each with its strengths and weaknesses. Classifier performance depends greatly on the characteristics of the data to be classified. [There is no single classifier that works best on all given problems; this is also referred to as the “no free lunch” theorem (NFL)] (Whitley& Watson, 2005).

In general the selection of appropriate models is an iterative process. In the first step, different models are selected, based on the experience and expertise at hand to train each of these models with the training dataset. All trained, pre-selected models are then applied to the validation dataset and the model with the most satisfactory performance here is chosen for deployment in the real life application scenario. The performance measure could be the ability to correctly predict the class or in this particular domain, the resilient systems of the validation set. Other constraints which can influence the model selection are the clarity or comprehensibility of the results from the models, the compactness of the knowledge representation in the models etc. (Owotoki et al., 2006).

[123] Here, (supervised) machine learning is defined as a branch of computational intelligence that is [concerned with learning computer programs to automatically improve with experience through knowledge extraction from examples]. (Hady, 2010)

For the problem of selection of the appropriate flood resilient systems for the given conditions, representatives of the most frequently used data mining algorithms were analysed and pre-selected out of the group of all classifiers, reducing the span of the analysed options to the following classification methods:

1. Decision Trees (J48, Partial Decision Tree- PART)
2. Meta Learners/Boosters (LogitBoost, Logistic Model Tree- LMT)
3. Exemplar based learning (Nested and Non-Nested Generalised Exemplars NGE and NNGE resp.)
4. Artificial Neural Networks-ANN (Multilinear Perceptron Layer -MLP)

In this way a range of different classification principles is considered and their applicability for the concrete application domain can be tested. The reasons for their selection as well estimation on their performance for this concrete domain is given in the following text together with their description.

1. Decision Trees (DT): are one of the fundamental techniques used in data mining. It is a graphical representation of all possible outcomes and paths by which they may be reached (Berry& Browne, 2006). Berry& Browne, 2006 give a comprehensive description of the main characteristics of the DT model, which are here summarised. A DT can be used for categorical and continuous response variables. If the response variables are categorical, the DT is referred to as classification tree. A DT consists of a root and internal nodes, connected by branches, extending downwards from the root node until terminating in a leaf. The root node, as a first state of a DT, is assigned to all of the examples from the training data. Beginning at the root node, which by the convention is placed at the top of the decision tree diagram, attributes are tested at the decision node, with each possible outcome resulting in a branch. Each branch then leads either to another decision node or to a leaf node. If each node split into two parts, the DT is binary. An example is the node assessing whether the building has a basement or not (basement y/n). If each node split into three or more parts, the DT is referred to as non-binary (multi-branch). This would be a node classifying an example based on their external walls (external wall type: concrete, masonry, timber…). If an internal node cannot be further split, it becomes a terminal node. When a terminal node is reached, its stored value (content) is reached. An example of DT for the resilient built environment is depicted in Figure 3-28, depicting the application of 2 different leaves (flood resilience systems) based on 2 design criteria (decision nodes).
A decision tree is easy to interpret when its size is manageable and as such the size of the DT may be of greater importance than the splitting of variables. In terms of their design, [the DTs should not be either too small or too large] (Berry& Browne, 2006). Smaller trees are usually not exhaustive, i.e. do not describe the training data well, and as such the problem can occur for the new data sets. It the trees are too large, it can happen that some of the leaves contain too little data to make any dependable predictions when applied to the new data sets. For the successful application of DTs, the stability of decision tress has to be ensured. The instability of the DTs refers to the case when the same algorithm, applied to slightly different data,

produces a very different model. In order to make the trees more stable several methods have been developed and used such as bagging, arcing and boosting (Berry& Browne, 2006). For the scope of this work, boosting methods have been used and will be introduced in the section *Boosting*.

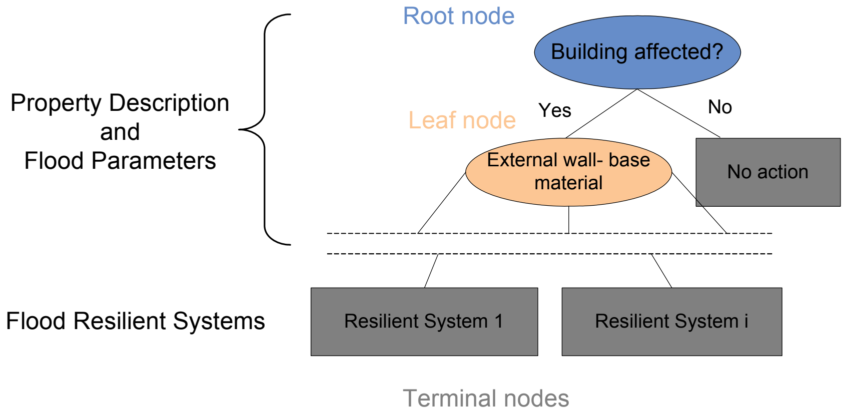

Figure 3-28 The structure of the Decision tree (DT) given for the example of resilient planning for the built environment

Mode of application: DTs do not require as much data as the other universal approximates such as neural networks and are well suited for high dimensional applications (Berry& Browne, 2006). They are also used for partitioning data and identifying local structures in small and large databases. They have two objectives: producing an accurate classifier and understanding the predictive structure of a problem. The important advantages of tree models are that they can be constructed efficiently and are easy to interpret (Landwehr et al., 2005). They are widely in use due to the clear representation of the relations between the input data and target outputs. They accept several types of variables as input parameters: nominal, ordinal and interval and as such are suitable for the domain of flood resilience planning. DTs are quite robust with respect to missing values and distribution assumptions regarding the inputs (Berry& Browne, 2006).

Decision Tree Algorithms: Implementation of DTs differs primarily in how the trees are constructed (modelled). In general, DT modelling consists of two parts: (1) creating the tree and (2) applying the tree to the database (Dunham, 2003). The DTs are created recursively, utilising different algorithms, the most frequently used being the basic one called Iterative Dichotomiser 3 (ID3) (Quinlan, 1990) and its further developments C4.5 and C5.0. The objective of all DT algorithms is to minimise the size of the tree, while maximising the accuracy of classification.

ID3: This algorithm uses the notion of entropy to build the "best tree" (Quinlan, 1990)

$$Entropy(S) = -\sum_{j=1}^{k} P(C_j)\log_2(P(C_j)) \quad \text{Eq. 3-8}$$

Where

$P(C_j) = \frac{freq(C_j)}{|S|}$ denotes the occurrence probability of the attribute C_j.

In the method of Quinlan, 1990, the algorithm takes all unused attributes and counts their entropy concerning test samples, finally choosing the attribute with the minimal entropy. It makes the node that contains that attribute. The algorithm is repeated until a leaf is reached or until the entropy reaches 0. It uses information gain as an evaluation test to rank attributes and to recursively build decision trees where at each node the attribute with the greatest gain among the attributes not yet considered in the path from the root is located. The information gain denotes the increase in information produced by partitioning the actual training data according to the candidate split Sv, where v is the number of possible values for the target attribute D.

$$G(D,S) = Entropy(S) - \sum_{v=1}^{n} \left| \frac{S_v}{S} \right| Entropy(S_v) \qquad \text{Eq. 3-9}$$

It has some shortcomings (e.g. cannot handle continuous attributes or data with missing attribute values) which are addressed by other algorithms like C4.5, which is an improved version of ID3 proposed by Quinlan.

C 4.5: A decision tree uses a graphical tree to represent knowledge (Quinlan, 1993). All leaves (end nodes) of the tree correspond to classes (resilient systems) whereas other nodes correspond to values of the non-class attributes (input parameters) (Shahnaz, 2006). A path from root to leaf corresponds to a classification rule. At every node in a decision tree a test is performed to find the leading attribute based on possible information gain. The node is then split according to the values of the leading attribute. This process of node-splitting continues until stopping criteria, which are well defined for the specific implementation of the decision tree, are met. C4.5’s improvement to ID3 includes the abilities to deal with numeric attributes, handle missing values, the improved leading attribute selection method and tree compactness due to post pruning. **J48** is the Weka[124] implementation of the C4.5 algorithm.

The Partial Decision Tree (PART) algorithm combines the ideas of C4.5. Unlike ID3, it does not perform global optimisation to produce accurate rules sets (Frank & Witten, 1998). The procedure of generating the partial trees is based upon the separate-and-conquer idea. It builds a rule, and then removes the instances covered by this rule. It then continues generating rules recursively for the remaining instances until none are left.

Application of DT for resilient planning

Following the research and experience on the decision trees and the corresponding literature, Decision Trees are usually a good choice for the weak classifier to use. They tend to divide the input space into nested regions in order to minimise the least square error. In addition, no

[124] The WEKA Platform will be introduced in Chapter 4.

transformation of a variable is necessary. In a system with a hierarchical structure the DTs tend to perform well, which qualifies them for the decision making on resilient systems.

2. Meta learners/Boosting:
Meta Learners are used in combination with other algorithms to improve their performances.
A popular class of meta learners are boosting algorithms (e.g. Li, 2010). The primary idea of boosting was to combine several weak[125] classifiers to improve the single classifier performance and has been introduced in the machine learning community at the beginning of the 1990's by Freund and Schapire 1996, 1997 (Lutz, 2007). Here, each classifier is dependent on the previous one, and focuses on the previous one's errors. The first practical boosting algorithm used for the classification problems is the AdaBoost (Friedman et al., 2000). It is a stepwise process, and in the first step the classifier is applied to the original data. Here equal weights are assigned to all instances in the training set. In the following step a weight is given to different classification results; the misclassified examples get more weight and the classifier is applied to a weighted version of the data. After the second classification, the same procedure is performed; [the weights of the misclassified observation of the second classifier are again increased and the classifier is once more applied. This process is repeated several times and the final classifier is a weighted majority vote among all the simple classifiers] (Lutz, 2007). AdaBoost can be considered to be an adaptive and aggregative algorithm. Adaptive means that subsequent classifiers focus on the misclassified examples from the previous ones. As AdaBoost contains the contribution of a subsequent classification it can be considered to be aggregative.
Mode of application: Booster algorithms have, in general, a wider scope of application that the single classifiers, as by definition the boosters improve the errors of the previous classifiers in a raw. Boosting trees have received a lot of attention and have been shown to outperform simple classification trees in many real-world domains, being considered one of the best 'off-the-shelf' classifiers[126] (Landwehr et al., 2005).Various authors showed that boosting algorithms can perform well in high dimensional classification problems (e.g. Lutz, 2007), which qualifies them for application in the resilient built environment domain. The main disadvantage is seen in a higher computational complexity than the single classifiers. An additional problem is seen in reduced interpretability of the aggregated classifiers in comparison to the single ones (Landwehr et al., 2005).

Boosting algorithms: There are various implementations or extensions of the AdaBoost algorithm, mostly implying decision trees as a base learner (classifier). Commonly used examples are LogitBoost and Logistic Model Tree (LMT) (e.g. Lutz, 2007).

LogitBoost: is an adaptation of the AdaBoost algorithm. It uses Newton steps for fitting a logistic model by maximum binomial likelihood, also known as the linear log exponential loss

[125] Weak means that they are slightly better than random guessing (Lutz, 2007).

[126] Learners that are not optimized with regard to a particular domain (Landwehr et al, 2005)

function (Lutz, 2007). The LogitBoost algorithm can be seen as a generalisation of the classical logistic regression, which models class probabilities $p_{i,k}$ as (Li, 2010):

$$p_{i,k} = \Pr(y_i = k | x_i) = \frac{e^{F_{i,k}(x_i)}}{\sum_{s=0}^{K-1} e^{F_{i,s}(x_i)}} \quad \text{Eq. 3-10}$$

Where:

training set is given as $\{y_i, x_i\}_{i=1}^{N}$

N- number of feature vectors (samples)

x_i- i^{th} feature in vector

$y_i \in \{0,1,2,...K-1\}$ is the i^{th} class label

$F^{(M)}(x) = \sum_{m=1}^{M} \rho_m h(x;a_m)$ - additive model that is a function of M terms and

$h(x;a_m)$ - base (weak) learner typical regression tree

ρ and a_m – parameters learned from data by maximum likelihood that is equivalent to minimising the negative log-likelihood loss

$L = \sum_{i=1}^{N} L_i$ and $L_i = -\sum_{k=0}^{K-1} r_{i,k} \log p_{i,k}$ where $r_{i,k} = 1$ if $y_i = k$ and $r_{i,k} = 0$ otherwise.

LogitBoost build aggregative model using a second order approximation of the loss function L.

The fitting is done iteratively by selecting in each iteration the basis function that is most parallel (most correlated) to the negative gradient of the loss function and adding them up successively.

This function changes linearly with the classification error and is therefore less sensitive to noise and outliers. The most popular choice for the base learner is trees. They can easily model different degrees of interaction (model complexities) and no variable transformations are needed. The number of iterations M is estimated by 10-fold cross-validation (CV[127]).

The regression functions used in the LogitBoost algorithm can only be fit to numeric attributes, so the nominal attributes must be converted into numeric ones in order to perform a classification process (Landwehr et al., 2005). Also, the regression functions that have to be fit in an iteration of LogitBoost cannot directly handle missing values. Commonly the mean (for numeric attributes) or the mode (for nominal attributes) of the values for each attribute are calculated and used to replace missing values in the training data.

Logistic Model Tree-LMT is an extension of the LogitBoost algorithm that combines the linear logistic regression and tree induction methods, taking advantage of their complementary advantages. [The former fits a simple (linear) model to the data, and the process of model fitting is quite stable, resulting in low variance but potentially high bias. The latter, on the other hand, exhibits low bias but often high variance: it searches a less restricted space of models, allowing it to capture nonlinear patterns in the data, but making it less stable

[127] will be introduced in the section on testing and validation model later in text.

and prone to overfitting.] (Landwehr et al., 2005). LMT consists of a standard decision tree structure with a logistic regression function in its leaves, as shown in Figure 3-29. Unlike the ordinary decision trees, the leaves don't have a class label but a regression function associated to them.

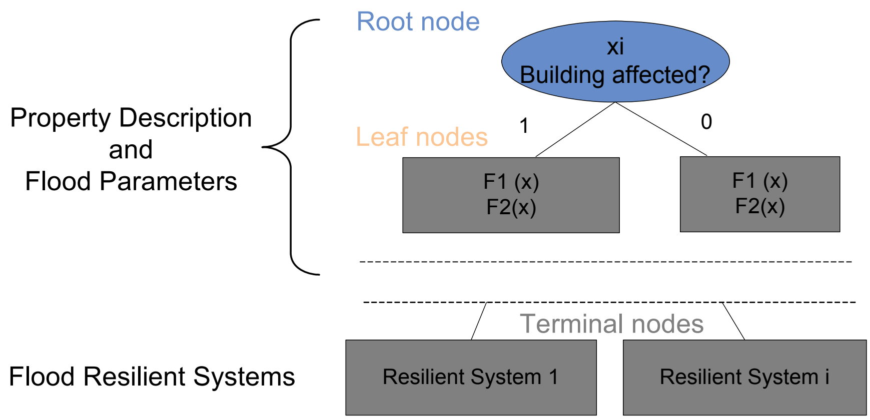

Figure 3-29 The structure of an LMT, where instead of class labels the logistic regression function are at leaves

3. Exemplar-based learning (generalised exemplars)

Exemplar based learning is a method [where every example is stored in memory without changing of representation.] (Salzberg, 1990). The set of examples then accumulate forming category definitions (e.g. the set of all examples described as '*building'* by one person form that person's definition of a '*building')*. However, this mere accumulation of new examples has some shortcomings, the main one being under-representation of large disjuncts[128] (Brent, 1995). This problem can be overcome by generalising instances stored in the database. This method is referred to as the method of generalised exemplars. [Generalised exemplars represent more than one of the original examples in the training set. In a geometric sense, if an instance database is a set of points in an n-dimensional problem space with n being the number of features in each example, a generalised exemplar is an n dimensional region covering a finite area of the problem space.] (Brent, 1995).

The learning process is performed in a way that the learner (in case of machine learning- the algorithm) compares new examples with the ones that exist in the database and looks for the most *similar* ones. This principle of similarity varies depending on different implementation of this method. In the case of the nearest neighbour method, the similarity metrics, which is inversely related to distance metrics, has been used (Salzberg, 1990). The new example is then classified according to the class of its nearest neighbour (Brent, 1995). As the problem of matching resilient systems to input parameters is rather parameter intensive, the variation k-nearest neighbour has been used for the scope of this work, where [a vote among the k nearest neighbours determines the class of the new example.] (Roy, 2003).

[128] Large disjuncts are likely to have only a few exemplars in the training set (Roy, 2003)

For numeric attributes the similarity is usually based on Euclidean distance, where each example is treated as a point in an n-dimensional feature space given as (i.a. Roy, 2003):

$$D_{EH} = W_H \sqrt{\sum_{i=1}^{m} W_i \left(\frac{E_i - H_i}{\max_i - \min_i}\right)^2} \quad \text{Eq. 3-11}$$

D_{EH} - Euclidean distance between the example E_i and exemplar H_i
E_i is the i^{th} feature value on the example
H_i is the i^{th} feature value on the exemplar
W_i - feature weight according to their importance
W_H- exemplar weight according to observed accuracy

Where:

$$E_i - H_i = \begin{cases} E_i - H_{upper}, \text{when}: E_i > H_{upper} \\ H_{lower} - E_i, \text{when}: E_i < H_{lower} \\ 0, \text{otherwise} \end{cases} \quad \text{Eq. 3-12}$$

where H_{upper} and H_{lower} are the boundaries of the hyperrectangles for this feature.
For symbolic attributes the distance is simplified to:

$E_i - H_i = 0$ if E_i is in the exemplar/hyperrectangle Eq. 3-13

$E_i - H_i = 1$ if E_i is not in the exemplar/hyperrectangle

Applying the Euclidean function all features are treated equally, and so share the same scale in feature space, this scale being linear along each axis. [As the distance is calculated over all parameters, this method should perform better if the exemplars in the database are clustered into denser regions. In that sense, this method behaves the same as conceptual clustering] (Fisher and Schlimmer, 1988). Applying this method, both numeric and symbolic features can be regarded. However, symbolic features are more problematic as they do not fit the Euclidean feature space model. To overcome this, similarity between symbolic features is determined by counting the matching features (Brent, 1995). [For domains containing a mixture of numeric and symbolic features the Euclidean distance function is adopted, with the distance between two symbolic values trivialised to zero if the features are the same, and one if they are not.] (Brent, 1995).

For solving the matching problem in flood resilient planning, the system will compare new parameters and system descriptions with the existing ones stored in the database (exemplars), and look for the most similar ones. Then, the resilient systems assigned to the most similar exemplar will be assigned to the new example.

Depending on how the examples are being regarded after calculating the Euclidian distance, the most frequently used k-nearest neighbours methods are given as follows:

- nested generalised exemplars (NGE)
- non nested generalised exemplars (NNGE)

Nested Generalized Exemplars Method (NGE)

Salzberg (1990) introduces a method of learning using nested generalised exemplars (NGE[129]). "Nested" means that exemplars may be completely contained within one another or overlap one another. The classification with the NGE algorithm has been illustrated in Figure 3-30a.

The learning process begins with a database containing a small number of seed exemplars. In the case of a new example, the NGE method classifies it by calculating the Euclidean distance from the existing exemplars in the database. Referring to Eq. 3-7, the distance (similarity) is measured between a new data point (example- E) and an exemplar already stored in the memory (a hyperrectangle (H) in E^n). Hyperrectangles represent each generalisation by an exemplar in which each feature value is replaced by either a range of values for a continuous-valued domain, or a list of possible values for a discrete-valued domain (Cost& Salzberg, 1993). The system computes a match score between E and H by measuring the Euclidean distance between the two objects. The distance function is equal to zero if the new example falls within a hyperrectangle. Because the NGE method allows hyperrectangles to nest and overlap, an example may fall within more than one hyperrectangle, which can bias the classification process. In this case the NGE method returns the class of the hyperrectangle covering the smallest area of feature space. The NGE method handles discrete features in a way in which the distance function is set to zero if two features match, and one if they do not.

The feature difference for the hyperrectangle is defined as given in Eq. 3-7, considering the exemplar weight W_H is given as (Cost& Salzberg, 1993):

$$W_H = \frac{p+n}{p} \qquad \text{Eq. 3-14}$$

p- number of correct predictions

n- number of incorrect predictions

Consequently, for all correct predictions the W_H function will have a value of 1. The noisy examples will gradually disappear as they are not correct for any of the examples and their value will be increasingly greater than 1. [In this way the weighting scheme penalises poorly

[129] NGE is a variation of a learning model, which was originally proposed as a model for human learning by Medin and Schaffer (1978) (Salzberg, 1991)

performing exemplars, including noisy examples. Also, in order to start with positive predictions, the NGE method considers only the exemplars that start well. The seed examples always have a value of zero (i.e. they predicted themselves correctly)] (Cost& Salzberg, 1993). Defined in this way, the W_H is a measure of reliability, or the probability of making the correct prediction for each exemplar.

Application of NGE for resilient planning

Transferring this method to the case of resilient planning means that the problem in n-dimensional space is to be solved, where n represents the number of all parameters and system descriptions defined in 3.3.2.1. However, considering the type of the parameters and system description that is a combination of nominal and numerical values (e.g. type of building and water height), it is questionable if this method will perform when matching the appropriate resilient systems to input parameters. Also, the problem of overrepresentation of small disjuncts can hinder well performance of this method for the given domain, especially in the initial learning phase (starting from seed examples). If the training sets are rather small, the small disjuncts have too high an impact on the classification performance. In this context, the NGE is introduced for the scope of this work in order to explore the possibility for the identification of the key parameters during the learning process where the algorithm recognises the key parameters relevant for the selection of the appropriate resilient system as introduced by the parameter Wi.

Non-Nested Generalized Exemplars Method (NNGE)

The Non-Nested Generalised Exemplars (NNGE) method is considered as an extension of the Nested Generalised Exemplars (NGE), addressing the problem of over-generalisation due to nesting and overlapping that is allowed in the NGE method. In the NNGE method, generalisation is being performed by merging exemplars, forming hyperrectangles that represent conjunctive rules with internal disjunction (Brent, 1995).

The NNGE method classifies new examples by determining the nearest neighbour in the exemplar/ hyperrectangle database using a variant of the Euclidean distance function (Brent, 1995).The feature difference for the hyperrectangles is calculated as given in Eq 3-7. Based on the calculated distance the algorithm selects the closest class. If any attribute is missing the NNGE method ignores it and it therefore does not contribute to the distance function. The final distance is divided by the number of existing attributes. The NNGE method is attractive where a more compact representation is needed in comparison to the widely used k-nearest neighbour (Brent, 1995).

For the learning process, the NNGE method also uses the dynamic weight function, but in contrast to the NGE method it modifies the weights only in the case of a wrong prediction (and not in case the system classifies correctly) and can be given as (Brent, 1995):

$$W_i' = \frac{n}{p+n} \qquad \text{Eq. 3-15}$$

Application of NGE for resilient planning

The principle of both methods (NGe and NNGE) is illustrated in Figure 3-30. Here a 2-dimensional features space has been used (k=2), defined by the parameters water depth (numerical) and type of basement (categorical). The existing feature space is subdivided by 3 hyperrectangles (HYP 1-3), which are created based on the existing exemplars in the database. They correspond to a set of measures (or part of resilient systems) that are to be applied in the case that the examples fall into the boundaries of the hyperrectangles.

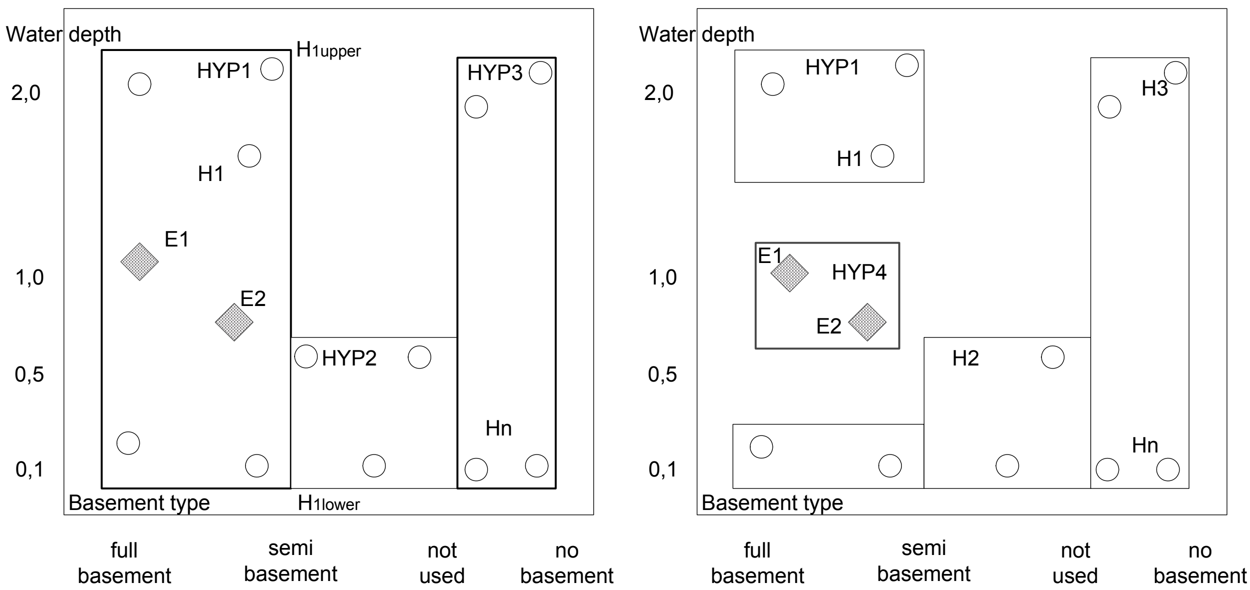

Figure 3-30 The principle of: a) NGE, b) NNGE Algorithms; classification of examples E1 and E2 based on the exemplars H_i stored in the database

The classification of new objects is based on the calculation of the Euclidean distance as given in Eq 3-7 in the case of both algorithms NGE and NNGE. However in the case of NGE the new objects are classified within the rectangular HYP1, as they fall into its boundaries. On the contrary, the NNGE method considers overrepresentation of the hyperrectangle HYP1 and classifies the new examples E1 and E2 as a separate group dividing the HYP 1 into 2 hyperrectangles, avoiding overlapping and nesting. Here it also must be mentioned that the Euclidean distance for the parameter 1 as a numerical value (water depth) will be calculated by applying the Eq 3-6, whereby the parameter 2 as a categorical parameter will have a Boolean function as described in Eq 3-10.

4. Artificial Neural Networks (ANN):

Artificial neural networks (ANN) map the input parameters to the output resilient systems by mimicking the information processing capabilities at the centre of intelligence in humans and other animals – the nervous system (Owotoki, Manojlovic et al., 2006). The biological neuron receives impulses (information x) through numerous branches (called dendrites). The information is then weighted in synapses (junctions between dendrites and the axon branch) and further aggregated and superposed in the axon hillock. When the aggregated signal in the axon exceeds a certain threshold value, an output signal is generated and transmitted to the connecting neurons (He& Xu, 2009). The information processing of a biological neuron is given in Figure 3-31.

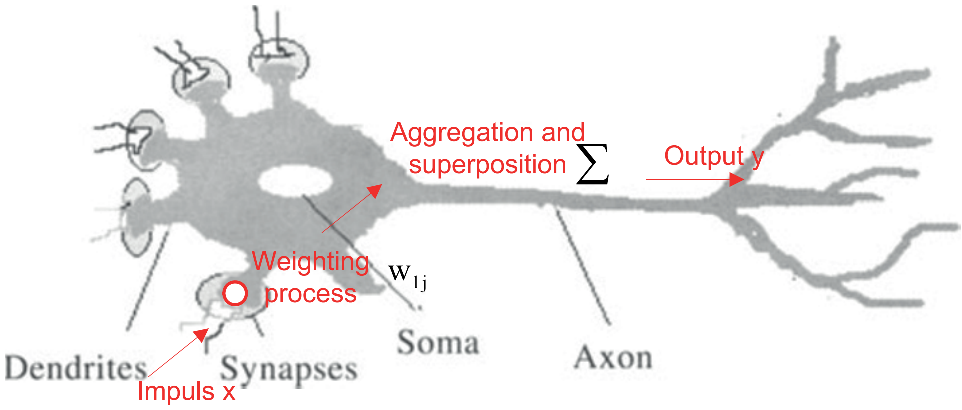

Figure 3-31 Information processing by a biological neuron (adapted from He and Xu, 2009)

The ANN algorithms are based on the same principle. A general scheme of ANN system composed of one neuron is given in Figure 3-32.

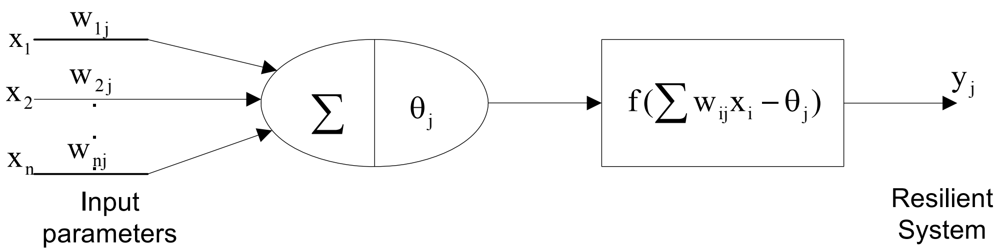

Figure 3-32 Artificial neuron model (adapted from He&Xu, 2009)

Following the He&Xu, 2009, an input signal, consisting of an array of numbers/ parameters x_i is introduced to the input layer of processing units or nodes. The generated signals can be amplified or inhibited through weights, w_i, associated with each connection of the observed neuron. The nodes in the adjacent layer act as summation devices for the weighted incoming signals. The incoming signal is transformed into an output signal, y_j, within the processing units by passing it through a threshold function f. The learning in the interconnected neurons (or perceptrons) is stored in the synaptic weights between these neurons.

In a general case, an ANN consists of:

- input x_i (i=1,2,…,n) of n external neurons to a neuron j
- connection weights $w_{ii,}$ between the i^{th} external neuron and the neuron j
- activation threshold θ of the neuron j
- activation function $f(\sum w_{ij}x_i - \theta_j)$,
- output y_j

The connection between input and output is given as

$$y_i = f(\sum_{i=1}^{n} w_{ij}x_i - \theta_j) \quad \text{Eq. 3-16}$$

Where the activation function can take different forms. The simplest one is the step function given as:

$$\theta(x) = \begin{cases} 0, x > 0 \\ 1, \text{otherwise} \end{cases} \qquad \text{Eq. 3-17}$$

A continuous function enables smooth shareholding, the most commonly used being the sigmoid function that can take values between 0 and 1 and is given as:

$$\theta(x) = \frac{1}{1+e^{-x}} \qquad \text{Eq. 3-18}$$

If the outputs of a network are to be interpretable as a probability of the data falling into the corresponding category, the softmax function is applied and is defined as:

$$\theta(x) = \frac{e^{(w_i x_i)}}{\sum_0^n e^{(w_n x_n)}} \qquad \text{Eq. 3-19}$$

The model with one neuron describes the simplest form of an ANN algorithm. For solving concrete problems, the ANN is usually composed of several neurons according to a particular topological structure; the most frequently used being the feed forward neural network and feedback neural network (recurrent). They describe the way the information is being processed within the ANN algorithm. The first one has only forward information transfer without feedback, whereby the latter includes the reverse transfer information in addition to the forward processing. In that sense, the feedback methods can be adapted to past inputs (Boden, 2001).

Mode of application: ANN algorithms are usually used for the problems without analytical mathematical solutions or if their derivation is rather complex. When ANN algorithms are used for classification the threshold function is used as classification criteria (He& Xu, 2009). In that sense they can be applied to solve the problem of the selection of an appropriate resilient system and are considered for this work. However, the ANN model required a high amount of data for training from the very beginning, which can obstruct its performance in the case that expert knowledge on resilient systems is not or partly available.

ANN Algorithms: The ANN algorithms are differentiated based on the learning synapses and consequently the main algorithms fall into one of the main groups being *feedforward* or *back propagation* learning algorithms (He& Xu, 2009). The most commonly used algorithm implies a topology composed of several layers, as simple perceptrons are very limited in their representational capabilities. For example, they cannot represent more complex functions including nonlinear separable models such as XOR (exclusive OR). This can be overcome by including additional, hidden layers in between the input layer and the output layer in the network (Seung, 2002). This model is referred to as a multilayer perceptron model (MLP). By virtue of its universal function approximation property, MLP plays a fundamental role in neural computation and has found its application in many different areas including pattern recognition, image processing and intelligent control (Seung, 2002). MLP can be implemented based on information processing procedures, feedforward and backpropagation. For the scope of this work, an MLP with back propagation learning has been considered, exploring the potential for improvement in the initial training results throughout the process. It is proven that a MLP can approximate any function by converging its weights using back propagation learning (Owotoki, Manojlovic et al., 2006). As this domain can lack data from the very beginning, it is to assess the performance of the backpropagated model to overcome this deficiency.

Multilayer Perceptron with Back Propagation Learning (MLP):

The multilayer perceptron model (MLP) has a layered structure consisting of an input layer which itself consists of sensory nodes, one or more hidden layers of computational nodes, and an output layer that calculates the outputs of the network (e.g. Bullinaria, 2010), as illustrated in Figure 3-33.

Neurons in a hidden layer that do not receive inputs from the input layer are connected to the neurons in the previous hidden layer. Hence, the output of a hidden neuron is sent to the next layer which may either be another hidden layer or the output layer. Finally, the output layer sends its output to the environment. (Braspenning et al., 1995).

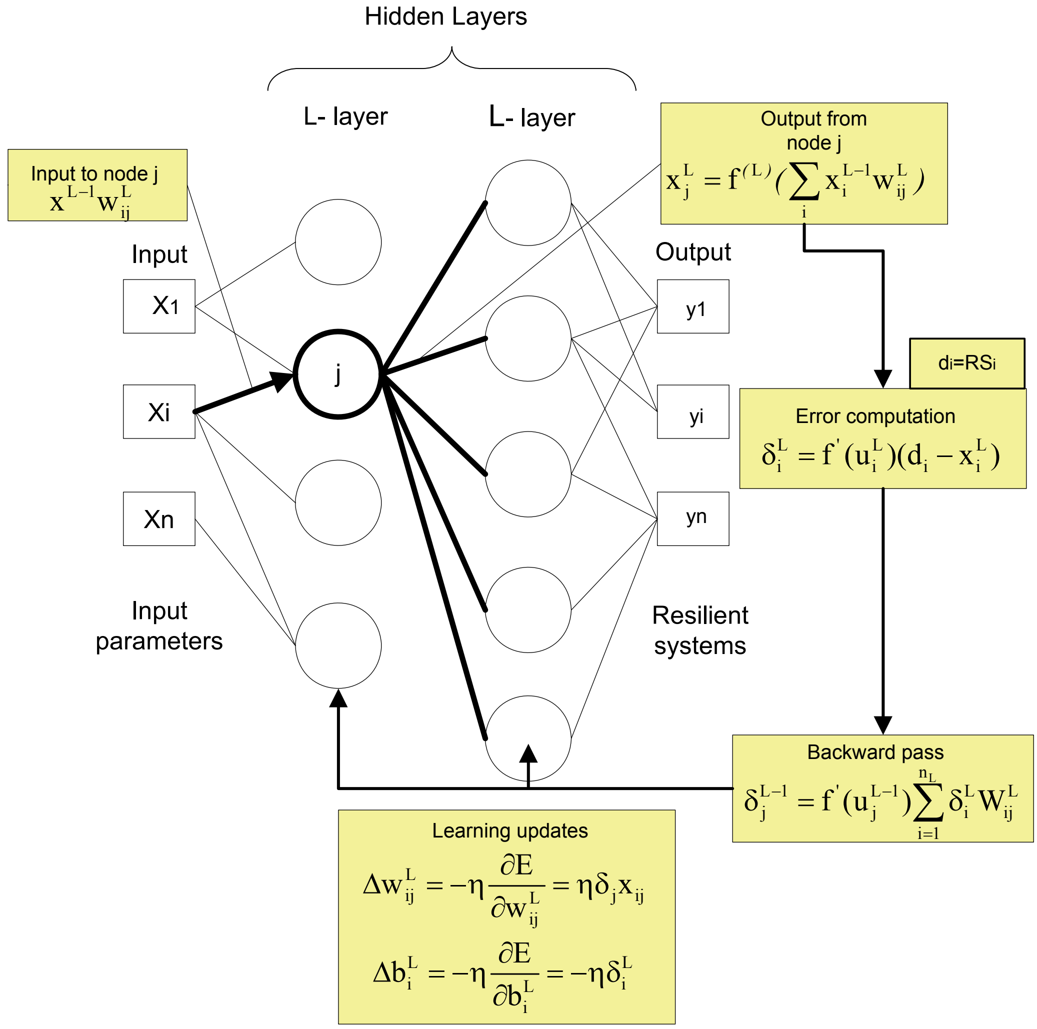

Figure 3-33 Artificial neuron model (based on Bullinaria, 2010 and Seung, 2002)

Applying the backpropagation algorithm, [the objective is to change the weights w and biases b so that the actual output x^L becomes closer to the desired output d, considering the number L of synapses and L+1 number of neuron layers. Hense, the training of an MLP with back propagation learning consists of the following steps] (Seung, 2002):

1. Forward pass: The input vector x^0 is transformed into the output vector x^L by evaluating the equation

$$x_i^L = f(u_i^L) = f\left(\sum_{j=1}^{n_{L-1}} w_{ij}^L x_j^{L-1} + b_i^L\right) \quad \text{Eq. 3-20}$$

2. Error computation: The difference between the desired output d and actual output x^L is computed as:

$$\delta_i^L = f'(u_i^L)(d_i - x_i^L) \quad \text{Eq. 3-21}$$

3. Backward pass; The error signal at the output unit is propagated backwards through the entire network by evaluating:

$$\delta_j^{L-1} = f'(u_j^{L-1})\sum_{i=1}^{n_L} \delta_i^L W_{ij}^L \quad \text{Eq. 3-22}$$

4. Learning updates; the synaptic weights and bias are updated using the results of the forward and backward passes. In that phase, neurons apply an iterative process to the number of inputs variables to adjust the weights of the network in order to optimally fit the sample data on which this training is performed.

At the beginning of the training the output neurons are activated equally. As the training process advances, one neuron is activated more than the others, depending on the feedback and error function that is being propagated along the network.

There are different methods to define the error function, the most commonly used is the cost function (Bullinaria, 2010) that measures the squared error between the desired and actual output and is given as:

$$E(w,b) = \frac{1}{2}\sum_{i=1}^{x_L} (d_i - x_i^L)^2 \quad \text{Eq. 3-23}$$

Where x^L is a function of w and b arises through the equations of the forward pass.

The single weights are then updated according to the rule:

$$\Delta w_{ij}^L = -\eta \frac{\partial E}{\partial w_{ij}^L} = \eta \delta_j x_{ij} \quad \text{Eq. 3-24}$$

$$\Delta b_i^L = -\eta \frac{\partial E}{\partial b_i^L} = -\eta \delta_i^L \quad \text{Eq. 3-25}$$

Where η is defined as the learning rate. On one hand, increasing the learning rate speeds up the adaptation process, but on the other hand may cause the system to become unstable (Braspenning at al., 1995).
δ_j represents the error responsibility for a particular error belonging to the node j and is given as:

$$\delta_j = \begin{cases} y_j(1-y_j)(d_j - y_j) \\ y_j(1-y_j)\sum_{downstream} w_{jk}\delta_j \end{cases} \qquad \text{Eq. 3-26}$$

The first function of the Eq. 3-26 refers to the output layer nodes, whereby the latter is given for hidden layer nodes (Sumathi& Sivanandam, 2006).
$\sum_{downstream} w_{jk}\delta_j$ refers to the weighted sum of error responsibilities for the nodes downstream form the particular hidden later node. For this calculation, the attribute values are to be normalised i.e. assigned the values between 0 and 1.

Choosing appropriate activation cost functions depends on the concrete domain and data mining process to be performed, as well as the number of layers and output classes. The problem of the selection of an appropriate resilient system is a classification problem where various authors (e.g. Bulliaria, 2010) recommend the application the of cost function as given in Eq. 3-21 and softimax or sigomond functions for output and hidden activations respectively.

Extracting knowledge from data to deliver technically appropriate resilient systems for the built environment based on the given parameters

The algorithms presented in this chapter can perform differently for different data sets. In that sense, the $M_{optimal}$ function mainly depends on the type and size of the domain as well as on the number of attributes and the available data. Decision trees are expected to perform better in hierarchical domains (Berry& Browne, 2006), whereby the ANN algorithms perform well when used for larger datasets. The potential is seen in the booster algorithms where the combination of two algorithms can improve the performance of the week(er) classifier.
In the domain of the flood resilient systems for the built environment, the classification algorithms as explained in the section *Data Mining Classification Methods* match the flood and sociotechnical parameters as given in Table 3-9 and Table 3-34 to the flood resilient systems for the built environment given in Table 3-5. The classification process depicted in Figure 3-27 applied to the flood resilient built environment domain can be visualised as given in Figure 3-34.
For the implementation process it should be tested which of the models perform best for the given dataset i.e. for the given number of datasets and the key attributes. A voting system should be introduced to ensure that the results of the model that perform best for the given conditions is considered and its result delivered to the user. The procedure is given in Chapter 4- Implementation.

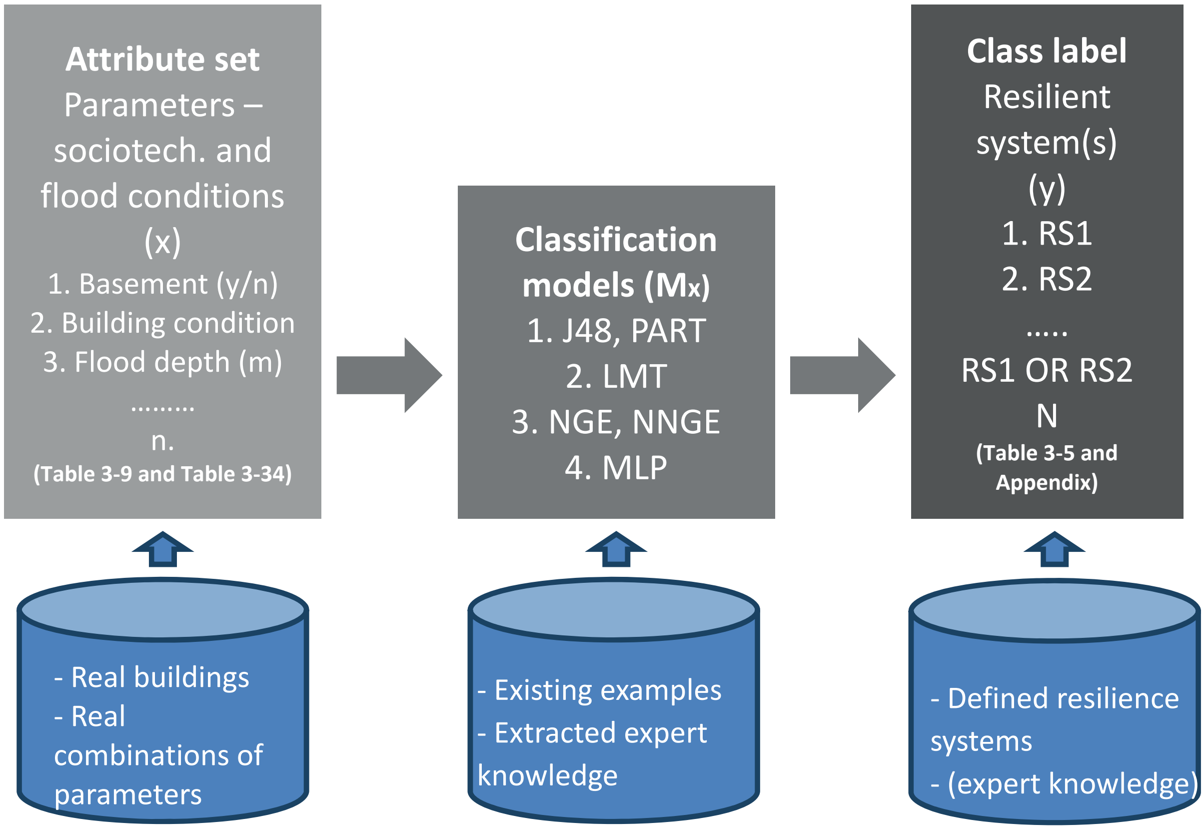

Figure 3-34 The classification process for the resilient built environment and the corresponding data sources

It is also to mention that this is a very attribute intensive process and the key attributes should be identified that decisively contribute to the derivaiton of the $M_{optimal}$ function. The extracting knowledge from data can be optimised by finding balance between the key attributes, level of detail of the defined resilience systems and effort for collecting and preparing datasets.
The datasets can be prepared for two basic cases:

- Generic cases- different combinations of sociotechnical and paramerers are considered which do not have a specific reference to any region, but should cover possible general cases. The source of data in this case can be the based on the existing buildings (real) or real combinations of socioeconomic parameters (synthetic datasets). The associated classes are generated from the existing examples or extracted from the experts' knowledge.

- Specific cases - the datasets can be derived considering the constraines by flood resilient systems of the urban system on a larger scale for a particular case (refer to Figure 3-14). In that case, the resilient systems applied to the single properties have to fit in the resilient systems at the neighbourhood/district level. This concept can also be connected to building restrictions or codes and are to be managed in cooperation with the relevant authorities. The datasets are generated utilising the specific data of the studied area (sociotechnical and flood system).

Testing and Validation Methods of data mining algorithms (Model Evaluation)

Classification accuracy (CA) of a rule set is the ratio of the number of correctly classified objects from the test set and all objects in the test set (e.g. Owotoki, 2007).

$$CA = \frac{Correct\ \Pr edictedVal\ ues}{TotalNumbe\ rOf\ \Pr edictions} \qquad \text{Eq. 3-27}$$

For the scope of this work, two frequently used tests have been considered as evaluation models being (Owotoki, 2007):
SPLIT method: It consists of building two independent data sets which will be used as well as a training and test set. A proportion of 2/3 is usually reasonable for the training set and the rest, i.e. 1/3, is used for testing. After training the test set is used to validate the model by comparing the output from the data to the known class of the test set example. The accuracy of such a comparison is the predictive accuracy of the model. This method is suitable for large datasets (with a large number of samples).
k- Fold Cross validation is used for datasets with a moderate size. The data set is divided into k-subsamples, k-1 samples are used for training and the remaining sample is used for testing. This is repeated k-times, k-fold cross validated.

The classification accuracy is usually the main argument whether to choose a model or not. This is a good stopping criterion while training a model because it yields a fairly reliable estimate of the error on future data. The error function is to be defined for the given domain and conditions.

Summary of the Steps of the Knowledge Discovery/Data Mining Process utilising CI

Data mining is usually considered as one step in the large knowledge discovery process (KDP). The KDP can be divided into the following nine steps, which are also taken as the basis for the work performed within this Thesis (Fayad et al., 1996, Brahman&Anand, 1994):

1. **Defining and understanding the application domain**. This step includes learning the relevant prior knowledge and the goals of the end user of the discovered knowledge.
2. **Creating a target data set.** Here the data miner selects a subset of variables (attributes) and data points (examples) that will be used to perform discovery tasks. This step usually includes querying the existing data to select the desired subset.
3. **Data cleaning and pre-processing**. This step consists of removing outliers, dealing with noise and missing values in the data, and accounting for time sequence information and known changes.

4. **Data reduction and projection**. This step consists of finding useful attributes by applying dimension reduction and transformation methods, and finding invariant representation of the data.
5. **Choosing the data mining task**. Here the data miner matches the goals defined in Step 1 with a particular DM method, such as classification, regression, clustering, etc.
6. **Choosing the data mining algorithm (model selection)**. The data miner selects methods to search for patterns in the data and decides which models and parameters of the methods used may be appropriate. Model selection is a problem in statistics, machine-learning, and data mining. Given training data consisting of input-output pairs, a model is built to predict the output from the input, usually by fitting adjustable parameters. The selection of an optimal model, which should perform best on test data, is the object of the model selection process.
7. **Data mining**. This step generates patterns in a particular representational form, such as classification rules, decision trees, regression models, trends, etc. The successful application of data mining requires data preprocessing, i.e. dimensionality reduction, cleaning, noise/outlier removal, post-processing (understandability, summary, presentation of a good understanding of problem domains and domain expertise)
8. **Interpreting mined patterns**. Here the analyst performs a visualisation of the extracted patterns and models, and a visualisation of the data based on the extracted models.
9. **Consolidating discovered knowledge**. The final step consists of incorporating the discovered knowledge into the performance system, and documenting and reporting it to the interested parties. This step may also include checking and resolving potential conflicts with previously believed knowledge.

These steps applied to the case of flood resilient planning considered for the scope of this work are given in Table 3-35.

Table 3-35 Data mining process applied for matching the input parameters to the technically appropriate resilient systems on the property level

KDP process	Domain: Flood resilient planning on property level
Defining and understanding the application domain	Flood resilient planning on property level. The domain and the problems are described in section 3.2.
Creating a target data set	Selection of key parameters and system description indicators and summarising them under input parameters as described in section 3.3.2.1. Collecting data and extracting knowledge from experts on appropriate resilient systems as given in section “Extracting knowledge from data”.

Data cleaning and pre-processing	Out of the created data set, the noise data are to be removed. As the experts create the seed datasets, the noise is expected to be low.
Data reduction and projection	Selection and discussion of the key parameters that influence the decision for the flood resilient system.
Choosing the data mining task	For the purpose of solving the matching of resilient systems to input parameters, the classification method has been selected as given in 3.3.2.2.
Choosing the data mining algorithm (model selection)	The classification methods have been selected as presented in 3.3.2.2.
Data mining	The process of matching the appropriate resilient system utilising CI algorithms will be performed utilising the algorithms applied within the WEKA software (http://sourceforge.net/projects/weka/). The implementation process is described in Chapter 4 and the application on selected datasets in Chapter 5.
Interpreting mined patterns	For each dataset and methods the results are to be analysed and interpreted. The accuracy of the models for given datasets is to be analysed and the applicability of selected algorithms for solving given problems will be discussed. It is given in Chapters 6 and 7.
Consolidating discovered knowledge	The discovered knowledge is incorporated into the system. It is shown in section 4.2.

Data mining and computational intelligence represent a power tool to extract knowledge and recognise patterns from previous experiences and data. The possibility that the system learns from previous experiences and existing knowledge makes it attractive for solving the problem of mapping the flood resilient system to given conditions, as the process can start even without having an exhaustive set of rules. This initial set can be used as a seed for further learning process. Still, the main drawbacks of this method must be considered. They can be summarised as:

- lack of real data, which can lead to the problem of small disjuncts in datasets
- wrong selection of the appropriate data mining method based on the domain specific features

In general, the limitations of data mining are primarily data or personnel related, rather than technology related (e.g. Seifert, 2004). Successful data mining requires skilled technical and analytical specialists who can structure the analysis and interpret the output that is created. The potential of single computational algorithms has been discussed earlier in the text.

3.3.2.3 Option Analysis and Decision Making

The analysis of options is devoted to assessing alternative resilient options (flood resilient systems) and their evaluation according to different criteria. Those criteria, the procedures for decision making, are based on the cost-benefit analysis (CBA) or multi criteria analysis (MCA).

Cost Benefit Analysis (CBA)

For the cost benefit analysis decisions are made based on the optimal ratio of the costs of the investment (i.e. measures) to benefits (reduction in damage potential). Here, all costs are expressed in monetary terms, and are adjusted for the time value of money. For the scope of this work, a simplified method based on the LAWA, KVR Leitlinie 2005 guidelines, primarily developed for large scale investments in water resources management, has been used.

Cost assessment:
In order to make a fair comparison between different FReS, both cost groups should be analysed:

- Direct costs
- Indirect costs

According to LAWA, 2005 costs of measures can be split into cost of investment, operational costs and costs of reinvestment depending on the timing of investment and frequency.

For monetary assessment of the different scenarios it is not enough to only consider the one-off expenses (investment costs), but also the ongoing costs during the discounted time of the analysed measures. Those operating costs can be split into:

- costs of personnel
- material costs
- energy costs

In case flood barriers are elements of the selected FReS, the following costs should also be taken into account (Garvin et al., 2013):

- Operating costs/Training costs (are related to the required product specific activities like transport, mounting, dismounting and cleaning. The training costs are related to mounting and dismounting of the product, including personnel).
- Maintenance costs (required maintenance/ replacement schedule of the chosen product).
- Storage costs (depend on required storage conditions as well as required storage area and volume. The latter can be expressed by the term Storage-Volume and Storage-Surface per installed product length and height)

In order to compare the benefit and cost values in the CBA, costs should be expressed in annual values for the discounted period.

Annuity factor (KFAKR)

$$\text{KFAKR}\ (\text{p},\text{n}) = (\frac{p \times (1+p)^n}{(1+p)^n - 1}) \qquad \text{Eq. 3-28}$$

Where:
p - interest rate [%]
n - discounting period [a]

The KVR guideline, 2005 recommends the interest rate of 3%. The discounted period is dependent on the type of measures and can be found in the literature (e.g. Rath, 1995). For the discounting year the tables published in Rath, 1995 and LAWA, 2005 have been used and is assigned to the value of 100 years. This discounting period can also be applied for demountable elements and joints as well as pumps, as they are relatively seldom used and their maintenance is covered through the operating costs.

$$annualCosts(CostOfInvestment) = GrossCostOfInvestment \times KFAKR \qquad \text{Eq. 3-29}$$

The costs of maintenance are estimated to be 1% of gross investment costs. Additionally the expenses for logistics during the flood event (in case of a pump, mounting of flood barriers) can be considered.
Those costs are expressed in net values; for the real values VAT should be added to it.

$$AnnualCosts\ (Operational) = 1\% \times GrossCostOfInvestment \qquad \text{Eq. 3-30}$$

$$TotalAnnualCosts = annualCosts(CostOfInvestment) + AnnualCosts(Operational) \qquad \text{Eq. 3-31}$$

A list of the measures and the associated costs (mainly investment costs) is given in Appendix 3.4.

Benefit assessment (damage reduction)

Benefit is calculated as a potential reduction in flood damage due to the application of flood resilience measures. In order to put the benefit in the relation with the associated costs, the potential reduction in the expected damage has to be expressed at the annual level.

Expected annual flood damage (EAD) is computed as the integral of the damage probability function (e.g. Neubert et al. 2009, Zevenbergen et al., 2009):

$$EAD = \int D(x)dP(x) \qquad \text{Eq. 3-32}$$

Where
EAD is the annual expected damage
$D(x)$ is the flood damage caused by flood depth x, [€/event of the probability p]
$P(x)$ is the probability of flood x, [1/a]

The probability distribution functions $P(x)$ of a flood are a result of a probability assessment, whereby the corresponding damage $D(x)$ is calculated based on the damage assessment procedure given in section 3.3.1.
For a practical calculation of the annual damage, the integral can be represented by a sum of single damage assessment over a finite time interval as:

$$EAD = \sum_{i=1}^{n} S_{[i]} \times \Delta P_i \qquad [€/a] \qquad \text{Eq. 3-33}$$

Where:
EAD - expected annual damage [€/a]
ΔP_i - is the difference between the probabilities of the flood events P_i and P_{i+1} [1/a]
n - time interval [a]
$D_{[i]}$- damage of the flood event i[€]

The events should be selected to cover the whole span of cases when damage occurs, beginning with, for example, 5 year flood and further including the events for which the flood maps i.e. flood parameters are available (20,50,100 year flood events). Some authors define a certain number of events to be considered for the calculation of EAD (e.g. Chen et al., 2014 at least 3 events to calculate the EAD).

For assessing the benefit of applied resilient measures, the damage assessment is performed for both, the case without and with the measures. This difference represents the benefit for the resilience plan and is given as:

$$\bar{B} = \bar{D}_{without} - \bar{D}_{with} \qquad \text{Eq. 3-34}$$

Where
$\bar{B}$ - benefit of the deployed flood resilience measures
$\bar{D}_{without}$ - EAD for the case without resilient measures
$\bar{D}_{wih}$ - EAD for the case with resilient measures

Benefit Cost Factor (BCF):

The benefit-cost ratio is calculated as the ratio of the benefits and costs on the annual level (e.g. Neubert et al. 2009).

$$BCF = \frac{Benefit(\bar{B})}{AnnualCostOfMeasures(C)} \quad \text{Eq. 3-35}$$

Table 3-36 Benefit-Cost-Factor

Cost Benefit Ratio	Description
<1	Unfavourable, the costs of measures are higher than the annual damage that can be avoided by its application
>1	Favourable, the costs of the measures are lower than the avoidance of the potential annual damage to the building
=1	The costs and benefit are balanced

The CBA presented above can be applied in the case that the probability of occurrence is known, which is not always the case. In that case, the cost benefit analysis can be performed by assessing damage for the flood depths of different scenarios and relating them to the costs of different technically applicable resilient plans.

The ratio obtained in a CBA is based on pure monetary benefit and investments. However for decision making for the flood resilient built environment involves other aspects such as reliability and aesthetics, which are rather neglected within the CBA.

Life Cycle Assessment (LCA) and life expectancy of the built environment components

A cost benefit analysis performed in this way considers only the benefit obtained in the actual point of time, without anticipating the future benefits. In that sense the temporal component of resilience and resilient performance are not considered. As the city can be understood as a living organism with its own urban dynamics (Zevenbergen et al., 2008), it is necessary to analyse the life cycle of the built environment and life expectancy of constructions.

All elements of the urban fabric need periodic upgrades. Buildings have lifetimes ranging from 30-300 years, but the exterior surface usually changes every 200 years (Zevenbergen et al., 2008).

Life expectancy of components in the assessment of whole life costing plays an important role (Harvey, 2001). For example, for softwood windows, the average typical life reaches 35 years, varying from an average minimum of 20 years up to an average maximum of 55 years. The potential factors for early deterioration such as exposure level, local air quality or timber quality are to be considered when assessing the whole life costing of softwood windows.

Various national agencies assess those parameters for different building types. For example, BS 7543, 2003 reports that the basic causes of deterioration in buildings are due to the action of weathering, biological infestation, stress, chemical interactions, physical interactions and

normal use. BS 7453, 2003 also states that deterioration will be accelerated by: factors such as poor design/detailing inappropriate selection of material, component for intended use or quality of material or component used.
The aspect of LCA will not be analysed in detail within the scope of this work. It is tackled to achieve a more objective and realistic presentation of the costs and benefits as well as the aspect of the adaptive resilient capacity and the ways it can be integrated in the long term urban planning.

Multi Criteria Analysis (MCA)

MCA is a decision-making procedure developed for complex problems including qualitative and/or quantitative aspects of the problem in the decision-making process. It [describes any structured approach used to determine overall preferences among alternative options, where the options accomplish several objectives.][130] In MCA, the objectives are specified and corresponding attributes or indicators are identified. The output of the analysis the following options are possible: a single most preferred option, ranked options, short list of options for further appraisal, or characterization of acceptable or unacceptable possibilities[130].

By making a decision on the resilience plan for a specific case, the user confronts different criteria and creates scenarios that have to be processed applying MCA. Each criterion can be assigned a specific weight that shows its importance relative to other criteria under consideration. For decision making based on multi criteria value assignment for different criteria, there are meanwhile a large number of techniques and methods applied. For the scope of this work, the method of *ranking and rating*[131] has been considered. Here, each criterion is assigned a value showing its rank in the pool of considered criteria (e.g. 1-100). This is then multiplied with the impact factor of each option regarding the given criteria.

The overall scope of a considered option equals the sum of the single products of impact and rank as is given as:

$$S_A = \sum_{i=1}^{n} r_i \times i_i \qquad \text{Eq. 3-36}$$

S- overall score of the option A
r_i - ranking of the criteria i
i_i - impact of the option A on the criteria i

In the decision making process for the resilient built environment, the main criteria for assessment of the acceptability of the suggested measures can be summarised as economical, technical and aesthetic and social. For decisions regarding the resilient built environment, the criteria are given in individual levels as depicted in Table 3-37. Those criteria are to be

[130] http://unfccc.int/ (last accessed: January, 2015)

[131] more complex methods, such as goal programming or analytic hierarchy process have been beyond the scope of this work.

evaluated for each technically appropriate resilient system assessed within the decision making process.

Table 3-37 Criteria analysis for resilience adaptation plans for the built environment

<table>
<tr><th>Category</th><th colspan="4">Criteria</th></tr>
<tr><td>I) Technical aspects and reliability</td><td colspan="2">1. Assessed during the technical selection process given in section 3.3.2.2</td><td colspan="2">2. Performance of the system during a flood event- e.g. effort for logistics</td></tr>
<tr><td>II) Cost effectiveness</td><td>1. Costs of investment</td><td>2. Maintenance costs</td><td colspan="2">3. Cost-Benefit ratio</td></tr>
<tr><td>III) Social and Aesthetic</td><td>1. Changes in the building layout</td><td>2. Impact on lifestyle</td><td>3. Influence on the privacy, right of use</td><td>4. Preserv. of cultural heritage</td></tr>
</table>

3.3.3 Implementation and Assessment of Resilience Performance

3.3.3.1 Implementation

After the decision for a resilience plan for the built environment has been made, the adopted resilient system is to be implemented. It starts with the specific planning that can involve professional stakeholders or can be directly implemented by dwellers. In both cases, the performance of the applied system has to be assessed and evaluated. For the implementation phase it is of high importance that the resilient technology is properly implemented, especially in the case of sealing measures for basements against flood water under hydrostatic pressure (e.g. water proof concrete). The quality of implementation should be guaranteed by standards and codes such as DafStb, 2004 for the design and implementation of waterproof concrete. Regular maintenance should generally be provided for the implemented measures (e.g. flood products for openings or perimeter flood barriers). This maintenance must be considered by assessing the performance of the measures.

3.3.3.2 Assessment of resilience performance

The decision making process developed in this work and illustrated in Figure 3-15 foresees that the ***resilience performance*** of the adopted resilience systems is assessed during and after a flood event for given conditions (flood typology and system description) addressing the main components of restorative and adaptive resilience. The total assessment of the resilient performance is given based on the proxy indicators defined for different resilient capacities as given in Table 3-4.

3.3.3.3 Feedback loops

Feedback loops in this process of decision making developed in this work have the objectives of ensuring constant improvement of the decision making process and the selection of an appropriate flood resilient system for the given conditions. As presented in section 3.3.2.2, learning aspects have already been included in the technical selection process, which correspond to the "inner feedback loop" referred to in Figure 3-15. In this loop, based on the results delivered by the system, the feedback from experts and private stakeholders is given based on their applicability for the specific case, which is then used for the training of algorithms. Here it is regarded whether the resilient systems and technology suggested are technically appropriate for the given case.

"The outer feedback loop" refers to improvement of the decision making process based on the assessment of the resilience performance of the selected system according to the parameters listed in Table 3-4.

Also, there are different types of feedback depending on the timing of the assessment and user groups as well as the aspects of measures to be assessed. In terms of timing, flood resilient systems can be assessed during and after flood events, whereby the main types of user groups are experts and dwellers. While the experts assess the technical aspect of the resilient systems and technologies applied, dwellers assess for example the social aspects of the selected measures in terms of their impact to the lifestyle or their logistical suitability during a flood event.

Finally, the resilient system at the property scale send a feedback to the elements of an urban systems at larger scales as shown in Figure 3-14 containing the information about the performance of a resilient system. This step is important as the adopted resilient systems can have an impact to the overall- holistic system that in Figure 3-1 and introduced in section 3.1. The key issues to be addressed are given as:

1. How the suggested FReS is in line with the planning procedures and strategies at higher scales?
2. What is the hydraulic impact of the suggested systems on the flow and flood conditions in the area?

Therefore, those feedback parameters given above can feed into the holistic model introduced in section 3.1. that has an objective to assess the overall risk propagation based on the behaviour of different agents.

The main feedback information depending on timing and user type is given in Table 3-38.

Table 3-38 Types of feedback describing resilience performance of measures per user type

Resilience performance proxies		Type of users delivering feedback		Feedback loop
		Experts	Dwellers	
I	Threshold value of the design flood	√	√	Outer
Restorative resilience:				
Recovery Capacity:				
I	Time to equilibrium (return to the acceptable state)	√	√	Outer
II	Resources and effort needed for reaching the equilibrium	√	√	Outer
III	Level of permanency and impact of the (tangible) damage occurred	√	√	Outer
IV	Damage evolution	√	√	Outer
Coping capacity:				
V	Flexibility of the contingency measures	√	√	Outer
VI	Continuous supply of the services	√	√	Outer
VII	Sensitivity to malfunctioning (criticality)	√	√	Outer
Adaptive Resilience:				
VIII	Transformability of the system	√		Outer
Further parameters of the decision making process as given in Figure 3-14				
II-2	Technical suitability of selected RS	√		Inner
II-3	CBA	√		Inner/ Outer
II-3	MCA	√		Outer
	Multi scale analysis	√		External (to the elements of urban system on larger scales)

3.3.4 Data collection and data management

Designing flood resilient built environment in the context of the holistic risk assessment is a data intensive process as shown in sections 3.3.1 and 3.3.2. In order to perform the decision making process as given in Figure 3-15, it is necessary to collect required data in the level of detail required by the single modules and make them available throughout the decision making process. The following requirements have been assessed as decisive for the efficient data collection procedure for resilient planning:

1. enable collection of data by making use of all relevant data sources (experts, dwellers, site visits)
2. avoid double work – e.g. data to be collected for damage assessment and data mining make use of the same data types, which are to be differently pre processed
3. optimise data collection procedure; for the damage assessment method as developed in this work, the building element is given as the basic unit for damage assessment. In order to avoid overlapping and double collection and storage of data (especially interior walls or doors as they are shared by different rooms), the collection method should enable topological representation of the collected elements.

Further, the collected data should be stored and organised in a way that the single modules of the decision making process can easily and to the sufficient level of detail access the required data.

Therefore, the following considerations on data collection and management have been set:

I. In order to collect data from all relevant sources, different modes of collection should be considered such as web-based systems or interviews.

II. Data collection module is to be designed in a way to be understandable for dwellers and tailored to their interests. For achieving it, the dwellers should be involved in the design process.

III. A database should be used for data storage and administration.

3.4 Capacity building of stakeholders focusing on dwellers[132]

Capacity building of stakeholders should support the effective participation of stakeholders within their role in FRM and should accompany all the facets of the decision making process presented in section 3.3. It is a long-term learning process bringing stakeholders from the state of no or little awareness and knowledge to the state where they can be proactive players. Also, capacity building requires the ability to think in systems (e.g. Tippett& Griffits, 2007), paving the road for the holistic approach. Considering the role of dwellers given in Table 3-2, the key tasks to build their capacity are defined as:

1. Raising flood hazard/ risk awareness
2. Delivering relevant information to the dwellers for accepting their own role in FRM
3. Delivering required knowledge/ expertise required for taking proactive actions
4. Supporting and motivating dwellers to take actions (proactive behaviour)

Raising hazard/risk awareness (1) implies improvement of the perception of a flood as a phenomenon in terms of its extent, intensity and the consequences it can cause following the definition of risk as given in Eq. 3-1. This is the crucial step for understanding the necessity for action and getting motivation for further participation in the capacity building process. *Relevant information supporting the acceptance of own role* (2) is related to understanding

[132] Some parts of this chapter have been published in Vojinovic (2015) as the author's contribution.

the complexity of FRM in terms of its hydrological, but also socio-economic aspects, including the responsibilities of different stakeholder groups. Here the scope of the individual role has to be defined and made transparent and understandable to dwellers. *The relevant expertise/knowledge (3)* should emphasise the scope and strategies of flood risk management in general and focus on the measures for protecting individual properties. *Supporting pro-active behaviour (4)* is related to motivating the stakeholders to take actions.

In more detail, the addressed topics are given in Table 3-39.

Table 3-39 The topics reflecting relevant expertise/knowledge to be delivered to dwellers:

Nr	Topic
1	Complexity of flood risk management o Flood as a natural phenomenon o Modelling of floods including uncertainties o Strategies of flood risk management, paradigm shift o Multidisciplinarity and roles of stakeholders
2	Flood Risk Assessment ▪ Flood hazard ▪ Flood vulnerability ▪ Flood risk
3	Flood resilient measures and systems ▪ Safety chain of resilience
4	Resilient built environment (wet proofing, dry proofing) and resilient systems

Defined in this way, the capacity building process has a strong *learning* component[133], imposing a question of how this learning process is being performed and how the theoretical didactic concept can support it in its full extent. Here the existing learning theories serve as a source of verified strategies, tactics and techniques for defining the capacity building strategies.

In modern psychology the learning process is described by three main theories being *Behaviourism*, *Cognitivism* and *Constructivism*[134] (e.g. Baumgartner& Payr, 1999, Zimbardo, 1996). They differ in the way they describe the learning process itself, motivation for learning, the factors influencing it or what the role of learners and teacher is.

The *behaviouristic* approach defines learning when a proper response follows the presentation of an environmental stimulus. The key elements are the stimulus, the response and the associations between the two (Ertmer& Newby, 1993). The processes in the mind are not

[133] This issue has been discussed in detail in section 2.3.2

[134] Within this work only an overview of the theories is given as they are the source of verified strategies and techniques to perform the-learning process including the one to be performed within capacity building. A detailed analysis and study on those theories was beyond the scope of this work and the references for further reading are given.

considered, as they are understood as being a "black box" in the sense that response to stimulus can be observed quantitatively, independently of processes occurring in the mind. The learner is reactive to conditions in the environment and the environmental conditions are given priority when assessing the dominant influencing factor that shapes the learning process. The methods to be applied based on this theoretical view should focus on arranging environmental conditions for the stimulation of correct stimulus-response pairs, or rewarding even after successful completion of intermediate phases. It should be applied for mastering early learning steps before progressing to more complex levels of performance (Ertmer& Newby, 1993). The main criticism related to this theoretical approach is related to its inability to adequately explain the acquisition of higher-level skills (e.g. problem solving), causing its limited application in comprehensive education.

The *cognitivistic* view defines learning as [a mental activity that is equated with discrete changes between states of knowledge] (Ertmer& Newby, 1993). Cognitive theories stress the acquisition of knowledge and internal mental structures. They focus on how information is processed (received, stored, organised and retrieved) by the mind. According to the cognitivistic view the learner is an active participant in the process and the learning goal is to make the learner understand how to apply knowledge in different contexts. It means that the learner has to understand the rules and interdependences among single elements or facts in order to acquire relevant knowledge. The methods to be applied should serve for supporting this process by simplification or standardisation. Information has to be structured or sequence indicating interdependences among single chunks of facts. Also, the learning environment should be created that allows the application of previously acquired knowledge (e.g. use of relevant examples, analogies). The main criticisms of this approach are related to the difficulty to transfer the acquired knowledge into practice, as it is based on the reproduction of knowledge without giving any relation to its practical applicability (e.g. Tergan, 2004, cited in Pryadko, 2005)

According to the *constructivistic* view, learning can be defined as a process of creating meaning from experience (Bednar et al., 1991). It means that what we know of the world results from our own interpretations of our experiences (e.g. Baumgartner& Payr, 1999). In the learning process the learner is an active participant where both the learner and environmental factors are critical, as it is the specific interaction between them that creates knowledge. According to this approach the learning methods must include all three of these crucial factors: 1. activity (practice), 2. concept (knowledge) and 3. context (culture) (e.g. Brown et al., 1989, Tergan, 2004).

They should involve authentic tasks anchored in meaningful context and relevant for the topic being taught. Learners are encouraged to construct their own understandings, which have to be validated, usually in social networks i.e. by explaining individual views, ideas or concepts to others in the group (promoted by social cognitivism). This theoretical approach, although it has received increasing attention in a number of different disciplines (e.g. adult vocational trainings), it is still subjected to criticism. It is mostly related to the openness and self-determined nature of the learning process, which can be misleading, especially for novel learners (Tergan, 2004).

An overview of those main learning theories with their main characteristics has been depicted in Table 3-40.

Table 3-40 Overview of the main aspect of the main learning theories (adapted from Baumgartner& Payr, 1999, Ertmer& Newby, 1993)

Aspects/ Theories	Behaviourism	Cognitivism	Constructivism
Learning process	-Relates learning to proper relation between stimulus and associated response. - Learning is accomplished when a proper response is demonstrated Focus is set to correct responses. - The mind as a "black box"	- Learning is equated with discrete changes between states of knowledge. - Focus on conceptualisation of process - Learning is a mental activity that leads up to a response - Addresses how information is processed by the mind. - Focus on what the learners know and how they come to acquire it (Jonassen, 1991)	- Creating meaning from previous experience (Bednar et al., 1991) - mind filters the output to produce its own unique reality (Jonassen, 1991) - Reality is not discovered, but created (Siebert, 1997) - Perception, thinking, sensing and acting are not linear, but cyclic processes (Siebert, 1997)
Learner is	Reactive to conditions in the environment	Active participant Individual that processes environmental cues and cannot be controlled by them (e.g. Tulodzecki, 2000).	Active participant
Teacher is	Authority	Tutor	Coach
Learning goals	Correct input-output relation “Knowing what”	Making learner understand how to apply knowledge in different contexts “Knowing how”	Being able to react properly in a given situation “ Reflection in action”
Factors influencing learning	Environmental conditions are given priority.	Environmental conditions are given priority.	Both learner and environmental factors
Methods	- rewarding, even after reaching intermediate steps in the learning process e.g. Baumgartner& Payr, 1999). - arranging environment.	- Explaining complex form of learning (e.g. reasoning, problem-solving) where defined facts and rules are applied in unfamiliar situations (knowing how) - Simplification and standardisation (e.g.	- involvement of practice, knowledge and culture (e.g. Brown et al., 1989, Tergan, 2004,). - involvement in authentic tasks anchored in meaningful context - learners are encouraged

	conditions for stimulation of correct stimulus-response pairs - emphasis of mastering early learning steps	structuring, sequencing chunking of information) - Creation of learning environments that allow application of previous acquired knowledge (e.g. use of examples, analogies)	to construct their own understanding, which is then to be validated - promotes collaboration with others (in order to better articulate own understanding, ideas)
Main criticism	- acquisition of higher level skills are hardly explained (e.g. problem solving) - the state of the mind and the underlying ability of the learners is neglected	- low possibilities to transfer the knowledge into practice (e.g. Tergan, 2004)	Free, self-determined learning can suffer lack of orientation, inexperience of the learner especially in the initial learning phases
Main representatives	Pavlov I. (1849 - 1936), Watson (1878-1958) Thorndike E.L. (1874 - 1949), Skinner B. F. (1904 - 1990)	Brunner , Lewin K. (1890 - 1947), Kahneman D. (1934-), Tversky A. H. (1937-1996)	Piaget J. (1896-1980)

Although those theories represent different views and approaches, the border between them is not always obvious. Ertmer& Newby, 1993 concluded that [strategies promoted by different learning theories overlap terms of the level of cognitive processing required by the defined task and level of learner's task knowledge]. The common ground of those strategies is that learning is a continuous and complex process and it is constantly changing, both in nature and diversity, as it progresses (Shuell, 1990). In that sense, it would be meaningful to expose the learners to different approaches along different points of the learning continuum, which would then enable acquiring different competences. The pace and sequences of different learning methods should change as the learning process advances. Based on the main features of the presented model given above, the behaviouristic approach can serve for learning how to recognise and apply the standard rules, facts and operations of the topic being taught. Cognitive strategies are useful in teaching problem solving, where defined rules and facts are applied for developing and testing the created knowledge (e.g. Ertmer& Newby, 1993). Constructivistic methods are convenient for the improvement of social competences through discussions or dialog.

Analysing the main phases/requirements of capacity building it can be observed that learning is composed of different phases where the learners *acquire (grasp)* information, knowledge or experience (e.g. raising risk awareness) and phases where this acquired information or experience is being processed or transformed (e.g. acceptance of own role). *Behaviouristic* methods can serve for initiating learning motivation in raising risk awareness. It is achieved by establishing simple relations between the intensity of flooding, exposure and consequences, where the learner can even be allowed to vary one of the components and observe changes on the others. *Cognitivistic* methods can be applied to deliver relevant information and expertise. For example the necessity for paradigm change can be argued by development of logical sequences of information. Also, the considerable amount of information and knowledge related to non-structural measures can be structured and chunked, clearly indicating the interdependences of those chunks (e.g. safety chain of resilience). *Constructivistic* methods are necessary when addressing so called problems that have no single or one-way solutions (e.g. Ertmer& Newby, 1993). It is a case when selecting appropriate resilient strategies for the built environment on the property level. Here social contacts and discussion with the other learners and experts are crucial for being able to articulate and argue for individual views and understandings as well as understand the complexity of the problem.

This diversity of the learning methods for addressing stakeholders calls for different didactic means for delivering the knowledge. Face-to-face sessions are necessary for learning about concrete problems and discussions on flood resilient planning. In that sense face-to-face sessions support social contacts and the exchange of opinions involving more constructivistic learning methods. Face to face methods are also used to address concrete problems and examples, supporting active participation of learners, where they should construct their own understanding out of examples, as given in constructivistic theory. Still, understanding of processes and the whole span of resilience measures cannot be performed within single sessions and requires repetition which is supported by autodidactic methods. The autodidactic methods are merely based on concepts based on behaviouristic and cognitivistic learning methods. Learning in capacity building should become *active*, where the "knowledge is directly experienced, constructed, acted upon, tested, or revised by the learner (Thompson et al., 1989).

Summarising the main features of the capacity building as a learning process based on the desk study presented in this section, the following requirements/ postulates are set for developing concepts for capacity building of dwellers in urban flood risk management:

- It is a continuous process that encompasses skills of different nature for which diverse tools and methods are required taking advantage of different learning theories
- It is a holistic process, single elements and tools have to be integrated into a sound capacity building strategy; the single elements should support the four phases as given in the definition of capacity building of stakeholders
- It is an active learning process

Those prerequisites are supported by the Experiential Learning Theory- ELT (e.g. Kolb et al., 1999). The ELT attempts to express the holistic nature of the learning process, taking the learners outside of their comfort zone which then causes the learner to extend their current knowledge, skills and abilities. Also, ELT considers learning to be a continuous process where for the learning intervention to be successfully integrated into the learners cognitive scheme, [the learning cycle should "touch all the bases – feeling, reflecting, thinking, and acting – in a recursive process that is appropriate to the learning situation and what is being learned] (Kolb et al., 1999). This theory is referred to as "experiential", emphasising the role of experience in the learning process. Experiential learning engages the learner at a more personal level by addressing the needs and underlying ability of the individual.

In order to support the capacity building process of stakeholders, the experiential learning concept based on the didactic principle of Kolb& Fry, 1975 has been adopted. It divides the learning process into four steps, ranging from concrete experience (1) through reflection (2) followed by the abstraction of the concepts learnt (3), to testing the acquainted knowledge in new situations (4).

Here, knowledge is continuously gained through both personal and environmental experiences (Merriam et al., 2007). The single steps together form a closed learning circle and can be applied to any selected stakeholder group. Kolb& Fry, 1975 argue that the learning cycle can begin at any one of the four points - and that it should be approached as a continuous spiral. However, it is suggested that the learning process often begins with a person carrying out a particular action and then seeing the effect of the action in this situation. This learning cycle demonstrates that it is not sufficient to have an experience in order to learn. For achieving the optimal efficiency of the learning process, it should employ the whole learning cycle. Although this learning process can be generalised, the pace of learning and time required for single phases is individual, a fact which has to be considered when developing learning concepts for single groups.

Transferring this learning process to capacity building of private stakeholders means that they have to experience floods (ph1), reflect on their own flood situation and accept that they have to be active (ph2), and obtain relevant knowledge/expertise (ph3) to the level that they are able to apply it on a concrete case (ph4) as shown in Figure 3-35.

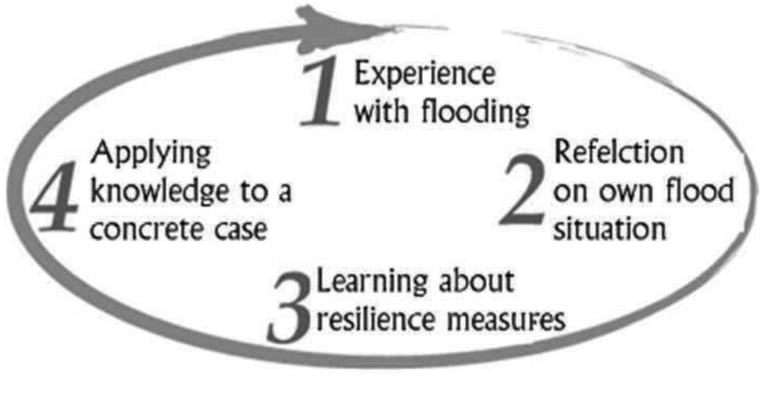

Figure 3-35 Methodological framework for building capacity of stakeholders based on Kolb's cycle (adapted from Kolb& Fry, 1975)

This learning activity is a process, whose pace and intensity depend on the initial knowledge and capacity of the learners, as well as the motivation or time available for learning. As such, it has to be made available and easy accessible to the targeted group. Regular, repeated ways to inform about different types of measures for the resilient built environment are stated as one of the key recommendations for the successful process of capacity building (e.g. Steinführer, 2009, Grothman& Reusswig, 2006).

The capacity building strategy presented in Figure 3-35 challenges the learners to learn new skills, new attitudes or even entirely new ways of thinking as reflected in the paradigm shift in flood management. It supposes a wide range of skills and knowledge that has to be built applying different tools and methods. New concepts for raising hazard/risk awareness and supporting autodidactic learning are crucial for improving the overall capacity building process.

3.4.1 New methods for capacity building of private stakeholders

3.4.1.1 Concept for raising hazard/risk awareness

The capacity building process depicted in Figure 3-35 starts with evoking or initiating a concrete flood experience with the aim of raising the hazard and risk awareness of stakeholders and motivates them for further action. For developing concepts for raising hazards/risk awareness it is crucial to understand the processes and mechanisms shaping the perception[135] and consequently awareness of flood hazard and risk. Due to its complexity, it is difficult to develop a general theory of risk perception (Weichselgartner, 2001). Modern research on risk and risk perception of natural hazards derives experience and methodologies from different disciplines such as psychology, sociology and disaster management, bringing it under a multidisciplinary banner. Risk as a notion, which can quantified based on the probability of occurrence and corresponding consequences as a rule differs from the perceived risk by individuals and as such becoming psychological, cultural, or social issue. Consequently, apart from formal normative approaches that intent to find a generally acceptable and quantifiable risk following the definition given in Eq. 3-1 (Weichselgartner, 2001), the approaches and theories are developed that involve individual or socio-cultural perception of risk and analyse factors that are decisive for its formation. Depending on their nature, the *psychological* and *socio-cultural* disciplines are devoted to analyse and quantify those factors[136]. The common ground of both of them is that they shift the focus of risk analysis from the objective, calculable risk of the normative approaches to individual, perceived or constructed risk that is of a subjective nature which is dependent on their mental structures or social environment. In that sense those approaches address the acceptance of risk rather than its assessments. Referring to its nature and dominant mechanisms, Sjöberg, 2000 evaluated risk perception to be [all about thoughts, beliefs and constructs].

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[135] The author acknowledges numerous discussions on the term *perception* (e.g. Sjöberg, 1997, Weichselgartner, 2001, Oltedal et al, 2004) that are questioning the justification of using this term in the context of risk. Still this term is used throughout this work referring to [the individual organization of stimuli relating to an extreme event or a human adjustment] (White 1974 taken from Plapp, 2003).

[136] This work focuses on the basic two methods. Other ones s such as trust-oriented concepts (Slovic 1993, Siegrist 2000), the mental models approach (Lave & Lave 1991), or concepts to include associations are taken out of consideration within this work.

The psychological approach addresses risk and risk perception in the context of psychological- cognitive processes. Here, [the psychophysical scaling and multivariate analysis are applied in order to produce quantitative representations or “cognitive maps” of risk attitudes and perceptions] (Slovic, 1987). The concept of “risk” means different things to different people and can be considered as individual, or subjective. It is often referred to as intuitive, to emphasise that the process *of* hazard and risk perception often occurs unconsciously (Plapp, 2003, Plapp& Werner, 2006). Risk is dependent on various factors, the main ones being initial knowledge, experience (familiarity), control and system of values (Slovic, 1987).

There are nine general types of factors which influence the subjective risk judgement as summarised in Table 3-41 (Fishhoff et al., 2000).

Table 3-41 Main criteria shaping subjective risk judgement (Fishhoff et al., 2000)

	Criteria	Description
1	voluntariness of risk	- do people face the risk voluntarily
2	immediacy of effect	- to what extent is the risk of death immediate…
3	knowledge about the risk	-by the persons who are exposed to the potentially-hazardous risk source
4	knowledge about the risk in science	-to what extent is the risk known and researched in science
5	control over the risk	-to which extent can this risk be controlled personally or by others
6	novelty, i.e.	-whether the risks are new and novel or old and familiar ones
7	chronic/ catastrophic	- whether it is a risk that may kill people one at a time (chronic risk) or a risk that can kill a large number of people at once (catastrophic),
8	common/ dread, i.e.	- whether people have learned to live with and can think about the risk reasonably and calmly, or is it a risk that people have great dread for, on the level of a gut reaction
9	severity of consequences	- how many people and their properties are exposed to this hazard?

Experience and emotions play a decisive role in the perception of hazards and risk (e.g. Plapp, 2003, Slovic, 1987). When perceiving hazard and risk, [the individual develops a set of strategies or rules that help them to reduce the complex tasks of assessing of probabilities and predicting values to simpler judgmental operations. This sets mental strategies that people employ in order to make sense out of an uncertain world and are referred to as ***heuristics***] (Slovic, 1987). Tversky& Kahnemann, 1974 define a set of those heuristics that shape the risk perception of natural hazards as:

- *Representativeness*- judging probabilities on the basis of how much they are similar to the available data
- *Availability*- the events that are still in the memory i.e. that are cognitively available are assessed more probable than the unknown ones
- *Anchoring* - the probability of an event is adjusted to the available information or understood information

They are mostly based on cognitive processes and previous experience (Mushal, 1997).
Although these rules are valid in some circumstances, the individual perception of risk is often distorted and in certain cases leads to systematic errors or cognitive biases, which can have a serious impact on risk perception (Slovic, 1987, Tversky& Kahnemann, 1974).
The most relevant cognitive biases for the research of natural hazards are summarised in Table 3-42.

Table 3-42 Cognitive bias in perception of hazard/risk (adapted from Musahl, 1997, Tversky& Kahnemenn, 1974 to contain the examples relevant for flood risk perception)

Cognitive Bias:		Description
Representativeness (Similarity)		
1	Insensitivity to prior probability of outcomes	The information about probability is ignored and judgment is created based only on the similarity criteria
2	Insensitivity to sample size	Ignorance about statistical behaviour of different sample sizes i.e. their deviations from normal distribution depending on the sample size when judging
3	Misconceptions of chance	Overestimation of reliability when judging *“Last flood events were rather mild, most probably the next ones will be the same”*
4	Insensitivity to predictability (“Halo effect”)	If the situation has been positive in the past, it is judged to continue in this way in the future *“Last time we were not affected, next time will be the same”*
5	Illusion of validity	As output the constellation that fits best to input is judged as most probable *“It is not raining hard; there is no chance that we’ll get flooded!”*
6	Misconceptions of regression	The tendency to judge future events based on the principle “regression to medium” “*Last flood event was terrible, the next one will be much milder”* or vice versa
Availability		
8	Bias due to retrievability of instances	For judgement of a size of a class, it appears bigger in case that more single cases are known *“Flooding is not an issue in our area; there has been only one (known) flood event in many years”*

9	Bias due to effectiveness of a search set	Judging the frequency of an event based on the availability on the context or search set
10	Bias of imaginability	For assessment of frequency of an event, the judgement is determined by the ease it can be derived from certain rules. The answer to "*How probable and severe do you estimate flood in your area?"* depends on the individual imagination
11	Illusory correlation	Finding correlations between two events only because of their appearance at the same time
Anchoring		
12	Insufficient adjustment	The judgement is dependant (or adjusted) on the starting point (information given before) *To assess the flood probability in own area, a person will base his judgment on the values provided by an external person (e.g. greater than 30%).*
13	Bias in probability judgements	Underestimation of conjunctive[137] and overestimation of disjunctive[138] events

Psychological approaches emphasise the importance of experience and cognitive processes for forming risk perception. However, this approach neglects the influence of the social and political environment, which is stated as a main deficiency of this theory (as stated in e.g. Markau, 2003).

In the socio-cultural theory the risk is regarded as a societal construct, where the *cultural understanding* shapes the perception of hazard and risk (Plapp, 2003, Markau, 2003). In order to assess how people construct risk, it is necessary to analyse how they deal with risks in their social environment and daily situations. Based on this constructed risk, the individuals define their course of action. For the definition of risk perception it is important to analyse so called ways of life that are defined as a combination of social environment and cultural bias (Thompson et al., 1999 taken from Plapp, 2003). [Among all possible risks, those selected for worry or dismissal are functional in the sense that they strengthen one of these ways of life and weaken the others.] (Wildavsky, 1991).

Risk is here a multidimensional concept that comprises subjective "quantitative" assessments based on experience and information as well as perceived or attributed "qualitative" risk characteristics within a certain social, cultural and historical context (Plapp, 2003).

An overview of those main approaches introduced in Plapp, 2013 to risk and risk perception has been summarised in Table 3-43.

[137] conjunctive events- events dependant on each other

[138] disjunctive events- events independent of each other

Table 3-43 Overview of the main approaches to risk and risk perception

Aspects/ Theories	Formal normative	Psychological (-metric)	Socio-Cultural
View	objective	subjective	subjective
Expression of risk	R=probability x consequence	Based on Intuitive judgement	Risk as societal construct
Parameters shaping perception	No influence of perception	Experience, knowledge, control, system of values (Jungemann, Slovic, 1987)	Cultural understanding (e.g. Plapp, 2003)
Bias	-	See Table 3-42	
Criticism	No influence of personal perception or acceptance of risk	- missing dimensions (e.g. neglects social context of perception) - data collection methods one-sided (no external validation)	- not adequately operationalised - low importance of culture adherence in reality (Oltedal, 2004) - difficult to apply to the individual level (Plapp, 2003)

There is still no generally accepted method for the assessment of risk perception (e.g. Markau, 2003). In natural hazard research, they are usually combined (e.g. Plapp, 2003) in order to assess all relevant factors that are shaping the perception of the studied natural hazard. Those outcomes serve as a basis for the definition of strategies for raising flood awareness. In general, personal risk must be distinguished from general risk (Plapp, 2003).

Those basic theories on hazard perception and risk awareness help us to study the perception of the hazard and risk of natural hazards or floods. In general they emphasise the role of cognitive processes and emotions when judging hazard and risk. The concept for raising hazard and risk awareness has to break the cognitive biases by confronting the individuals with facts and appeal to their emotions by removing the feeling that they can easily control the situation (Musahl, 1997, 2009[139]). Also, low flood risk awareness is attributed to a lack of information and invisibility of the threat (e.g. Burningham et al., 2008). Interactivity is crucial in motivating the learner and plays an important role in the design of tools (e.g. Niegeman, 2003, Issing& Strzebkowski, 2002). It should be used for increasing the visibility of the threat.

In order to raise hazard/risk awareness the following decisive elements or postulates have been developed in this work (referred to as *Postulates of raising flood awareness)*:

1. *Delivering facts*
2. *Appealing to emotions for creation of personal experience*
3. *Integration of single elements and the learners through interactive actions*

[139] Personal communication 5th October, 2009

1. Delivering facts: This is performed by means of information material in a textual or graphical form. The main tools are the flood maps. Based on flood maps[140] the dwellers can assess their own hazard and risk. Within the concept of raising flood awareness, this information is to be *visualised* or presented in a way that can be easily understood by the stakeholders. The advantages of GIS based software are taken advantage of.

2. Appealing to emotions: The process of raising flood awareness by appealing to emotions is performed by creation of real situations which can evoke or create emotional reactions towards floods among the stakeholders. It should address the residents that haven't experienced flooding at all, but also keep the issue hot among the "experienced" stakeholders in times of no event by applying different media and tools (e.g. Steinführer, 2009). This requirement is often assessed as being decisive for the efficient raising of flood awareness (e.g. Grothmann& Reusswig, 2006). Visualisations of flood situations should be as realistic as possible (e.g. Grothmann& Reusswig, 2006). The requirement for creating "as realistic as possible" situations calls for tangible and real models and methods that enable hands on experiences with floods. As we cannot rely on *real* flood events that happen on an irregular basis, models of a haptic nature should be used, in which the flood events are simulated, enabling tactile contact with "flood water". Multimedia effects should support the effect of flooding. In order to achieve their optimal effect, they have to be integrated in one concept and logically linked (Schulmeister, 2002).

3. Integration of single elements and the learners through interactive actions: It is to be achieved by interaction of the single elements for raising risk awareness of the tasks mentioned in 1. and 2. and actively involving stakeholders in the process. By creating cause-consequence chains (Plapp, 2003) the components of risk and their interactions can be visualised. It implies visualising the flood event (cause) and the extent of the corresponding impact (consequence). Further, the learners are enabled to create different flood scenarios and observe different effects of flooding extending the cause-effect chains.

The postulated and design aspects/elements for development of concept for raising flood awareness are summarised in Table 3-44.

Table 3-44 Main requirements/ postulates and design elements for developing concepts for raising hazard/risk awareness

Nr	Postulate	Design aspects/elements
1	Delivering facts	**Flood maps**, info material, flood symbols
2	Appealing to emotions	Real flood events, **virtual flood event**, **multimedia**, pieces of art
3	Integration of single elements and learners	- interactivity among single elements (given in 1 and 2) including flood maps - interactivity with the users

[140] Definitions of flood maps are given is section 2.1.5.

The developed concept has been depicted in Figure 3-36.

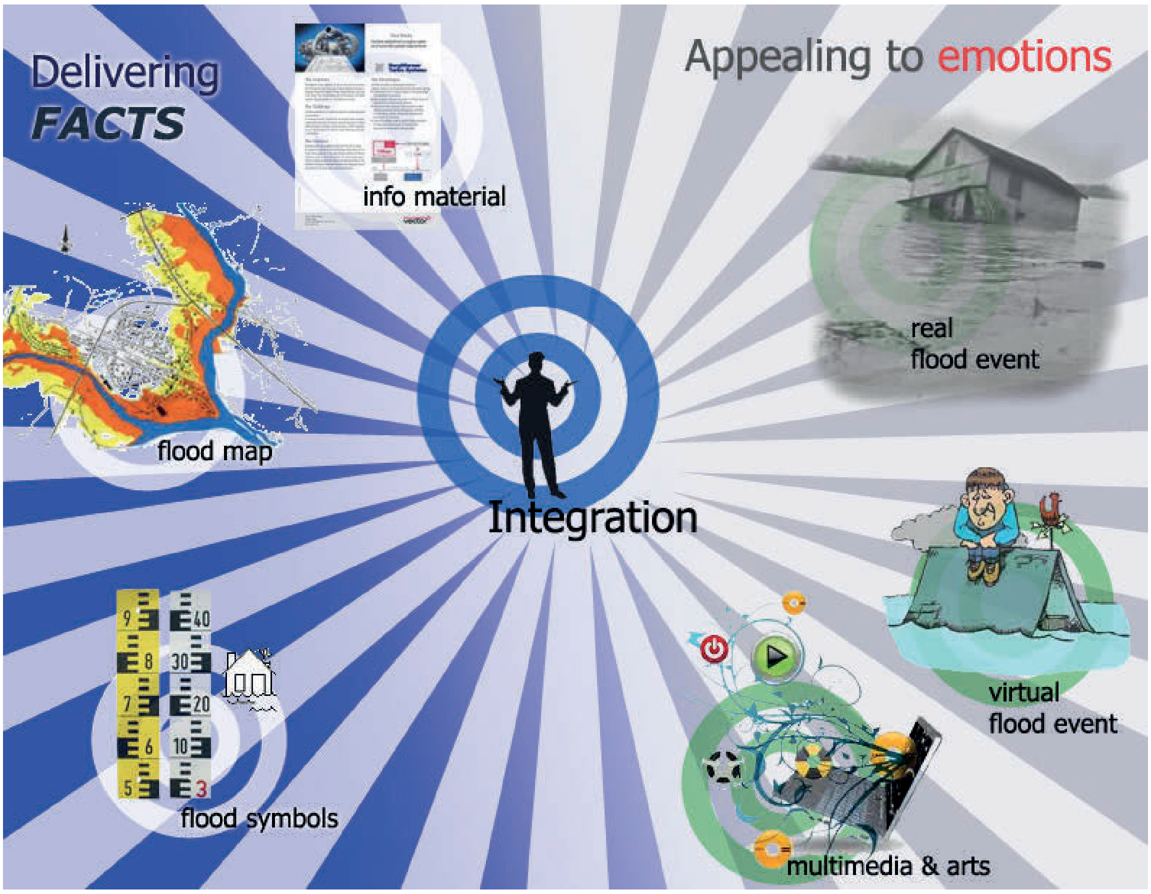


Figure 3-36 Conceptual design of tools for raising risk awareness

3.4.1.2 Concept for supporting autodidactic learning

The autodidactic learning process tailored to individual skills is supported by web based learning (in a form of e-learning). E-learning is understood as an "application of information technologies for improvement/supporting of the learning process" (e.g. Baumgartner et al., 2002). The e-learning methods imply a range of advantages related to organisational aspects, learning style and preparation of the learning material.

In terms of the organisation of the learning activities, the main advantages are that the learning process can be performed independently from the place and time, i.e. the learner can decide on when and where to learn (e.g. Michel 2002, cited in Pryadko, 2005), and the learning material can be accessed anytime and repeated as often as required. In this way, the learners can control the learning process and schedule it according to their agendas. Considering the fact that dwellers are a rather heterogeneous group with different initial capacities and needs, three main types of learners (out of the group of private stakeholders) have been distinguished (Pasche et al., 2006):

- learners that want to learn about certain topics and possess rather limited knowledge on this topic.
- learners that already have certain knowledge on selected topics and need to reactivate it (extended definitions, stepwise processes), or are interested in concrete solutions or strategies for given situations (best practices, stepwise processes)
- learners that prefer learning in an interactive manner enabling them to interact with the system

Correspondingly, three ways of delivering required knowledge (given in Table 3-39) have been developed as depicted in Figure 3-37.

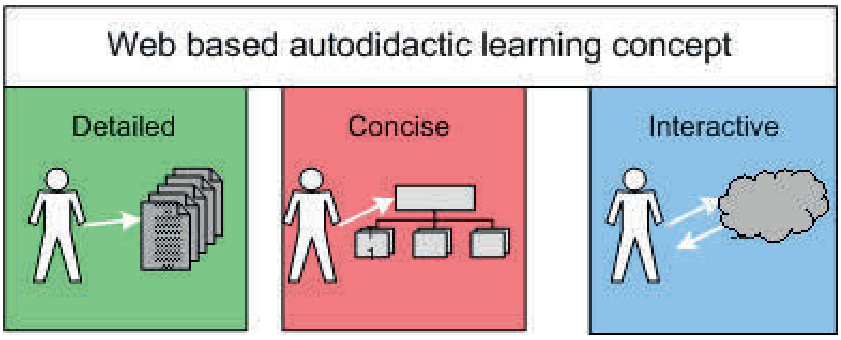


Figure 3-37 Conceptual design of autodidactic learning

1. Detailed: Implies delivery of detailed information about FRM on relevant topics. Here the information is prepared in a thorough way, explaining in detail the relevant processes and issues of FRM and flood resilient planning. The material is prepared either in a form of HTML documents or e-lectures. A clear structure of the addressed topics in the context of FRM should be available, enabling simplifying and associating of similar issues or creation of analogies with well-known problems or situations, which is in keeping with cognitivistic methods.

2. Concise: Implies presentation of key issues in a concise way, delivering extended definitions of the main terms and phenomena and summarising best practices or stepwise processes. Extended definitions are the ones that not only define the term, but bring it into the context and deliver associated methods or applications of it. The definition of terms can contain abstract terms (e.g. risk), general terms (e.g. non-structural measures) or concrete terms (e.g. waterproof concrete). The content should be in the form of html pages, but in order to support rapid screening of information and concise presentation of the materials, templates should be developed and used for presenting the selected topics. This reflects the objectives of the cognitivistic methods, where templates serve for structuring and simplifying the relevant information, chunking all relevant issues that can be brought in the context of FRM and defining their place and connections with the other issues in a discrete form, for example a mind map.

3. Interactive: The interactive way of learning is dedicated to improving the learning effect by allowing the user to interact with the content. The pathway through the system depends on the initial knowledge of the user. The material is prepared in the form of interactive tests defining sequences of question & answers structures. Depending on the level, those tests are conceptualised as question-answers pairs with simple interdependences, giving a good introduction into more complex topics and strengthening motivation for learning. In terms of the methods based on the learning theories, this can be considered as a behaviouristic method. The interactive aspect of web based tools is assessed as crucial. This is considered to be one of the primary reasons for the success of web-based systems (Stone et al., 2005). In the case of a lack of interactivity motivation among learners can sink rapidly (Da Rin, 2005).

Web based learning concepts, although they are increasingly being adopted and applied in the education of adults even outside of academia, set certain requirements for their successful application. They can be summarised under *content related* and *performance related*. In terms of content, the web based concept should cover the topics depicted in Table 3-39. The performance related criteria are summarised in Table 3-45.

Table 3-45 Performance related criteria for web based autodidactic concepts defined in this work

Nr	Criteria
1	easy to handle and understandable, supporting even lower levels of computer literacy
2	technically available and accessible for all targeted learners (limited use of plug-ins and extra software requirements)
3	easy to maintain and update

3.4.2 Assessment of efficiency of the capacity building process

Building the capacity of stakeholders starts with identifying the level of knowledge, the attitudinal behaviour and understanding of risk perceptions of the targeted stakeholder groups (WMO, 2005). The improvement of the resilience level achieved during the capacity building has to be evaluated by assessing the improvements in the knowledge level before and after the learning cycle. For the scope of the assessment in this work, the definition of Webler et al., 1995 that recognises cognitive enhancement and moral development as the two general components to social learning[141] has been adapted, focusing on the domain of urban flood risk management, dwellers and the main objectives of the capacity building process as given in section 3.4. According to Webler, 1995, there are three types of these enhancements, being:

- *changing knowledge* (adoption of new facts),
- *changing values and preferences* (evaluation of the new facts on the basis of modified values and assumptions)
- *changing behaviour* (find new ways to deal with complex and conflict-ridden issues in a constructive way).

[141] Taken from GoverNat available at: http://www.governat.eu/ (last accessed: January 2015)

Taking this approach as a basis, the criteria for assessment of the efficiency of a capacity building process are set as depicted in Table 3-46.

Table 3-46 Criteria for assessment of efficiency of the capacity building process

Nr	Criteria
1	Improvement of risk awareness and changing attitude towards own flood risk
2	Acceptance of own responsibility (by acquiring information about flood situation and management, possibilities and limits of the other groups)- being better informed
3	Acquiring required knowledge/ expertise for resilient planning
4	Applying new knowledge (proactive behaviour)

Both formative and summative evaluation procedures are to be considered. Those methods do not exclude but extend each other. Formative evaluation is a method of judging the worth of a program while the program activities are forming or happening. Formative evaluation focuses on the *process* (Bhola, 1990) and aims at its optimisation during the execution/implementation phase. Summative evaluation is a method of judging the worth of a program at the end of the program activities. The focus is on the *outcome* (Bhola, 1990). Especially in the initial phase, where the process is not established yet, the formative evaluation with open-ended questions[142] should be applied.

While a formative evaluation is usually open, summative methodology is based on pre-defined forms and questionnaires. Such a method requires high skills in formulating the "right" questions, and as such very extensive preparation is often required.

As the learning is composed of different phases, it is of high importance to perform a formative evaluation in order to have "quality control" and evaluation of achievement of the milestones that correspond to the intermediate goals of the learning phases. For this assessment, the qualitative analyses should be applied. Depending on the results, this process can be repeated. Still, in this case new methods are to be involved in the implementation as learning motivation drops rapidly if the novelty effect is missing (e.g. Kerres, 1998).

3.4.3 Integration of capacity building into the decision making process

The concept for stakeholder involvement presented in Figure 3-6 is composed of decision making and capacity building processes, which interact with each other and contribute to the overall process with different intensities depending on the phase. Capacity building should support the decision making process in all its facets and the synergies must be derived enabling the efficient action of both processes. Analysing the decision making and capacity

[142] Open-ended questions are questions to which there is not one definite answer (Waddington, 2000). They are usually used when the wording of interviewed persons is important and where the surveyors can not predict all answers beforehand.

building process for dwellers depicted in Figure 3-15 and Figure 3-35, a parallel can be drawn between their single elements.

In the beginning, the process is dominated by capacity building actions, in this case raising hazard/risk awareness (ph 1- experience with flood ph 1 of the capacity building). The reflection on an individual situation (ph2) is closely related to the risk assessment phase of the decision making process as both are related to the analysis, assessment and understanding of individual flood risk. Learning about resilience measures (ph3) covers the parameter analysis for the selection of appropriate resilience systems in the DM process. The application of knowledge to a concrete case (ph4) supports the technical selection process and option analysis of the development of a flood resilience plan for the built environment. The whole process ends up with an assessment of the resilience performance of the applied method. Those correspondences have been summarised in Table 3-47.

Table 3-47 Capacity building of stakeholders and supporting corresponding decision making phases

Nr	**Stakeholder involvement Strategy (Figure 3-6)**	**Capacity Building of Stakeholders (Figure 3-35)**	**Decision Making Phase (Figure 3-15)**
1.	Scoping	Experience with flooding[143]	-
2.	Scoping/Understanding	Reflection on own situation	Risk assessment
3.	Understanding	Learning about resilience measures	Resilience plan for built environment - Parameter analysis
4.	Experimenting	Application of knowledge to a concrete case	Resilience plan for built environment- Technical selection process, Option analysis, Cross-scale analysis
	Evaluation and decision making	Performance evaluation	

[143] Triggers the motivation for participation

4 Implementation

4.1 Overall concept for dwellers involvement

The concept for supporting dwellers involvement presented in Chapter 3 has been implemented through the development and integrated application of the web-based decision support tool for the resilient built environment (FLORETO) and the Interactive Learning Program (ILP) that is supported by the tools for raising flood awareness (Flood Animation Centre) and autodidactic learning (FLORETO-*Inform*).

4.2 Decision support tool

The methodology to support the decision making on the resilient built environment has been implemented applying the adapted V Model (based on Sommerville, 2004) (Figure 4-1).

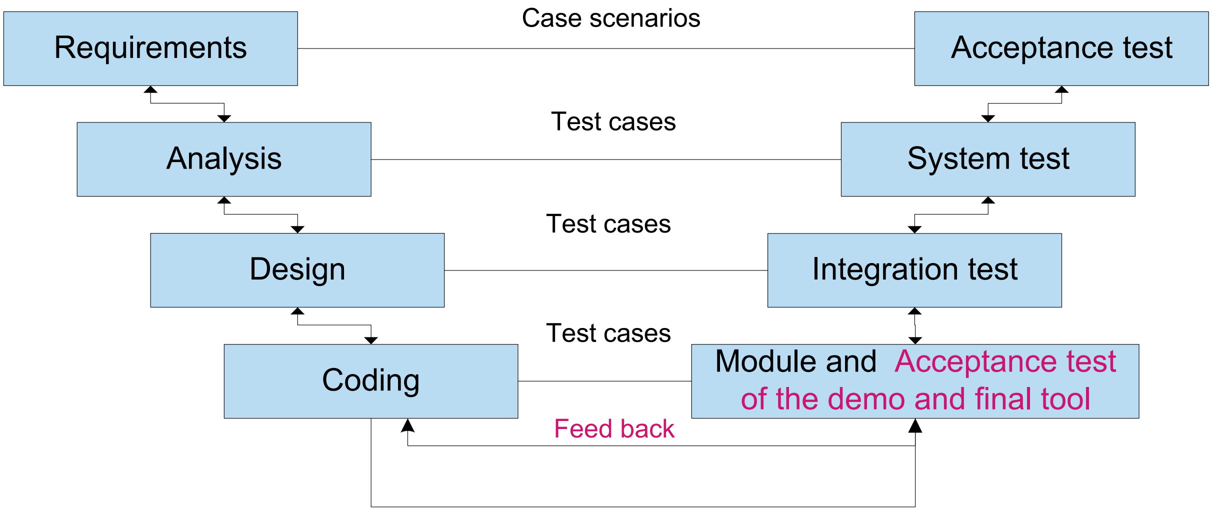


Figure 4-1 Adapted V Model (based on Sommerville, 2004. The changes are highlighted in red)

The V Model enables the integration of the quality control aspect, as validation and verification are integrated into the design procedure (Sommerville, 2004). Although it is recommended for large projects and systems, this model has been selected due to its simplicity and clarity as well as because it enables monitoring and user feedback options. The main steps of software development, being *requirements, analysis, design and coding*[144], are supported by corresponding tests as depicted in Figure 4-1 and are applied to design and implement the decision support tool the for resilient built environment targeting dwellers. In additional to the original V model, the acceptance tests of the demo and the final tool has been introduced at the end of the procedure in order to obtain feedback from the users regarding the product. This feedback is then fed into the development procedure as shown in Figure 4-1. The added elements to the original model are highlighted in red. The description of the demo tool and the walkthrough of the FLORETO current version are given at http://floreto.wb.tu-harburg.de/welcome-to-floreto-tool/previous-versions/ and http://floreto.wb.tu-harburg.de/welcome-to-floreto-tool/latest-version-floreto-walkthrough/ resp.

The software development procedure is explained in this chapter. Details related to the individual steps of the V model are given in Appendix 4.1. The corresponding tests are given within chapter 5, where the verification and tests on case studies are presented. The tests related to the code testing and debugging are not included in this work.

4.2.1 The implementation of the decision making process- Flood Resilience tool (FLORETO)[145]

Flood Resilience Tool (FLORETO) is designed as a web-based decision support system for property level resilient planning tailored to the user group-dwellers implementing the developed decision making method as given in Figure 3-15 and considering the requirements on data management given in section 3.3.4. Regarding the functionality criteria, FLORETO is easily accessible via web browser without downloading the software by selecting the corresponding option in the Flood Resilience Portal. The only installation required is Adobe Flash Player[146] which is free of charge and in most cases already included in the browser. FLORETO software architecture implements a client – server concept and is composed of three main tiers being:

1) User interface (UI) that runs on the client side, within the user's web browser, and is supporting Web2.0[147] technologies (available for standard browsers e.g. Internet Explorer, Mozilla Firefox, Safari). FLORETO offers a customised interface for defined key stakeholder groups – dwellers, experts and expert-administrator and the general public.

[144] Coding (programming) part of the implementation has been beyond the scope of the work. This activity has been performed at the Institute of River& Coastal Engineering, TUHH in a close cooperation with the author of this Thesis within the projects: RIMAX-UFM (http://ufm-hamburg.wb.tu-harburg.de/), SMARTeST (http://www.floodresilience.eu/), FLOWS (http://www.northsearegion.eu/iiib/), and KLIMZUG-Nord (http://klimzug-nord.de/). A summary of the main technological features is given in the Appendix 4.3c.

[145] Parts of this section have been published and submitted as the authors contribution to the report 4.2 of the FP7 Project SMARTesT, Manojlovic, N., Nauman T., Schinke R., Spekkers M., Toumazis A., Giangola-Murzyn A., Deroubaix J-F, Barocca, B., Moulin E. (2012) Flood reislience Tools, Report 4.2, SMARTeST

[146] http://get.adobe.com/de/flashplayer/ (last accessed: January, 2015)

[147] http://www.worldweb.de/ (last accessed: January, 2015)

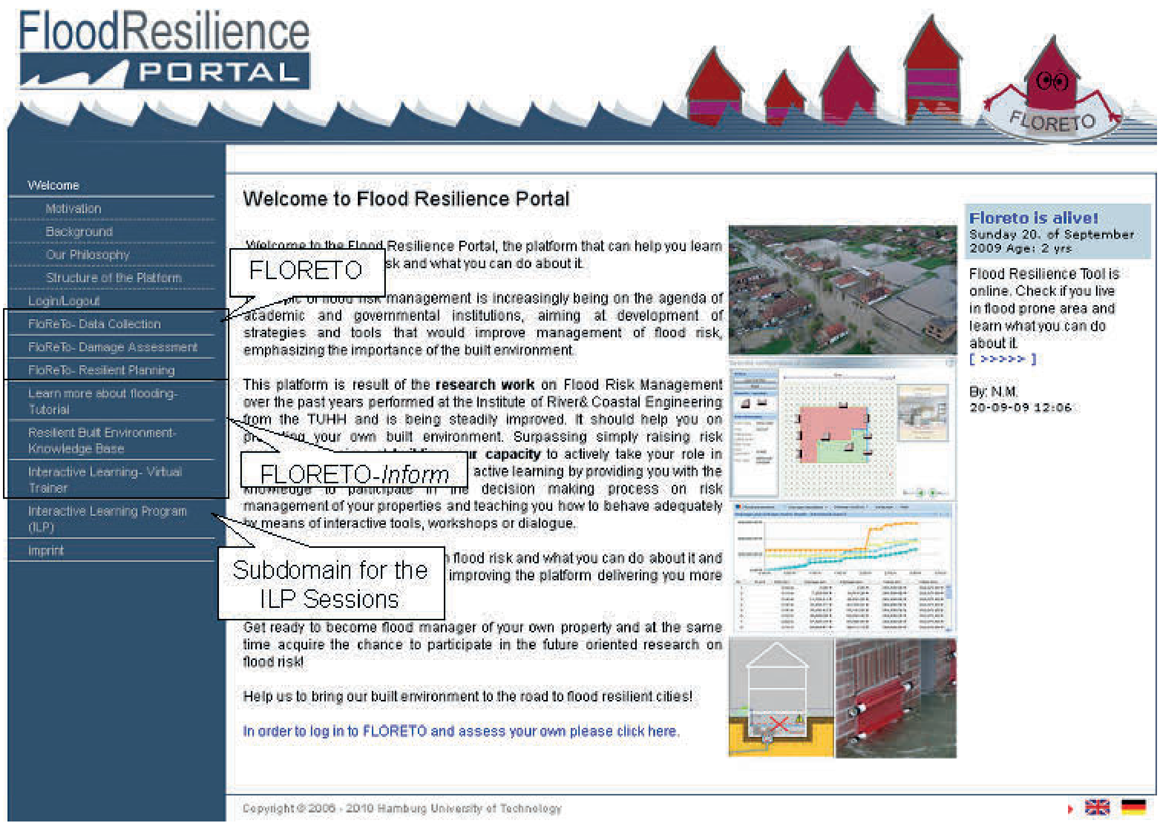
2) The functional (business logic) module contains the damage assessment business logic for risk assessment, data mining models for the technical selection process and the cost benefit analysis module. Business logic runs on the server side and implies a web server Apache[148] supported by the servlet container Tomcat[149].

3) A (relational) database management system (RDBMS) that stores the data required by both UI and business logic. This tier runs on a database server and communicates with other tiers by network protocols. FLORETO uses MySQL[150], a widely used open source RDBMS.

FLORETO is embedded in the Flood Resilience Portal, a web based platform (http://floreto.wb.tu-harburg.de) as shown in Figure 4 3 that encompasses:

- decision support through the FLORETO Tool
- capacity building by integrating the self-learning module (FLORETO-*Inform*) and participants' portal of the ILP, which implementation is given in section 4.3.

A joint platform gives a corporate identity and better overview of all required knowledge and activities as well as enabling better integration and interaction of individual modules and the assignment of the learning modules to the corresponding tasks in the decision making workflow. The welcome page of the Flood Resilience Portal is given in Figure 4-2.



148 http://wiki.apache.org/httpd/FAQ#What_is_Apache.3F, http://httpd.apache.org/ (last accessed: January, 2015)

149 http://tomcat.apache.org/ (last accessed: January, 2015)

150 http://www.mysql.com/ (last accessed: January, 2015)

Figure 4-2 Flood Resilience Portal encompassing the decision support tool FLORETO and FLORETO- *Inform* for capacity building of dwellers

The walkthrough of the FLORETO tool is given at the link: http://floreto.wb.tu-harburg.de/welcome-to-floreto-tool/latest-version-floreto-walkthrough/. A general overview of the FLORETO system architecture is depicted in Figure 4-3.

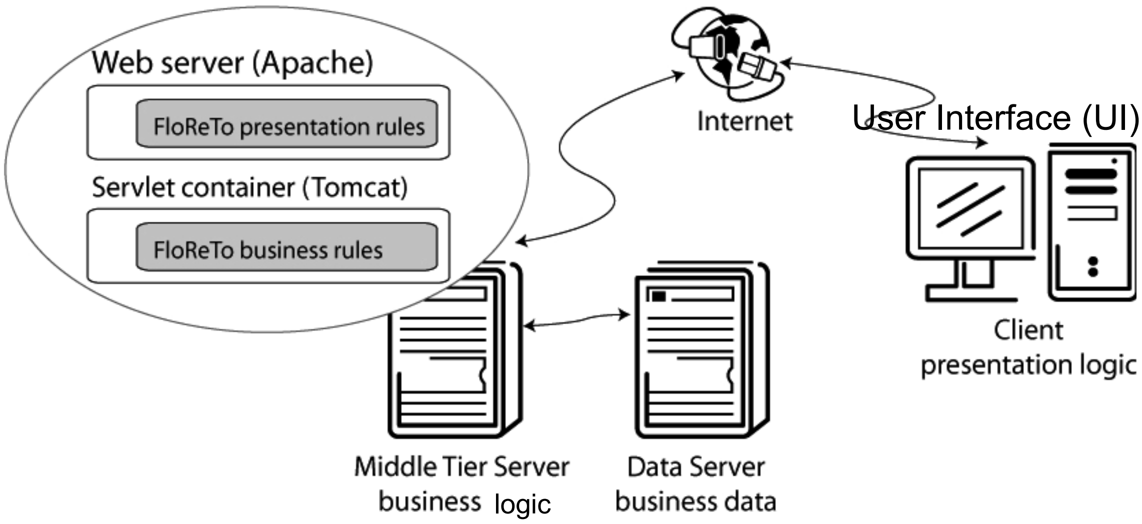


Figure 4-3 FLORETO- a three tier system[151]

The three-tier design of FLORETO has many advantages, the chief one being the modularity of such a system, enabling modification and replacement of one tier without affecting the other ones. In more details, the tiers are presented in the following sections.

4.2.1.1 User Interface (UI)- Client tier

The user interface should enable users to accomplish all assigned activities of the workflow presented in Appendix 4.2

The requirements for the tool given in Appendix 4.1 are considered for the development of the UI. For the design of the UI, the main design principles[152] (Stone et al., 2005) have been considered as a guideline and are summarised in Table 4-1 and thoroughly explained in Appendix 4.1.

[151] Adapted from http://www.linuxjournal.com/article/3508 and developed within FP 7SMARTeST Project (last accessed: January 2015)

[152] There is a significant body of literature addressing user interface and web design (e.g. Stone *et al.*, 2005, Shneiderman and Plaisant ,2009, Apple Computer, 2009; Microsoft Corporation, 2009). Still, design principles related to the complex browser based applications, which should fulfil both application and website requirements (such as FLORETO) with high interaction with the users and considering the available technology are rather scarce.

Table 4-1 General design principles for UI (Stone et al., 2005) and Nielsen and Molich* (1990)

Nr	Principle	Description
1	Visibility	First step to goal should be clear
2	Affordance	Control suggests how to use it
3	Feedback	Should be clear what happened or is happening
4	Simplicity	As simple as possible and task-focused
5	Structure	Content organized sensibly
6	Consistency	Similarity for predictability
7	Tolerance	Prevent errors, help recovery
8	Matching *)	Match between system and real world*)

This tool primarily targets dwellers and should be tailored to their interests and their role in UFM (primary users). However, as introduced in section 3.3.3.3, the experts should give their feedback on the resilient plans within the feedback loops and as such should be considered as users. Also, the expert coordinators and general public are considered as secondary users. The main users are summarised in Figure 4-4.

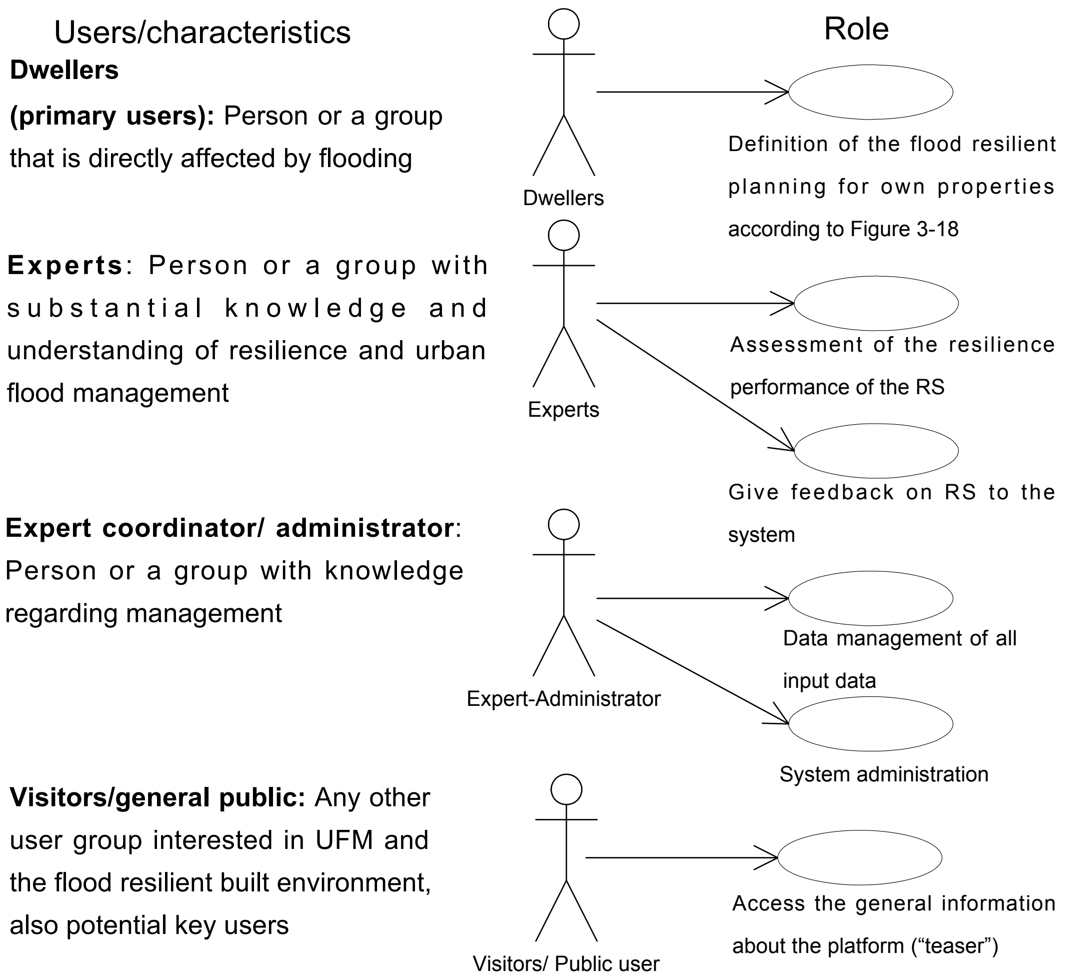


Figure 4-4 A UML Diagram depicting the user groups and their roles

The focus of this work has been the implementation of the specific functional requirements e.g. data collection of building elements or enabling topology for data collection as postulated in section 3.3.4. As FLORETO UI deals with a large amount of data, which can easily be graphically visualised, a graphical user interface (GUI) has been considered for the design. It also coincides with the requirement and expectations of the primary users being dwellers, as introduced in Appendix 4.1.

The three main features of the FLORETO GUI are given as:

(1) data collection i.e. the description of the buildings,

(2) input of the flood parameters and

(3) visualisation of the results.

1) Data collection- description of the buildings

The data collection module implements the workflow given in Appendix 4.2. In the workflow, the data to be collected are grouped into units that correspond to the description of different building elements. The data collection module implements four scene layouts as described in Appendix 4.1. Examples of different scene layout types (1)-(4) are given in Figure 4-3 to Figure 4-7.

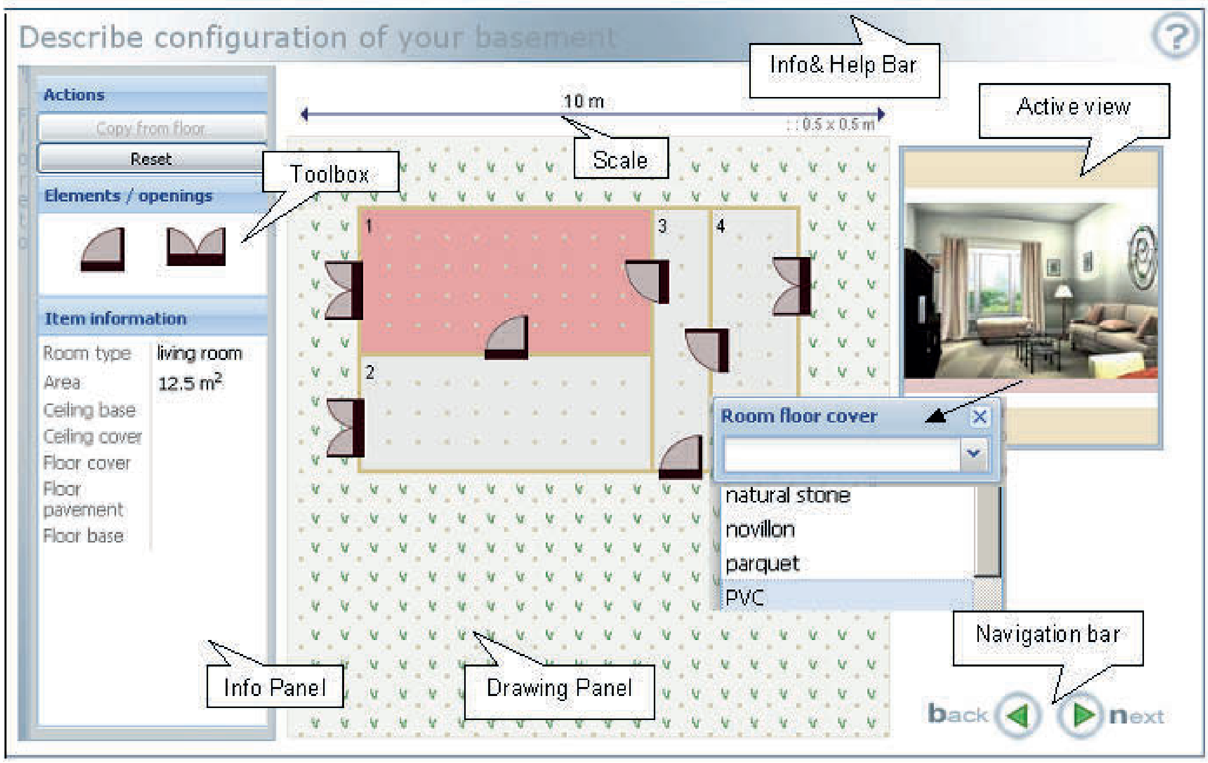


Figure 4-5 Example of the GUI for public user within FLORETO platform (scene layout type (2))

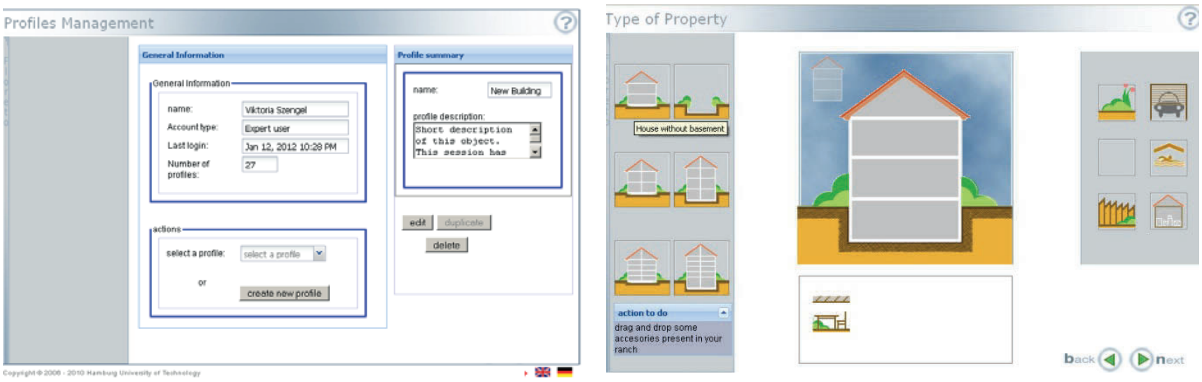


Figure 4-6: Examples of the FLORETO GUI interface a) entering the general information (4) b) layout type (1) enabling definition of the building type[153]

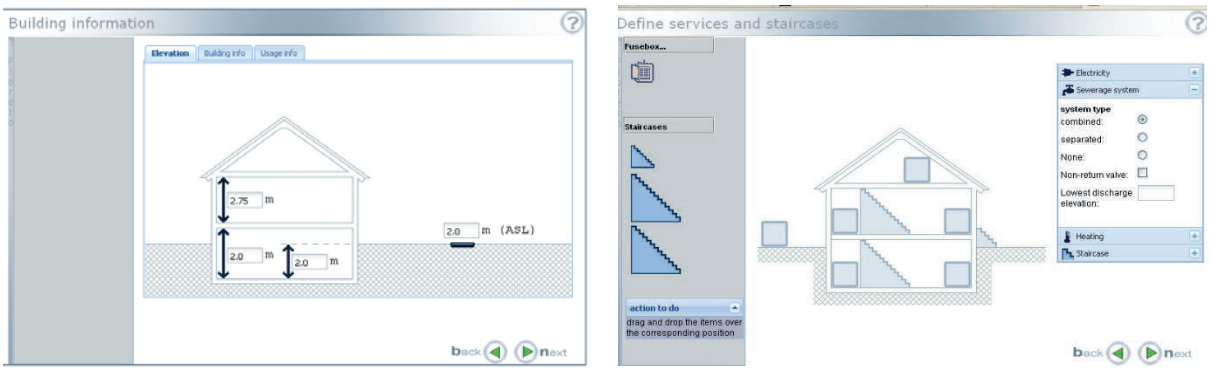


Figure 4-7 Examples of the FLORETO GUI interface a) layout type (3) enabling definition of the relevant elevation elements b) layout type (3)definition of the services and staircases

2) Input of the flood parameters

Flood parameters are to be defined or imported utilising GUI. The final model enables the full input of the flood parameters that result from the hydrodynamic modelling. The input can be performed either by importing of the parameters or by entering them by manually. The import can be performed from an external file or Web Coverage Server (WCS)[154] utilising GoogleMaps API[155]. The Google server returns an XML file also containing the coordinates of the entered address, given in the WGS:84 coordinate system. Those data are sent to the FLORETO server together with the building description defined by the user via GUI. The FLORETO Server communicates with the WCS or a file that contains the flood parameters (flood depth) and transforms the WGS:84 coordinates into the format that can be understood

[153] The user has an option to define the adjoining elements such as garden or swimming pool, but the corresponding damaging functions have not been implemented yet.

[154] http://www.ogcnetwork.net/wcs Coverage: Coverages represent digital geospatial information representing space/time-varying phenomena. (last accessed: January, 2015)

[155] The implementaiton of this service has been beyond the scope of this work and has been performed within the step *coding,* as a part of the FP7 Porject SMARTest and BMBF Funded projectz KLIMZUG.

by the WCS or the external file (in this case the Gauß-Krüger system). The corresponding flood parameters (flood depth) are then returned from the FLORETO server to the user as shown in Figure 4-11a.

The GUI enables editing of this parameter, but it has to be made clear to the user that the reliability of the suggested system depends on the data reliability. Within this work, the flood depth is the flood parameter that has been considered for the building of the data mining models as given in Chapter 3. For the damage assessment the GUI enables manual definition of the other parameters that are contained in the flood intensity matrix. How the import parameters are considered for the risk assessment and resilient planning is given in the section dealing with the business logic within this Chapter 4.

3) Visualisation of the steps of the decision making process and visualisation of results

The UIs for performing the steps of the data mining workflow and visualisation of results are given in the following section, which is devoted to describing the business logic.

4.2.1.2 Business logic

The business logic of FLORETO contains the damage assessment tool for risk assessment, data mining models for the technical selection process and the cost benefit module. It contains the logic necessary to perform the processing part of the workflow.

Damage Assessment Tool

The business logic containing the damage assessment tool implements the damage assessment theoretical concept given in section 3.3.1.2. The design of the module implies design of the User Interface and the business rules running on the server.

The user interface has been designed following the workflow given in Appendix 4.2 and considering the design principles of Stone et al., 2005 summarised in Table 4-1 and described in Appendix 4.1.

The following steps are implemented in the damage assessment module:

1. Input of flood parameters (either for a single event or for the defined ari)
2. Selection of items for which the damage should be calculated
3. Assessment of the potential damage for the selected items considering both functional and aesthetical aspects

Figure 4-8 to Figure 4-10 illustrate the implementation of steps 1-3 within the damage module user interface.

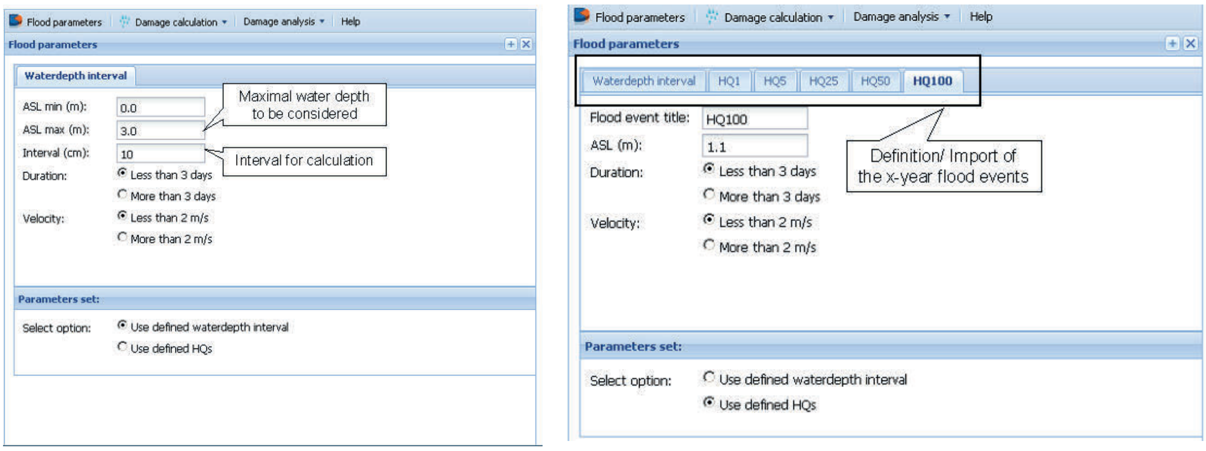


Figure 4-8 Step 1: Flood parameters for damage assessment (a) for a given event (b) for x-year floods

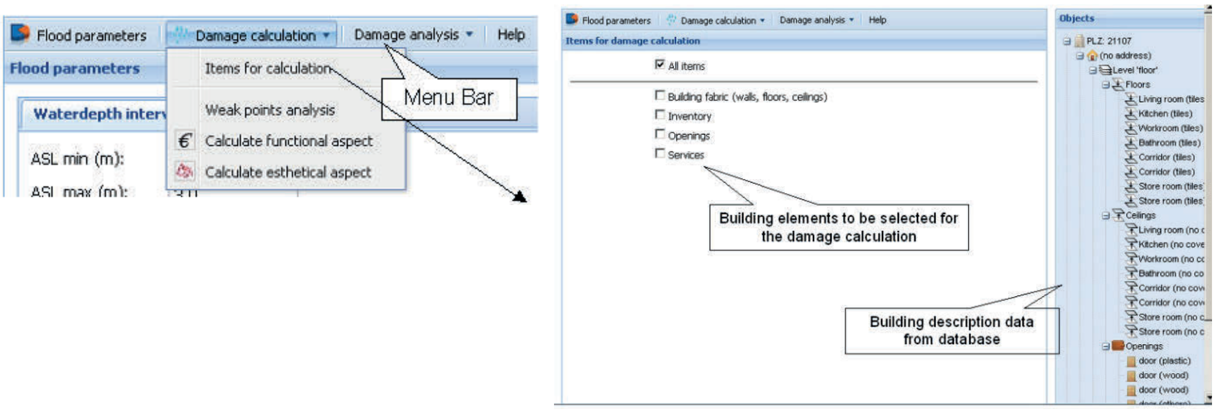


Figure 4-9 Step 2: a) Menu bar highlighting the damage calculation item b) Selection of the option items for damage calculation as a step of the damage assessment

Both types of damaging functions, *functional and aesthetical* are stored in the database and assigned to the corresponding building element or combination of elements. The main aspects of the data management are given in the section devoted to the database description. By choosing the scale of assessment from the building element up to the group of buildings, the user can get a damage assessment for a defined step (e.g. in the 10cm interval, see Figure 4-8) and given flood parameters in the form of a table and graphic as shown in Figure 4-10. The user can display the minimal and maximal estimated damage based on the range of costs considered for refurbishment. As a reference, the maximal and minimal value of the affected building elements is given. Alternatively, depending on the input flood parameters, the user can calculate the annual damage potential for the selected buildings. This result of damage assessment is the first input for scenario analysis, i.e. cost benefit analysis (CBA). In the post processing phase (Appendix 4.2), the user can print the report as a pdf or export the table (as a csv file) by selecting the corresponding option in the *Status bar*. The actual calculations of damage and risk are performed by the business rules that are stored and executed on the server (business logic) as shown in Figure 4-3, according to the theory described in 3.3.1.2.

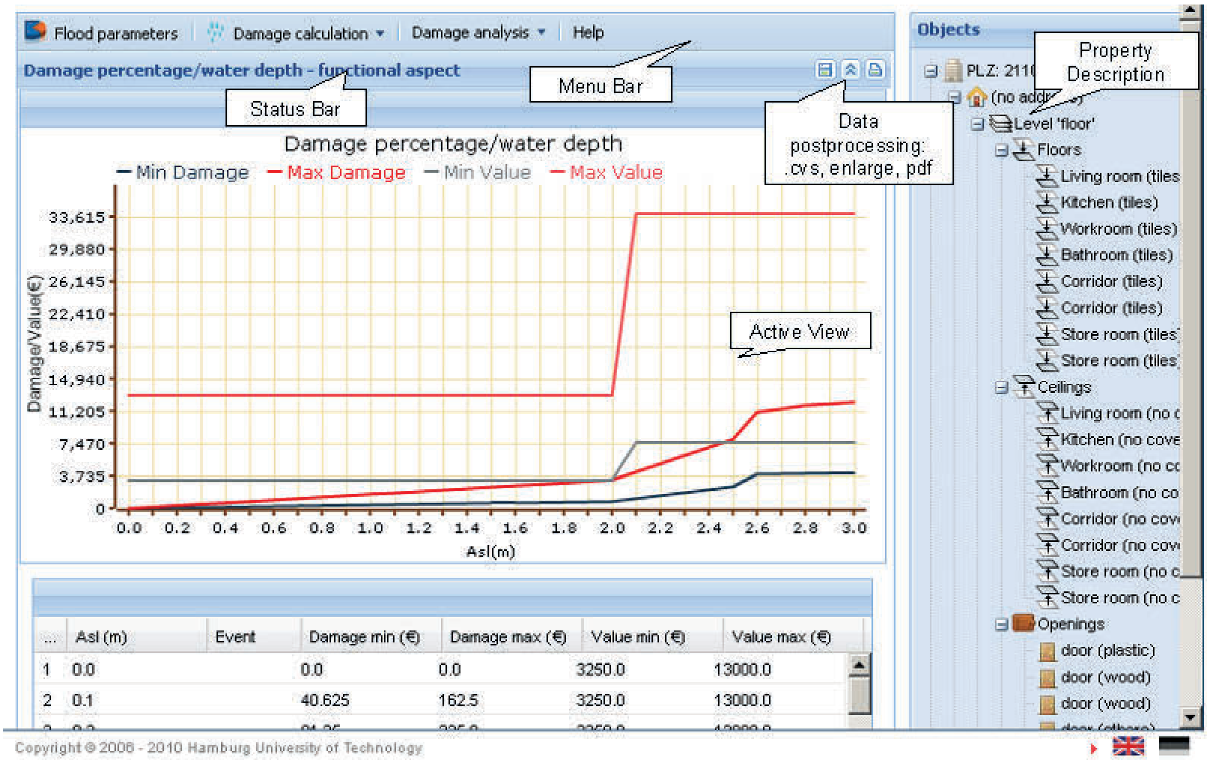


Figure 4-10 Step 3: The main view of the damage assessment module within FLORETO

Data mining models for the technical selection process of resilient systems

The main task of the data mining module is matching the users' inputs, representing the property description and flood parameters, to the flood resilient systems following the workflow as given in Appendix 4.2. After describing the property and importing the flood parameters, the user gets a suggestion of which resilient system(s) can be applied for the given conditions as given in Figure 4-11.

They are delivered in a very short and concise form as shown in Figure 4-11a. The more elaborated explanation of those systems is then delivered within the Tutorial or Knowledgebase of the FLORETO-Inform module or an external site of the SMARTEST[156] project devoted to explain FRe Technology and systems. The user gets a link to those pages as shown in Figure 4-11b and Figure 4-12 a) and b) resp.

[156] http://tech.floodresilience.eu/flood-resilience-measures (last accessed: Janaury, 2015)

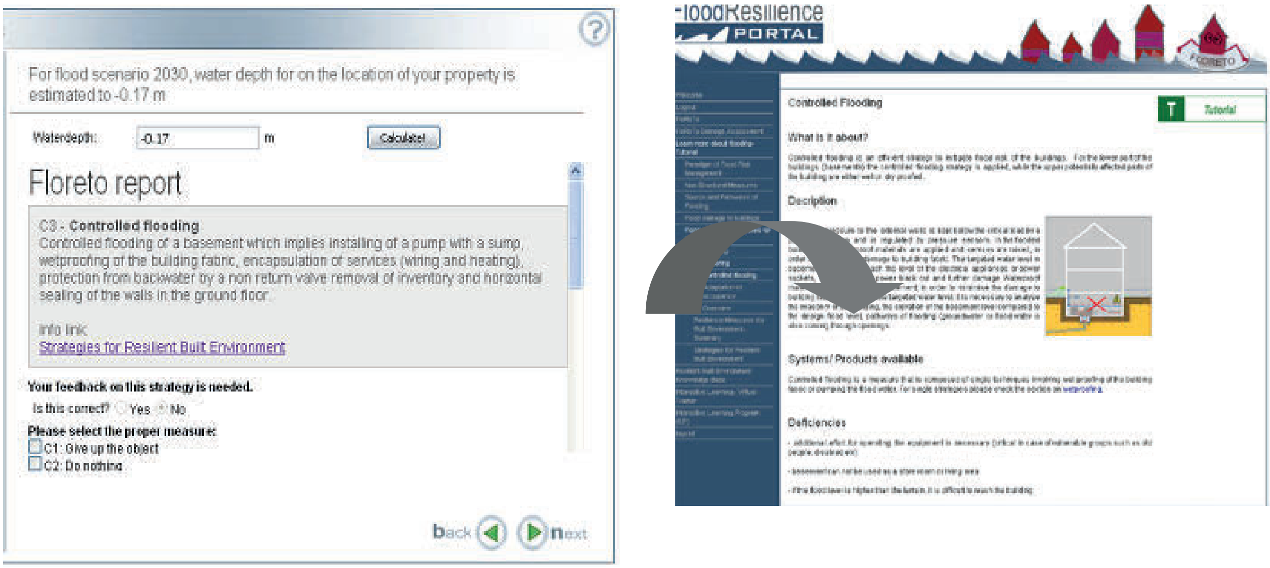


Figure 4-11a) an example of the UI for technical selection process with a feedback option b) description of the delivered resilient system in the *FLORETO-Inform* module

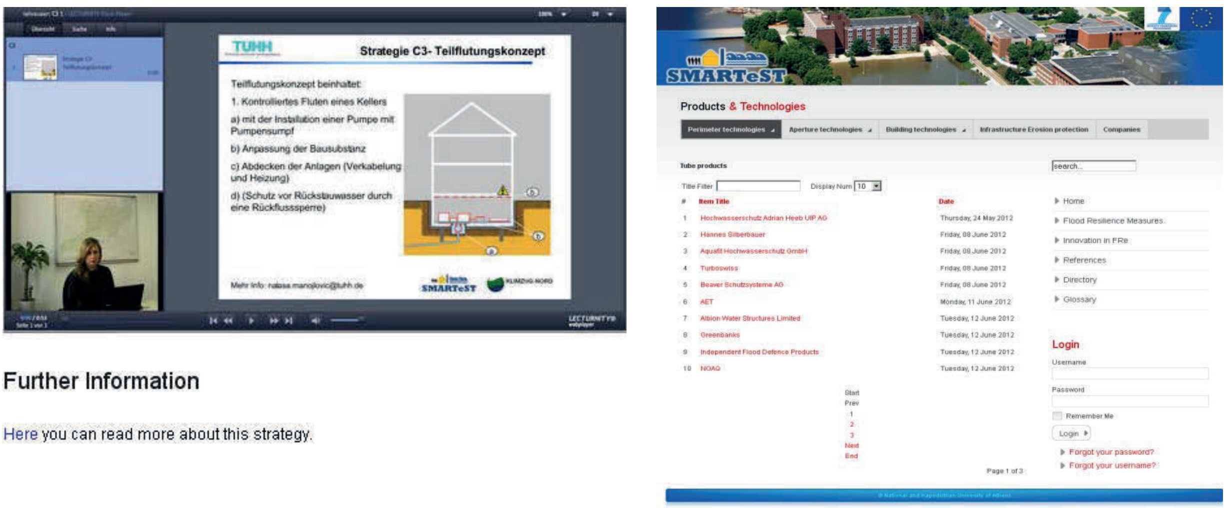


Figure 4-12a) explanation of the delivered resilient system utilising E- lectures b) further explanation of the delivered resilient system and possible resilient technology to be used (http://tech.floodresilience.eu/flood-resilience-measures)

Design of the business logic part of the data mining module has been performed in the steps following the knowledge discovery/ data mining process as given in Table 3-16. For the design procedure steps 6-9 are relevant for the implementation part and are given as:

1. Models Selection
2. Data Mining/ Classification process
3. Analysis/ Interpretation of results (will be given in chapter 6 when addressing the performance of the algorithms for the concrete datasets).
4. Consolidation of discovered knowledge -final integration in the FLORETO business logic

1. Models Selection: Within FLORETO business logic, the algorithms described in section 3.3.2.2 have been selected and considered for the implementation. They represent different classification patterns and are summarised in Table 4-2.

Table 4-2 Implemented algorithms within FLORETO

Implemented Algorithm	Type
J48	Decision Tree
Partial Decision Tree- PART	Decision Tree
LogitBoost	Meta Learners/Boosters
Logistic Model Tree- LMT	Meta Learners/Boosters
Nested Generalised Exemplars NGE	Exemplar based learning
Non-Nested Generalised Exemplars NNGE	Exemplar based learning

2. Data Mining/ Classification process: Within this process, the selected algorithms are being tested for the given model data from the case study areas described in Chapter 5. The tests on those models have been performed utilising the open source algorithms from the WEKA Machine learning platform[157] Version 3.4 and 3.6 (see Figure 5-24). WEKA implements the algorithms for data pre-processing, processing (classification) and postprocessing (visualisation). The data loaded in an appropriate format (.arff) is preprocessed and then analysed with special classifiers and visualised in order to provide an accurate output forecast of the class to be predicted (Bouckaert, 2013). The workflow of the classification process utilising the WEKA platform is illustrated in Figure 4-13.

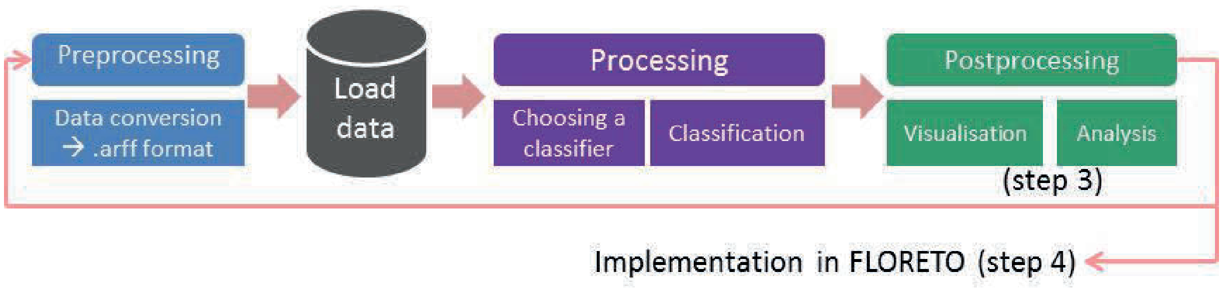


Figure 4-13 The classification process utilising the WEKA platform. This procedure has been used for the initial test of the datasets in the study areas described in Chapter 5. The results are interpreted (step 3) and the final solution implemented in FLORETO (step 4).

There are four classification schemes considered (Kemloh, 2008):

[157] http://www.cs.waikato.ac.nz/ml/weka/ also available at the http://sourceforge.net/projects/weka/files/latest/download; WEKA is open source software issued under General Public License, developed by the University of Waikato in New Zealand that implements data mining algorithms directly to a dataset using the JAVA language (last accessed: January, 2015)

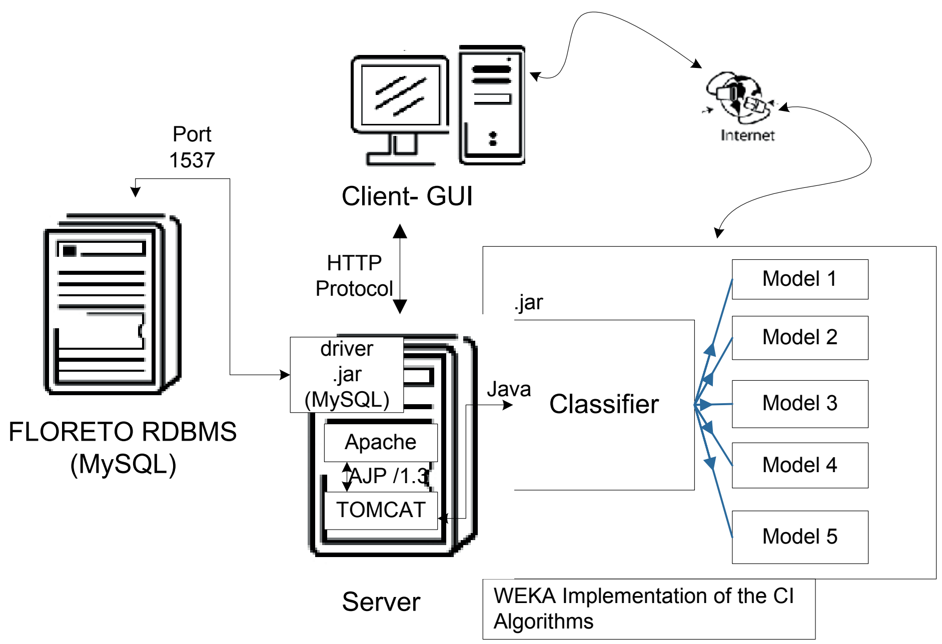
- *single model*- One single model is used for classification. The model ID is given as a parameter to the classifier class together with the instance to classify. In the absence of an ID, the model with the best cross validation result is used (cross validation[158] results are saved in the database).
- *simple voting*- voting takes place among each single model given above, where each model proposes one solution. There are in total 5 solutions proposed and the solution with the maximal count is chosen as the best. In the case of a draw, the class proposed by the model with the higher classification accuracy is considered to be the winner.
- *weighted voting* - The accuracy obtained during the training process is used as a weight indicator for the models (not fully implemented).
- *all models*- all results are considered for analysis. This option is used at the moment only for debugging purposes

3. Analysis/ Interpretation of results:

The results of the tests on real datasets are to be analysed and their potential to be used as a "seed" model discussed. For the given study areas, the interpretation of results is given in Chapter 5 and 6, when discussing the results.

4. Consolidation of discovered knowledge -final integration in the FLORETO business logic

The corresponding data model together with the WEKA algorithms (Table 4-2) have been embedded in FLORETO and used for suggesting flood resilient systems for the given flood conditions and system description as shown in Figure 4-14.



[158] Cross validation is introduced in section 3.3.2.2.

Figure 4-14 Software architecture of the FLORETO tool with the focus on the data mining business logic including the WEKA implementation (developed within the BMBF KLIMZUG and the FP7 SMARTeST Project and Kemloh,2008)

The classification process is performed for each new dataset entered by the user, based on the previous experience (implicitly stored in the data model).

The procedure is straightforward and can be resumed in two steps: (1) populating the data from the database and (2) calling the learning algorithms. After completing the data collection procedure, the data is sent to the server. The server communicates with the WEKA implementation within FLORETO, which performs the classification process of the new dataset. The classifier output is given in the ID form, which corresponds to the recommended resilient system. Based on the ID, the description of the resilient system is retrieved from the database, formatted and returned to the user as shown in Table 4-12a. The steps are repeated for all models. The accuracy is also computed and stored back into the database; the results are compared with the previous one and logged on a log file.

Module for Cost Benefit Assessment

Cost benefit analysis rounds the selection of the appropriate resilient systems within FLORETO. It is delivered to the user after the resilient plan as shown in Figure 4-15a and implements the concept given in section 3.3.2.3.

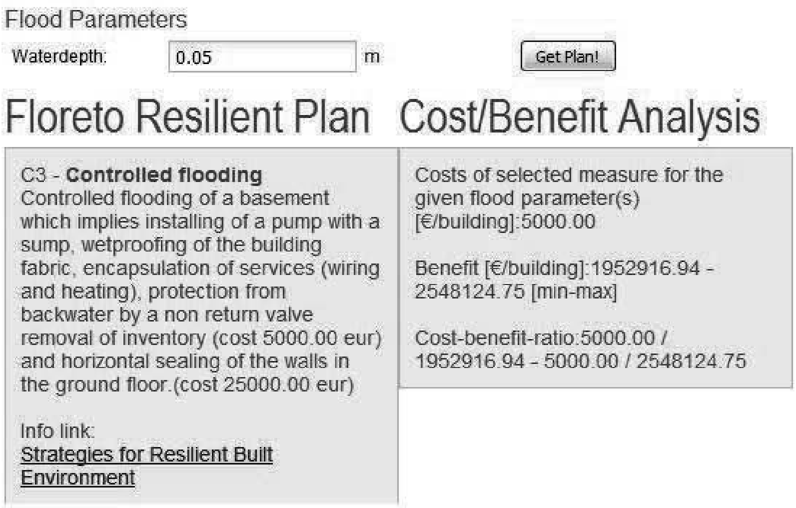


Figure 4-15 Cost-benefit option within FLORETO

Feedback modules

As introduced in Figure 3-19, feedback modules are integrated to enable constant improvement of the system. The feedback aspects differ for different users as explained in Table 3-21. The workflow is given in Appendix 4.2

The feedback module (see Figure 3-19) has been implemented in two parts. The first one is related to the appropriateness of the proposed resilient systems (inner loop). This should be performed by the expert users in the feedback mode as shown in Figure 4-16a.

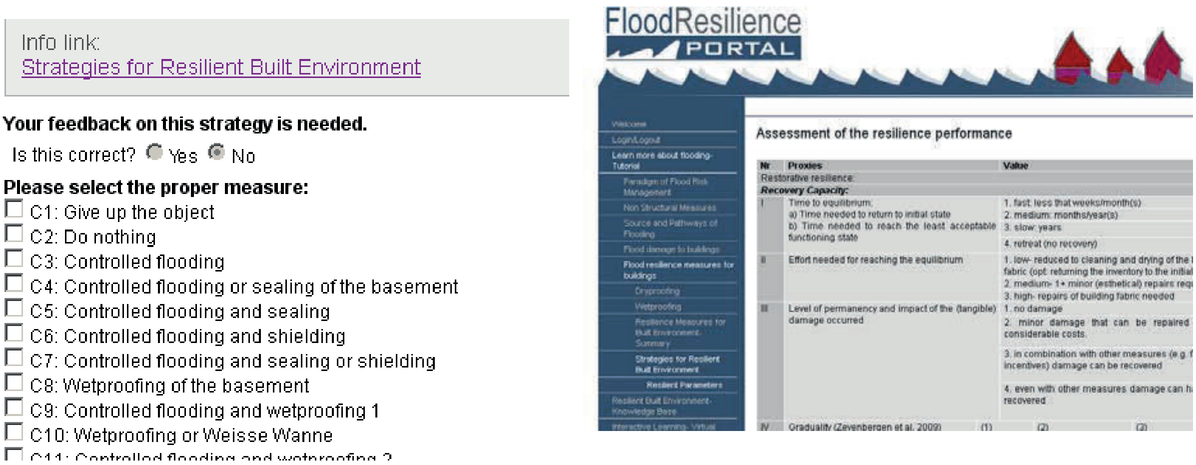


Figure 4-16 Feedback loop of FLORETO: a) inner loop b) outer loop

In this way it is possible to update the Knowledgebase for data mining with additional expertise, taking advantage of data mining procedures as explained in section 3.3.2.2. The results of the feedback procedures enable *consolidation of discovered knowledge,* and their integration in the business logic of FLORETO.

The outer loop is devoted to assessment of the resilience performance of the selected resilient system after being implemented. The feedback is expected from both, experts and dwellers as summarised in Table 3-25. The mode for experts is given in Figure 4-16b.

The module for MCA has not been implemented. The obtained resilient systems from FLORETO are discussed with the dwellers considering the parameters as given in Table 3-23.

III) Relational Database Management System (RDBMS)

The database tier contains all data collected by the user, as well as the data needed by the business logic for performing the required calculations. Those data are damaging functions and the resilient systems together with the costs associated to them. The FLORETO Database has been implemented using the open source database system- MySQL (http://www.mysql.de/). The database has a modular and flexible structure so that can be extended for further parameters and languages, by adding the attributes to the corresponding tables. The current version of the database contains 53 tables.

The design of the FLORETO database supports the main requirements/postulates of the GUI and the business logic being:

- Topology; The property description entered via user interface is stored in the data base, supporting the free drawing of the building elements. The principle is described in Appendix 4.1.
- Efficient storage of the data needed by the business logic addressing the following:
    - One of the main data to be stored in the database is related to the description of the damage functions. Damage functions are defined for different building components and are given per building element.
    - Measures used by the business logic are stored in the database given as single measures and resilient systems. They are used by the business logic including the WEKA implementation and returned via server to the client.
    - Data required for the knowledge discovery (data mining) are integrated as a table in the database.
    - For performing the cost benefit analysis, the costs of measures have to be available. They are stored next to the corresponding measures and given as [cost/unit] and used by the business logic to calculate the overall costs of measures.

The principles of the FLORETO database design and the corresponding examples are given in Appendix 4.3.

4.3 Implementation of Capacity Building Method

The methodological framework for the capacity building of stakeholders, given in section 3.4. has been implemented within the Interactive learning program (ILP). It is supported by the Flood Animation Centre (FAC), which implements the concept for raising hazard/risk awareness. The web based tool FLORETO-*Inform,* implements the concept for supporting autodidactic learning.

4.3.1 Methodological Framework for Capacity Building of Stakeholders

The Interactive Learning Program- ILP implements the concept of capacity building presented in section 3.4 and given in Figure 3-35. ILP is a blended learning program that involves a combination of different learning methods as depicted in Figure 4-17 and given as:

- *face-to-face sessions- workshops* (depicted as 1-4 in Figure 3-35)
- *extended face-to-face sessions- on site visits* (given as 1/2, 2/3, 3/4, 4/1)
- *autodidactic phase* that underlies the whole process

Figure 4-17 Interactive Learning Program for capacity building of private stakeholders based on Kolb's experiential learning theory (Kolb& Fry, 1975, extending the concept of Geissler 2006)

Face to face sessions follow the framework presented in Figure 3-34. The program extends the concept of Geissler, 2006 by introduction of the *extended face-to-face phase*, in which the continuity of the process and smooth transitions between the phases are achieved by the provision of more on site examples and additional material to participants which are to be processed within the autodidactic phase. The developed web based tool FLORETO- *Inform* is used for the autodidactic phase. The integration of the capacity building and decision making processes has been achieved by applying FLORETO to assess individual risk (phase1/2) and develop resilient plans for individual properties (phase 3/4). The summary of all the phases with corresponding objectives and methods are given later in the text and are depicted in Table 4-13.

4.3.2 Concept for raising hazard/risk awareness

The concept of raising hazard/risk awareness and the defined postulates have been implemented within the Flood Animation Centre (FAC), addressing the design aspects as given in section 3.4.1.1.

The facts (i.e. relevant flood information) are delivered in the form of digital GIS flood maps. Here, flood inundation data are provided for single spots and areas of interest (e.g. single properties) that are relevant for the users and are visualised by means of ***flood cylinders***[159] and a ***flood animation box***[159] .

Flood cylinders represent a set of 24 flood cylinders (2m, Ø20cm) (Geissler, 2006) that can be filled with water in real time, enabling envisaging and simulation of "real" flood events. They are connected to a GIS-flood map, enabling the user to fill the cylinders with water up to

[159] Those tools were originally developed and applied as single elements within the INTERREG IIIb Project FLOWS and are explained in Geissler, 2006 and Geissler 2014.

the level that corresponds to the flood probability of the location of interest (i.e. own property or neighbourhood). An emotional situation is created by walking through a “forest” of water columns, creating a feeling of a continuous water body surrounding the observers, which they can regard or even walk through (Pasche et al., 2007).

The cylinders are used for a better visualisation of the source characteristics, i.e. flood typology. For example, for the urban pluvial floods, the aspect of rapid and sudden raise of flood level is simulated by rapid filling of cylinders with water, which gives an idea on how uncontrollable such a process can be.

Flood animation box: The effect of the cylinders is supported by the envisaging of the *extent of potential damage* by means of the flood animation box ($2\times2\times2$ m) (Geissler, 2006). The box contents, which can be exchanged, are selected in a way to appeal to the emotions of the observers, showing a common situation/space in their daily lives (e.g. living room, office). The box elements demonstrate the vulnerability of different types of building fabric and inventory.

For the scope of this work, those two elements have been combined and connected to form one system, enabling a haptic demonstration of the elements of flood risk and their interactions. This interactivity between the elements of the FAC is achieved by the visual and functional interaction of the elements. The box is circled by the cylinders, creating the impression of their physical unity and where the cylinders represent the *source* of flooding and a threat for the *receptor,* i.e. flood box as depicted in Figure 4-18a. The water level in the flood box is coordinated with the water level in the cylinders, depending on the selected value in the flood map (Figure 4-18b). The users can interact with the FAC by creating different flood scenarios, but also by touching, feeling and moving the items of the flood box.

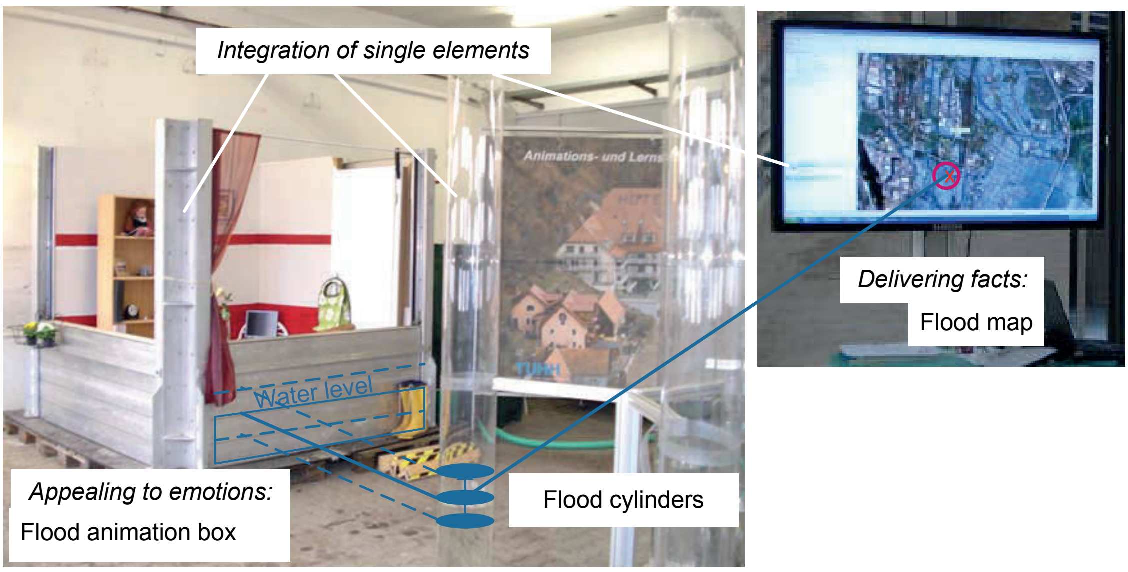


Figure 4-18 a) Conceptual design of FAC containing the main components

Media technology such as audio effects, animations, videos or light effects are used to support identification with the flood problem and strengthen the local context and relevance of the flood problem (e.g. filmed historic flood events in the area).

Appealing to emotions and further interactivity with the stakeholders in order to strengthen the experience effect has been achieved by the active involvement of the targeted stakeholders (dwellers) in the flooding process.

Within the flood simulation procedure performed in the flood animation box, the people or test persons are confronted with the situation of flood and the most critical issue during a flood event, which is the lack of time for decision-making. They have to take along the most important items (such as personal documents or the items that might be important in case they have to leave their homes for several days) and do not endanger their own lives.

This simulation should demonstrate the eventual weaknesses and unstructured reactions of their current behaviour in case of a flood event and make them aware that an efficient reaction without previous resilient measures can hardly be achieved.

Test persons should come from the areas potentially affected by floods, independently of age, gender or socio-economic and cultural background. Both inexperienced people, as well as the ones that already experienced floods can take part in the experiment. For assessing the performance of the experiment, interviews with the test persons before and after are conducted. The whole procedure is recorded, so that the behaviour can be analysed and discussed in detail after the simulation.

The simulation is composed of the following phases:

- *Preparatory phase*- devoted to setting the scene depending on the concrete situation (e.g. flood typology to be addressed).
- *Action phase*- during the simulated flood event, the test persons are given particular tasks to accomplish that correspond to the real situation in case of a flood (e.g. rescuing personal belongings or important documents).
- *Reflection & analysis phase*- after the simulation, the impressions are analysed and discussed. The individual flood situation is reflected on.

The frame program of the simulation event has been implemented as depicted in Table 4-3.

Table 4-3 Procedure of the flood training

Phase:	Time	Implementation
Preparatory phase	1-2 min	Begin and short introduction to the procedure
	1-5 min	Stepping into the box, getting familiar with the contents
	1 min	Test persons "living" in the box (e.g. reading newspaper, having a snack)
		Story depending on the given flood situation and relevance for the targeted group
Action phase	30 sec	Audio signal announcing flood (e.g. siren in case of a storm surge or thunderstorms and rainfall in case of pluvial floods)
	(30 sec)	Flood warning via megaphone (if applicable)

	max 5 min	Flooding of the box starts
		Response: Collection of items and temp store on the “safe” place in the box
		If not interrupted by the test persons before, the siren clears off the warning
	30 sec - 1 min	Flooding of the box finished. Getting out of the box
Reflection& Analysis	3-5 min	Interviews and wrap up

In the *preparatory phase*, the test persons get acquainted with the setting and enter the box. They should sit comfortably in the box and wait for the action. Before the simulation, the scenery has to be set depending on the addressed flood situation. The flood animation box is decorated as a home-like setting, creating a realistic situation and supporting personal identification of the test persons with the setting. Acoustic signals announcing a flood event are arranged depending on the flood typology. For example, for pluvial floods, acoustic elements such as rainfall or thunderstorms are used, whereby for storm surges, megaphone or siren should be prepared that to announce the case of emergency during the action phase.

In the *action phase,* the test persons are expected to react fast to the flood-warning signal.

For representing the situation in the most realistic way in a very small area and simulate the lack of time for action during a flood event, the test persons are given specific tasks. Those tasks are given depending on the flood typology and living situation in the area of concern and describe typical situations and operations that are to be done in the case of a flood. They can be divided into two main groups: *main* and *derived (side effect)* tasks. Main tasks encompass all operations that test persons are given to accomplish and are summarised in Table 4-4.

Table 4-4 Main tasks for simulation of a flood event in the FAC

Tasks	Items
Rescuing items of high intangible value	Important documents (e.g. ID card, passport, important contracts)
	Important data (hard disc, monitor, laptop)
	Photos, souvenirs, toys, books
Rescuing Items of high tangible value	Purse with money
	Souvenirs
	Jewellery
Collecting items of practical use for the given flood conditions	Glasses, medicines, cellular phone
	Pluvial floods: raincoat, umbrella
	Storm surges: emergency kit, cans
Taking safety measures	Switching off the electricity emergency switch

Those items should be temporarily stored in the box at a place which the test persons considered as safe (e.g. chair, or shelves), before they are finally evacuated from the box. While accomplishing those main tasks, some additional tasks emerge which the test persons have to accomplish. They are referred to as derived (side effect) tasks. For example, while rescuing different items some of the elements can get pushed by buoyancy forces and have to be secured. Such events further hinder the accomplishment of the main tasks and contribute to the chaotic behaviour. The arrangement of the items in the box should support the performance of those tasks as depicted in Figure 4-19. For example, the computer has to be fixed to the monitor and personal documents and purse with money stored in a “non obvious” place. The order and delivery of the tasks depends on the given conditions. Tasks can be given during the experiment or delivered before the experiments start. The experiment can be performed, both in presence or absence of observers. In the case with the observers the learning effect is extended to the whole group, which is supported by the discussion after the experiment.

In the *reflection& analysis phase*, the interviews and discussions with the test persons and observers are performed according to questions given in Appendix 4.4a. During the flooding procedure, 2-3 observers of the research team are present, taking notes, photographing or recording.

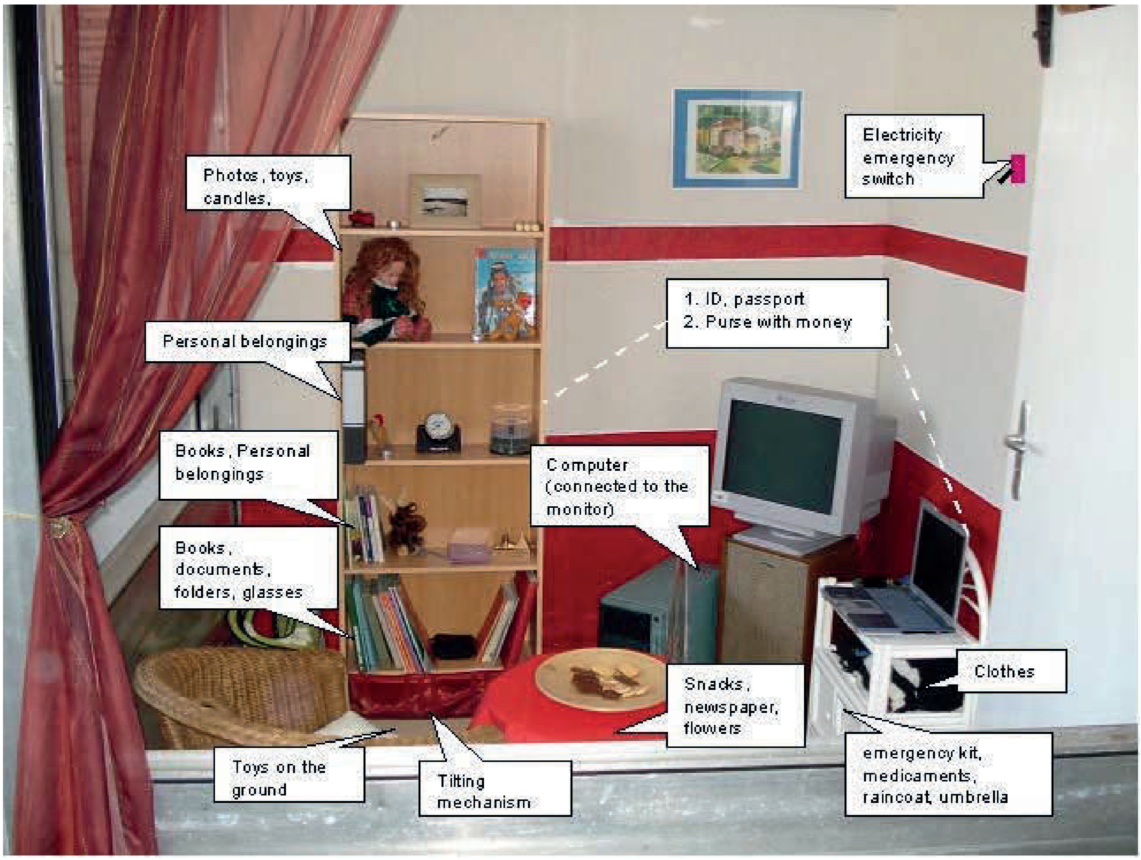


Figure 4-19 Setting of the flood animation box

A higher level of mobility and at the same time accessibility has been achieved by the development and implementation of a *road show*. In that way all elements of the FAC can be easily transported and assembled on site. A container (2,5 m x 6,0 m) has been used for the transportation and storage of the FAC elements: flood box, flood cylinders and multimedia. At the same time, its interior and elements (such as segmented doors, see Figure 4-20) are integrated into the scenery, optically and functionally. The neutral colour of the walls is a background emphasising the main element of the container – the flood box. The lawn in the container stresses the contrast between the “inside” and outside” of the flood box. Container walls are used to carry the monitors, which show the videos or depict flood maps that are connected to flood cylinders. The front wall of the box is transparent, enabling better observation of the process inside the box, i.e. flood simulation.

In this way, FAC can be exposed to larger groups of dwellers taking advantage of fairs or other public events. In this way the problem of accessibility of tools addressed in section 2.1.5.1. can be overcome.

Figure 4-20 Road show- container with the flood box

The main tools applied considering postulates of raising risk awareness are summarised in Table 4-5.

Table 4-5 Design aspects and implementation elements of FAC

	Design requirement	Implementation
1	Delivering facts	Flood maps delivered in a GIS based software
2	Appealing to emotions for creation of personal experience:	Flood animation studio: flood animation box flood cylinders
3	Interaction between single elements and the users:	*s-p-r-c:* Source-flood cylinders, Pathway/receptor- flood animation box Flood maps connected with the flood cylinders and flood animation box via GPS sensor and OpenGIS Technology *Interaction with users:* flood simulation

4.3.3 Concept for supporting autodidactic learning

The concept for supporting autodidactic learning has been implemented within the FLORETO-*Inform,* web based dissemination and learning tool implementing three different ways of delivering information/knowledge: *detailed, concise* and *interactive* as introduced in section 3.4.1.2. The three corresponding modules are given as *Tutorial*, *Knowledgebase-General Concepts (short: Knowledgebase)* and *Virtual Trainer*.

Tutorial (T)

Tutorial (T) delivers detailed knowledge about UFM focusing on flood resilience measures. The key issues are presented either in the form of a short, concise text or selected images put in the form of infographics, rather than using long plain texts. The infographics synergise the features of text and images, enabling dissemination of complex issues in a concise way. In order to enable easy navigation through the system, a consistent and easy to follow navigation tree is provided, where the user can easily switch from different topics and modules. Additionally, instead of having mere reading material as html pages, video sequences of e-lectures are used as depicted in Figure 4-21 a.

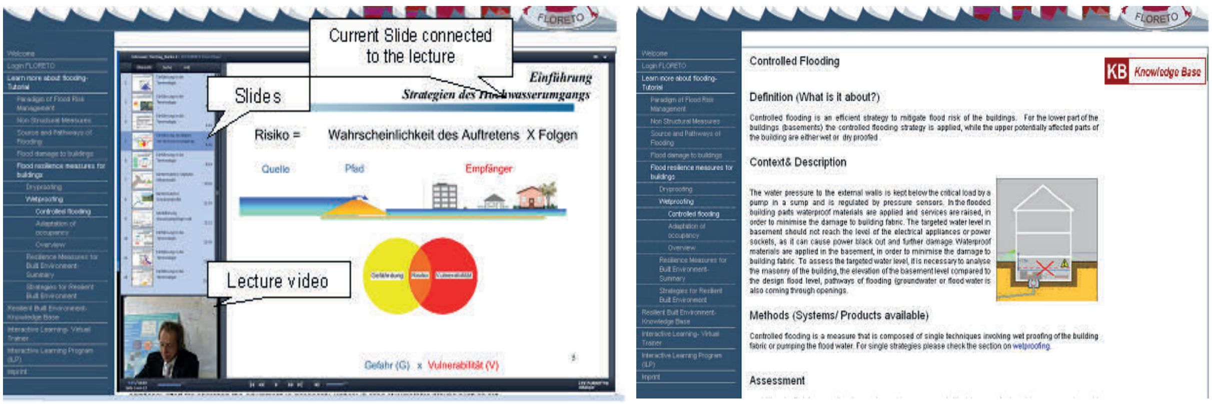


Figure 4-21 Examples of FLORETO-*Inform* for dwellers – a) Tas E-lecture b) Knowledgebase (KB)

The scope of the Tutorial covers the topic relevant to support the decision making process as given in Figure 3-15. Apart from delivering rather general information that can be considered as background knowledge (e.g. material on the source of flooding or flood resilience measures) which would correspond to phases 2 or 3 of the learning cycle, the tutorial contains rather concrete information and advice (such as how to apply waterproof concrete or which materials to use for making a building waterproof), which corresponds to its 4. phase.

Knowledgebase- General Concepts (KB)[160]

The objective of delivering concise and well-structured information on relevant issues has been implemented within the **Knowledgebase- General Concepts short Knowledgebase (KB)**. Access to those topics of UFM and FReM has been enabled via entry points. Those entry points are structured according to the following criteria:

I) Definitions of terms:

- *general terms* (e.g. 4As- safety chain of resilience)
- *abstract terms* (e.g. S-P-R-C model) and
- *concrete terms* (e.g. waterproof concrete)

II) Stepwise processes (e.g. assessing flood risk of the property, which explain the single steps to be performed when mitigating risk to the built environment)

III) Best practices (Performance of measures for the resilient built environment in real cases*)*

The selected entry points are organised in a logical structure and can be easily found and selected. It means that each of the relevant topics of flood risk management can be presented by a chain or tree of the subtopics, defining a flat hierarchical structure. This structure or mind map is depicted in Figure 4-22.

This map has a modular nature, enabling its further enhancement with new entry points or topics. Each KB page has a well-defined structure containing the subtitles, given as:

1. Definition (What is it about?)
2. Context& Description
3. Methods
4. Example
5. Assessment
6. Further Links

An example of a KB page within FLORETO is depicted in Figure 4-21b.

The KB is cross referenced with the Tutorial, enabling access to extended information on the selected topic.

[160] The Knowledge Base- General Concepts (KB) is not to be confused with the Knowledgebase of measures (KB- M). However, the KB-M can be inegrated into the KB.

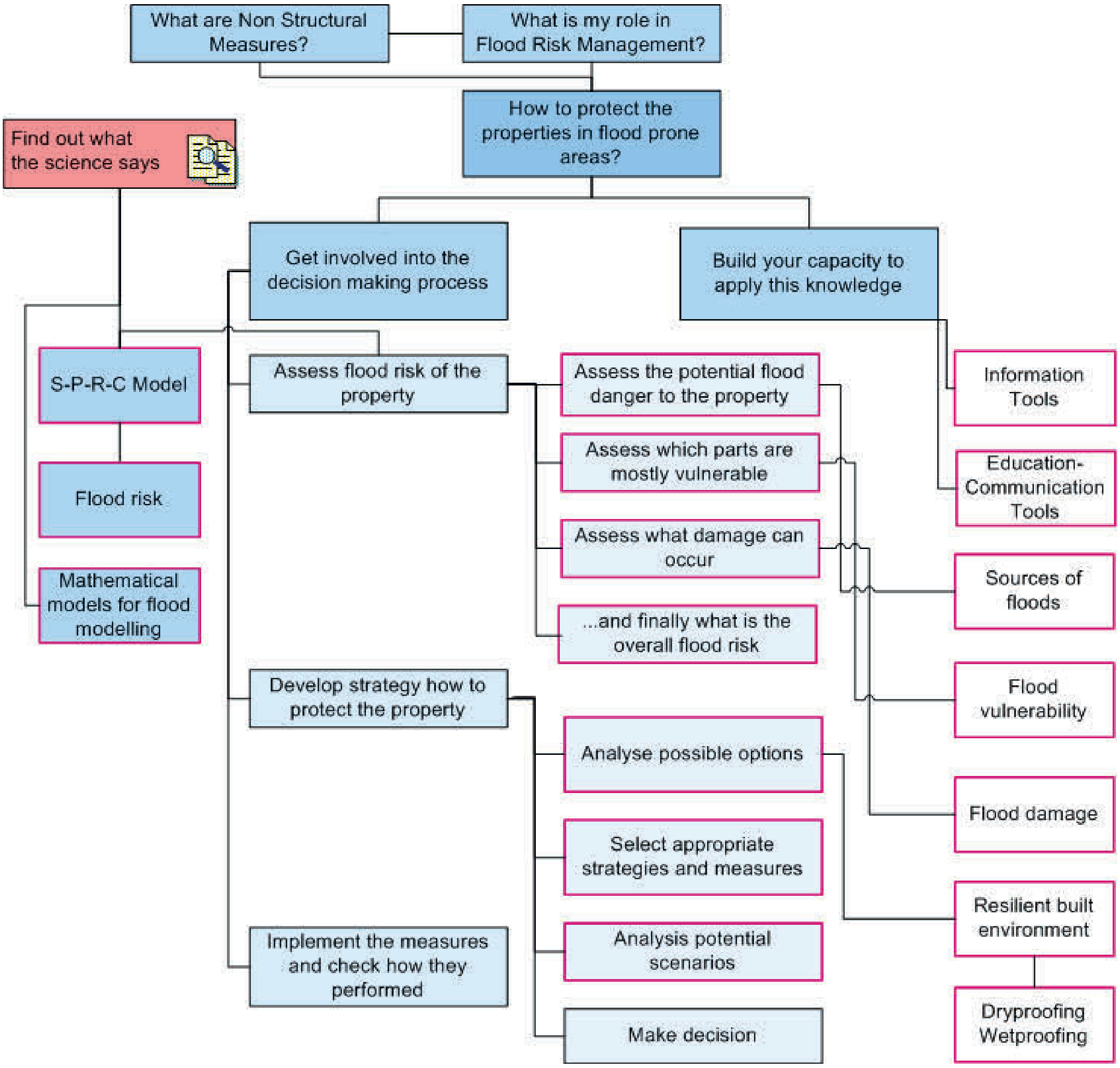


Figure 4-22 Mind map of the Knowledgebase (KB)

Virtual Trainer (VT)

The Virtual Trainer (VT) implements the interactive way of learning. The questions and answers sequences are defined and arranged in logical and traceable treads enabling interactive learning on the selected topic. Depending on the initial knowledge of the user, different knowledge sensitive sequences of questions are developed. The type of questions used is single or multiple choice or fill in a blank. The questions can contain text, photos, diagrams or video material. Correct answers end in a direct path through the topic whereas no or wrong answers evoke new sub-questions or end up in the Tutorial or Knowledgebase as depicted in Figure 4-23a.

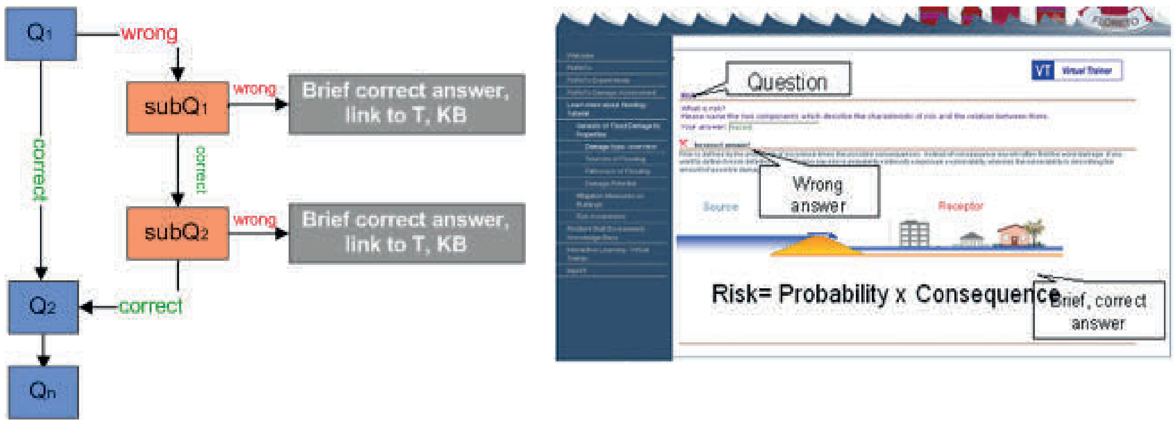


Figure 4-23 a) The concept of the Virtual Trainer (VT) (adapted from Pasche/Kraus/Manojlovic, 2006) b) example page of the VT

The implementation of the VT involves the Q&A sessions on the main thematic units being:

- Origin of flood problems in urban areas
- Flood risk management/ Flood resilience measures
- How to protect the built environment from flooding by applying flood resilient systems?
- Decision making for the resilient built environment on the property level

An example of a VT page is depicted in Figure 4-23b. Additionally, the VT contains tests for assessment of the efficiency of the ILP. They are discussed in section 4.3.6.

4.3.4 Concept for integration of capacity building and decision making process

Integration of the capacity building and decision making processes has been achieved in two main aspects:

I) Integration into Flood Resilience Portal:

1. FLORETO-*Inform* has been integrated into the *Flood Resilience Portal*
2. Communication platform for the face-to-face sessions has been integrated into the *Flood Resilience Portal*

II) Integration within the ILP

1. FLORETO has been integrated into learning phases of the Interactive Learning Program (ILP)

Integration of FLORETO-Inform into Flood Resilience Portal

Taking advantage of its web based architecture and having been provided a content management system for managing learning material, FLORETO-*Inform* has been integrated into the Flood Resilience Platform as shown in Figure 4-2. In this way the integration of the two processes is facilitated and the linkages between FLORETO and the modules of

FLORETO-*Inform* have been optimised. The added value of this integration is the visual (or even corporate) identity of these two tools, enabling a higher recognition value of both tools.

Integration of the sub-domain for the Face-to-Face Sessions into Flood Resilience Portal

A special part of the Flood Resilience Platform is designed as a collaborative platform supporting the process of ILP as depicted in Figure 4-24.

Figure 4-24 ILP sub-domain within the Flood Resilience Portal

Users that are at the same time the participants of the ILP can access the password protected domain and obtain all relevant information related to organisation of the session. Further, this sub-domain is linked to the *FLORETO-Inform* domain enabling easy coordination of the sessions and required materials to be prepared for each. This connection is made visible to users using the navigation bar on the right side as shown in Figure 4-24 and is referred to as the download and homework section. In this way, further visual and corporate integration of the two tools has also been achieved.

Integration of FLORETO into ILP

FLORETO is being integrated into the ILP learning cycle depicted in Figure 3-35. In the 2. phase of the learning cycle, devoted to "reflection on own flood situation", FLORETO is supporting the risk assessment of single properties. In the 4. phase, devoted to "applying knowledge to a concrete case" FLORETO is used for development of resilient plans for own properties. The way it is being integrated into the learning cycle is given in section 4.3.5.

4.3.5 Implementation of the Interactive Learning Program (ILP)

The ILP has been implemented following the framework depicted in Figure 3-35 as:

1. phase- face to face session "experience with floods"

The ILP starts with raising hazard/risk awareness. The Flood Animation Centre (FAC) is applied, giving local context and relevance to flood problems by using local flood maps and performing the flooding simulation.

The session starts with a short introduction to the scope of the ILP, followed by the part devoted to raising hazard/risk awareness and applying FAC. The implementation of the FAC takes place in two parts. The first interactive part of the session aims at generating experience or feeling for flood hazards by applying the flood cylinders. By means of a GIS system and available flood maps, the participants can experience a flood situation on their own property and play scenarios for different design flood events (e.g. 100-year flood). The second interactive phase implies conduction of the flooding simulation (see section 4.2.2). During the session, the participants are asked to note their impressions and comments or answer particular questions. Those questions are dependent on the concrete situation and participant groups. The general questions are given in Appendix 4.4b (IV).

Table 4-6 Implementation of the first learning phase of the ILP "Concrete experience"

Nr	Activity
1	Introduction to the scope of the ILP
2	Getting familiar with the FAC
3	Interactive phase 1: Creating flood scenarios using flood cylinders
4	Interactive phase 2: Flooding simulation
5	Summary and wrap up of the impressions

1.a. extended face to face phase from "experience with flood" to "reflection on own flood situation" supported by the autodidactic phase

Following the methodological framework given in Figure 3-35, personal identification with flood problems and increased risk awareness should induce reflection on the participant's own flood situation. This process is supported by meeting people from different stakeholder groups (residents, authorities, planners etc.) which have already experienced flooding or it is a part of their everyday business. It can help in building the personal identification of the dwellers-participants with the narrators, as exchanging experience with other stakeholders is assessed as one of the keys to successful action learning (e.g. Tippet& Griffins, 2007). Discussion with other stakeholders and facing real cases and problems improves holistic thinking about flooding, trying to understand interdependences among the processes, institutions or responsibilities.

The central figure of this phase, a narrator retelling his personal experiences, is being used as a means to improve the "experience" effect. He explains his flood problems and concerns, shows pictures or videos of the flood event on his property (Geissler, 2006). The participants also visit the affected houses (for example the narrator's house or properties in the vicinity). During the onsite inspections, the reflection on the causes and origin of floods to properties is being initiated by discussions on site. The dwellers-m participants are also given the "homework", which is to be done utilising the FLORETO-*Inform.* The topics from all three modules including E-Lectures (see Figure 4-21) are to be prepared as depicted in Table 4-7.

Table 4-7 Topics and material from the Flood Resilience Portal supporting the autodidactic and intermediate phase from "experience with flooding" to "reflection on own situation"

Tutorial	Knowledgebase (Entry points)	Virtual Trainer
- Flood risk management (part 1) -Origin of flood problems in urban areas - How to model floods - E Lecture: Flood Risk (S-P-R-C model)	- Source of floods - *What does science say about it*: mathematical models for flood modelling - *What does the science say about it*: S-P-R-C model	- Origin of flood problems in urban areas - Flood risk management/ flood resilience measures

The critical issues about the role distribution should be discussed. Participation of the authorities' representatives is of crucial importance in this phase as the dwellers have to understand the limits of institutional flood management and recognise the necessity for their own involvement. Regulations and legal frameworks related to public participation (e.g. in Germany the novelties due to the FCA, 2005, §31 of the WHG) should be presented. Also, the authorities should learn about the main concerns and problems of the dwellers and discuss them, establishing mutual trust between the parties.

2. phase- face to face session "reflection on own situation"

The personal reflections and the experiences of other stakeholders open questions which the dwellers- participants usually cannot answer themselves. The main learning objective of this phase is to create a basis for understanding one's own flood situation. It implies explanation of the complexity of (urban) flood risk management (UFM). Within this phase, flooding as a natural phenomenon as well as a social, institutional and ecological issue and the way they interfere with each other are explained and made more transparent. Flooding should be analysed on both levels, in general and by addressing concrete problems in the studied area including the individual properties of the participants. This phase should deliver the outcome that the participants understand the necessity and extent of their role in flood risk management. Understanding their role also means that they have to perceive the role of other stakeholders and their possibilities and limits. The residents should get an idea of the available resources of authorities and means to manage flood on the strategic/ operational level. Here the presence of the other key stakeholder groups is required, and these groups should present their positions and role in UFM.

The session starts with the introduction to the participants, querying their attitudes and expectations from the program. It is followed by the general introduction to UFM which should focus on the physical processes in the catchment, but also on the main legal, social and institutional aspects. The main issues addressed are depicted in Table 3-20. Short presentations on those main issues are given by the experts addressing both general problems but also the area specific issues. This is covered by the Tutorial and made available to participants within the sub domain of Flood Resilience Portal devoted to single face-to-face sessions (Figure 4-24). The program of the phase 2 is given in Table 4-8.

Table 4-8 Implementation of the second learning phase of the ILP "Reflection on own situation"

Nr	Activity
1	Introduction round: initial attitude, expectations
2	Introduction to UFM
3	Short presentation on the flood situation in the area (problem description as well as modelling results (http://floreto.wb.tu-harburg.de/index.php?id=83)
4	Position of the stakeholders-authorities: presentation on main activities of the relevant authorities
5	Discussion table: role distribution in UFM, deficiencies of current practice
6	Wrap up and feedback round regarding the key learning goals of the session

2.a extended face to face phase from "reflection on own situation" to "learning about resilience measures" supported by the autodidactic phase

The implementation of this intermediate phase is performed by visiting vulnerable spots relevant for the role of dwellers. As the role of residents is related to the protection of their own properties, the focus is put on tangible problems in the built environment on their own properties. The vulnerability of their houses is assessed, which further opens a discussion of how the flood situation can be improved. For this assessment, the participants are asked to describe their properties in FLORETO and analyse potential damage.

By means of FLORETO- Damage Module, the potential damage to single properties is assessed and discussed during a face-to-face session. In case of specific weak points or doubts, additional onsite inspection should be performed. Onsite inspections are additionally required in the case that the aspect of vulnerability and weak points of the urban system has to be extended to the neighbourhoods or districts level including bottlenecks of the local flood management facilities (e.g. retention basins with low capacity or hydraulic structures in the water course networks such as bridges or weirs in the vicinity). This also helps in clarifying the possibilities and limits of the local flood managers and authorities. The visited bottlenecks give a better insight into the local flood problems covering both aspects: reflecting on the concrete flood situation in the area and their own property, but also going a step forward by initiating the discussion on resilient measures that can be applied.

To further support the learning process and the preparation of the participants for the next learning phase, they are given assignments for home learning using the e learning platform on the topics as given in Table 4-9.

Table 4-9 Topics and material from the Flood Resilience Portal supporting the autodidactic and intermediate phase from "reflection on own situation" to "learning about resilience measures"

Tutorial	Knowledgebase (Entry points)	Virtual Trainer
- Flood resilience measures - Flood resilience measures and systems for built environment (part1) - Flood damage to buildings (part1)	- Resilient built environment - Dry proofing, wet proofing - Flood damage - Flood vulnerability	- How to protect your properties from flooding?

3. phase- face to face session "learning about resilience measures"

The main objective of this session is to introduce flood resilience measures by explaining and discussing the required expertise relevant for the role of private stakeholders. The examples examined and data collected within the intermediate phase serve to illustrate the extent of the problem and at the same time serve as a basis for the discussion on flood resilient measures. Those measures are presented in detail and discussed with the participants. Both general and concrete aspects of their implementation are considered and discussed according to Table 3-20. Collected and analysed data of weak spots (vulnerability and bottlenecks) in the local flood management (public and private) are presented and discussed, going step by step according to the central question of the workshop "How can I protect my property in an efficient way? or "How should I change my behaviour to comply with my role in urban flood management". A personal relation to presented problems additionally motivates the participants. The measures discussed serve as a basis for the last phase, where the gathered knowledge is applied for concrete cases by developing the solutions for their own properties. The implementation concept of phase 3 is given in Table 4-10.

Table 4-10 Implementation of the third learning phase of the ILP "Learning about resilience measures"

Nr	Activity
1	Introduction to the scope of the session
2	Feedback and discussion on assignment from the autodidactic phase
3	Presentation on flood resilience measures and resilient systems (http://floreto.wb.tu-harburg.de/index.php?id=81) and overview of different flood protection products (samples, videos, photos)
4	Vulnerability analysis based on the collected data via FLORETO-Damage module and onsite inspections
5	Discussion table: "How can I protect my property in an efficient way? How

	should I change my behaviour to comply with my role in UFM?”
6	Wrap up and feedback round regarding the key learning goals of the session

3.a extended face to face phase from “learning about resilience measures” to “applying knowledge to a concrete case” supported by the autodidactic phase

An overview of the relevant issues done in phase 3 can still be too abstract for participants as it does not give concrete hints on how to practice their role, which can lead to a hampering of the testing phase. Also, for most of the residents the application of resilience measures means a certain change in comfort and additional responsibilities (e.g. in case of application of demountable barriers), which requires further discussion on advantages and disadvantages of single measures. As they are related to something new and as such are *unknown*, reluctance to their implementation can exist. This phase therefore aims at increasing acceptance of the resilience measures among the residents by making them more tangible and understandable. As a basis for further discussion, the flood resilient plans delivered by FLORETO for the property descriptions performed in the intermediate phase 2a are used.

This intermediate phase is further used for visits to properties with already applied flood resilience measures and interviews with the owners/architects. Depending on the situation, both good and bad examples should be selected and discussed with the participants. The e learning material supports this process giving the required theoretical background as well as possibilities to test their knowledge in the virtual trainer as depicted in Table 4-11.

Table 4-11 Topics and material from the Flood Resilience Portal supporting the autodidactic and intermediate phase “learning about resilience measures” to “applying knowledge to a concrete case”

Tutorial	Knowledgebase (Entry points)	Virtual Trainer
- Flood resilience measures for built environment (part2) - Flood damage assessment of properties (part1) - Case study: Flood Resilience of the properties	- Resilient built environment - Dry proofing, wet proofing - Flood damage - Flood vulnerability	- Decision making on resilient built environment on the property level

4. phase face to face session -“ applying knowledge to a concrete case”

Within the last phase, the participants should apply the acquainted knowledge to a practical example, i.e. designing a flood resilient system for their own property. The results obtained by FLORETO are discussed in terms of their acceptance among the participants. Participants should express their concerns in terms of performance, maintenance or costs of measures. Also, each participant should identify which criteria are of importance for measure selection. After the resilient plans for each properties have been agreed upon, the participants have a hands-on experience by focusing on the details and design aspects of the measures of importance for them (e.g. aesthetic, performance) using paper and pen, plasticine, cardboard or even e- tools (such as e- whiteboards) and discuss the proposed measures with the other participants.

Table 4-12 Implementation of the learning phase “applying knowledge to a concrete case”

Nr	Activity
1	Introduction to the scope of the session
2	Initial discussion on the flood resilient plans obtained by FLORETO including discussion on assignment from the autodidactic phase
3	Discussion table: ”Discussion on alternative protection concepts. Criteria analysis for the selection of the final concept”
4	Measures for individual properties: “Hands on” experience: paper& pan or model making (e.g. cardboard, plasticine, wood)- representation of detailed with the focus on aspects of importance (e.g. aesthetic, performance related)
5	Wrap up and final feedback round regarding the key learning goals of the ILP

The phases of the ILP with corresponding methods and DM phases are given in Table 4-13.

Table 4-13 Phases and methods of the ILP with corresponding decision making stages

ILP Phase (Cap. Build)	Objective	Methods	Corresponding stage of DM
1.**Experience with flooding (p1)**	Triggering motivation, Raising flood awareness, Evoking memories on flood experience *“what does it have to do with me?”*	Haptic models: Flood Animation Centre (FAC) with flood animation box and flood cylinders Flooding simulation	
1a “experience with flooding to reflection” (ip 1-2)	Personal identification with the problem and initiation of the reflection process on own situation	Involvement of a narrator- a member of the SH group, sharing his experience Autodidactic preparation of the selected material in FLORETO-*Inform*	
2 Reflection on own situation (p2)	Demonstrating complexity of FRM (RBE) focusing on the problems on single properties *“what is going wrong?”*	Presentations on UFM, short videos, discussions with the key stakeholder groups on the issues such as: ▪ The source/reasons of flood? ▪ How can flood risk be assessed? ▪ What are the strategies of UFM? ▪ What is the role distribution of the key stakeholders? ▪ What is the leg. framework of UFM?	
2a “reflection to “learning about	Presenting vulnerable areas and spots in local UFM and own	Assessment of vulnerability of own properties by FLORETO Visits to the local bottlenecks and	Damage assessment

resilience measures" (ip 2-3)	properties	vulnerable sites of the local FRM (e.g. pumping stations, weirs), Autodidactic preparation of the selected material in FLORETO-*Inform*	Risk Assessment
3 Learning about resilience measures (p 3)	Delivering knowledge on flood resilience measures *"what can be done?"*	Presentation and discussion on local scale measures, their pros&cons, preconditions for their application using the examples from ***ip 2-3*** for generalisation of the concepts	Technical selection process Resilience plan
3a "learn about resilience measures to app. knowledge to a concrete case" (ip 3-4)	Demonstrating application of strategies and concepts delivered in ***p 3*** on concrete examples	Flood resilient plan of own properties by FLORETO Demonstration of concrete examples of applied measures, implemented in the area, Autodidactic preparation of the selected material in FLORETO-*Inform*	Resilience plan Option Analysis
4 Applying knowledge to a concrete case (p4)	Application of acquired knowledge to own flood situation *"what can I do?*	Developing plans for selected aspects of the resilient plan delivered by FLORETO (esthetical, performance) by means of sketch, plastic 3d models, e-whiteboard	Option Analysis Decision making
Assessment of resil. perform.	Assessment of behavioural changes after the ILP *"what have we achieved?"*	Questionnaires, oral feedback, phone interviews within a year after the ILP, Tests of Virtual Trainer	Implementation and assessment of resilience performance

4.3.6 Assessment of efficiency of the Integrated Learning Program

The last phase of the learning cycle finishes with an evaluation of the achieved resilience level. For the scope of this work the formative evaluation is performed (see section 3.4.2) by means of social science methods, such as questionnaires, interviews after the sessions or by making use of the interactive tests in the Virtual Trainer modus. The feedback after the sessions is based on open-ended questions in written and oral form, where the participants freely express their opinions or acquired knowledge (see section 3.4.2). The summative evaluation has been reduced to assessment of the application of flood resilient plans among the participants. Additionally the questionnaires for summative assessment that are applied before and after the program are given in Appendix 4.4b (I-IV). An overview of the applied methods depending on the criteria defined in section 3.4 is given in Table 4-14.

Table 4-14 Methods of assessment of efficiency of the ILP

Criteria	Method
Improvement of risk awareness	Formative: Feedback round after the first session
Acceptance of own role through improvement of understanding the relevant issues	Formative: Feedback round after the second session, VT test 1: "Understanding the processes"

Gaining knowledge/expertise	Formative: Feedback session after the "Testing" phase
Applying new knowledge (proactive behaviour)	Summative: Application of the flood resilience plan on own properties (interviews up to 1 year after the ILP)

In the case that the measures are applied and the flood occurred afterwards, additional assessment related to the efficiency of the resilient measures and flood protection products can be performed. The questionnaires are given in Appendix 4.4b.

4.3.7 Integration into the concept for the dwellers' involvement

The developed tools have been integrated into the framework for stakeholder engagement towards flood resilient cities shown in Figure 3-6 as shown in Table 4-15.

Table 4-15 Integration of the capacity building and the decision making process for the dwellers involvement

Nr	**Stakeholder involvement Strategy (Figure 3-6)**	**Capacity Building of Stakeholders- ILP (Figure 3-35)**	**Decision Making Phase (Figure 3-15) FLORETO**
1.	Scoping	"Experience with floods" Flood Animation Centre	
2.	Scoping/Understanding	Sessions and E Lectures on flood risk management (T,KB,VT)	Risk assessment utilising the FLORETO damage module
3.	Understanding	Sessions and E Lectures on flood resilient strategies and systems (T,KB,VT)	FLORETO Resilience plan for built environment - Parameter analysis
4.	Experimenting	Discussion of the FLORETO options and their impact on the overall system (Cross-scale analysis)	FLORETO Resilience plan for built environment- Technical selection process, Option analysis
	Evaluation and decision making	Performance evaluation	

The implementation of the integrated concept as depicted in Table 4-15 is performed within the Learning and Action Alliances (LAAs) method, which involves all relevant stakeholders in the decision making process (Ashely et al., 2008, Manojlovic et al., 2012) and follows the steps of the engagement process as given in Figure 3-6. The design and implementation of the overall LAA method has been beyond the scope of this work, but it has been used as a framework to embed the involvement of dwellers and study the efficiency of such a method to enhance the dwellers involvement.

5 Verification on case studies

5.1 Case study areas and research program regarding the parameters for verification

The developed and implemented methods and tools have been tested at different case studies. This process has been performed in two phases:

Phase 1. Testing and verification of the individual methodologies modules being:

- Methods and tools for the decision support on the resilient built environment
- Methods and tools for capacity building of stakeholders

Phase 2. Testing of the integrated application of the developed methods as a part of the stakeholder engagement process Learning& Action Alliances (LAAs)

The following aspects of the developed and implemented methods and tools for dwellers' involvement in the development of flood resilient cities have been verified/ tested at different case studies referring to the key research questions addressed in this work as listed in section 2.4:

Phase 1:

1- Theoretical model of the decision making process as summarised in Figure 3-15 with the main issues:

<u>I) Flood risk assessment:</u>

a. Parameterisation of damage curves for different building materials and compounds for different flood parameters and their combinations
b. Assessment of the perceived damage and acceptable risk among dwellers
c. Transferability of the damage functions

<u>II) Flood resilient plan for built environment:</u>

d. Validation of the parameters relevant for the definition of the resilience systems at the property scale as given in the knowledgebase of measures and described in chapter 3
e. Applicability of the defined resilient systems at the property scale

f. Cross scale analysis of the resilient systems relevant for the decision making on the property scale
g. Applicability of the CI algorithms for the technical selection process (accuracy of the models built)
h. Parameterisation of the MCA including CBA
i. Transferability of the methodology to different regions

III) Implementation and review

j. Relevance of the parameters for the assessment of the resilience level at the property scale (given in Table 3-4)

IV) Feedback options

k. The possibility to integrate the feedbacks into the business logic

2- The implementation of the decision making process- FLORETO as summarised in Figure 4-3 addressing the main issues:
   a. Technical performance of the tool and its components (GUI, BL, RDBMS):
      i. GUI: Technical reliability, robustness, completeness
      ii. Business logic: Technical reliability, robustness, operational time
      iii. Relational database management system: Technical reliability, robustness

   b. Acceptance of FLORETO among dwellers answering the following questions:
      i. Is the tool easy and free to use?
      ii. Is it assessed as useful?
      iii. Are the dwellers willing to use it for own properties? (Number of people using it, Number of people following the solutions the FLORETO delivered

3- The method for the capacity building of dwellers (Figure 3-35) implemented as ILP (Figure 4-17) with the main aspects to be tested given as:
   a. Raised risk awareness/ changed attitude towards own flood risk
   b. Acceptance of own flood risk
   c. Improved knowledge of flood risk management and flood resilient technologies and systems
   d. Proactive behaviour

The concept of capacity building has also been tested in terms of the tools developed given as:

Flood animation centre

e. Applicability of the methods and their comparison as presented in Table 4-3.

f. Raised awareness
g. Motivation of dwellers to further participate in the capacity building process

FLORETO –Inform

i. Acceptance of the tool as a part of the ILP among dwellers

Phase 2:

4- Engagement of dwellers within a stakeholder involvement framework towards flood resilient cities as summarised in Figure 3-6 has been tested regarding both, the aspects of the decision making and the capacity building process. The following criteria has been defined:
   a. Interest of dwellers to participate
   b. Raised risk awareness/ changes attitude towards own flood risk
   c. Acceptance of own flood risk
   d. Improved knowledge of FRM and flood resilient technologies and systems
   e. Proactive behaviour
   f. Possibility to apply FLORETO as a decision support system during the process

The obtained results of phase 2 are discussed in terms of the added value of the application of a combined method in comparison to the individual applications in phase 1.

In order to test/verify those aspects, a group of case studies has been selected based on the following criteria:

I) Data availability, which implies:
- The access to the required elements of the sociotechnical system (properties, dwellers, or other relevant stakeholders e.g. authorities or insurance)
- The availability of flood parameters such as flood maps, or any additional relevant information (e.g. presence of chemical or biological contamination)

II) Diversity of flood typologies:
- Riverine
- Pluvial
- Combined Pluvial& Fluvial typical for small urban catchments
- Lake
- (Storm surges)

III) Diversity of the elements of the sociotechnical system
- Built environment (old, new, refurbished or historic buildings)
- Social environment (societies with and without flood experience, low and high flood awareness)

Additionally, a regional spread of the selected case study areas has been considered in order to test the transferability of the developed methodology and tools.

The following case studies have been selected and used to verify/test the developed concepts and tools:

1. Lake Lucerne area, canton Nidwalden, Switzerland
2. Historic area of the City of Lauenburg, Germany
3. Hamburg Area, Germany with the focus on:
    a. The small urban catchment area of the river Kollau
    b. The urban catchment area of the river Wandse, Hamburg
    c. General aspects and attitudes regarding the flood management in the City of Hamburg

In order to verify the transferability of the tools (FLORETO) to other areas outside of Germany, a case study of Heywood, UK has been taken. Also, the area around the Lake Lucerne in Switzerland which has been used for the parameterisation of the damage curves, can be considered as a contribution to the transferability of the methodology developed.
The main aspects and modules to be tested with the associated flood typologies and characteristics of the sociotechnical system for the case study areas are shown in Table 5-1.

Table 5-1 Verification matrix- The aspects and modules to be tested with the associated flood typologies and characteristics of the sociotechnical system for the case study areas

Aspect/ Module	**Aspect**	**Flood Typology**	**Sociotechnical environment**	**Case study**
Phase 1: 1. Theoretical model of the decision making process as summarised in Figure 3-14				
I) Flood risk (damage) assessment	a. Parameterisation of the damage functions /`(functional and aesthetical) for the given sociotechnical system b. Assessment of the perceived damage and acceptable risk among dwellers c. Transferability of the damage functions	Lake	***Built:*** Old, New, Refurbished ***Social:*** Society with flood experience ***Other***: Mandatory Insurance	Lake Lucerne (Nidwalden), Switzerland Heywood, UK Hamburg, Germany

II) Flood resilient plan for built environment	d. Validation of the parameters for RS e. Applicability of the defined resilient systems at the property scale f. Cross scale analysis of RS g. Applicability of the CI algorithms for the technical selection process (accuracy of the models built)	Riverine	***Built:*** Old, New, Refurbished ***Social:*** Society with and without flood experience ***Other:*** Role of the authorities	Hamburg Area, Wandse, Germany, Lauenburg, Germany
CBA and MCA	h. Parameterisation of the MCA including CBA j. Transferability of the methodology to different regions	Riverine (large river)	***Built:*** Historic, Old, Refurbished ***Social:*** Society with flood experience ***Other:*** Low priority given to the problem	The city of Lauenburg, Germany, Hamburg Area
III) Assessment of the resilience performance	i. Relevance of the parameters for the assessment of the resilience level at the property scale	Riverine	***Built:*** Old, New, Refurbished ***Social:*** Society with and without flood experience	Hamburg Area, Germany
IV) Feedback options	k. the possibility to integrate the feedbacks into the BL	All		
2. The implementation of the decision making process- FLORETO				
a) Technical performance	I) Client Tier- User interface Technical reliability Robustness Completeness	Riverine	***Built:*** Old, New, Refurbished ***Social:*** Society with and without flood experience ***Other:*** Role of the authorities	Hamburg Area, Germany, Lauenburg
	II) Business logic Operational time Technical reliability Robustness	Riverine (small urban catchment)	***Built:*** Old, New, Refurbished ***Social:*** Society with and without flood experience ***Other:*** Role of the authorities	Hamburg Area, Germany
	III) Rel. Database management system Robustness Technical reliability	Riverine (small urban catchment)	***Built:*** Old, New, Refurbished ***Social:*** Society with and without flood experience ***Other:*** Role of the authorities	Hamburg Area, Germany

b) Acceptance by the users	i. Is the tool easy and free to use? ii. Is it assessed as useful? iii. Are the dwellers willing to use it for own properties? (Number of people using it, Number of people following the FLORETO solutions	Riverine& pluvial	***Built:*** Old, New, Refurbished ***Social:*** Society with and without flood experience ***Other:*** Role of the authorities	Hamburg Area, Germany
Transferability of the developed methodology and tool	Applicability of the method and tool to other regions	Riverine & pluvial	***Built:*** New, Refurbished ***Social:*** Society with and without flood experience ***Other:*** Role of the authorities and insurance	Heywood, Manchester, UK
3. The methods and tools for the capacity building of dwellers				
ILP (including FLORETO-Inform)	a. Raised risk awareness/ changed attitude towards own flood risk b. Acceptance of own situation c. Improved knowledge on FRM d. Proactive behaviour i. Acceptance of FLORETO Inform	Riverine & pluvial (small urban catchmen t)	***Built:*** Old, New, Refurbished ***Social:*** Society with and without flood experience ***Other:*** Role of the authorities	Hamburg Area, Germany
Flood Animation Centre	e. Applicability of the methods and their comparison as presented in Table 4-5. f. Raised awareness g. Potential to motivate dwellers to participate further in the learning process	Riverine & pluvial	***Built:*** Old, New, Refurbished ***Social:*** Society with and without flood experience ***Other:*** Role of the authorities	Hamburg Area, Germany
Phase 2: 4. Involvement of dwellers in a stakeholder engagement process as summarised in Figure 3-6				
Integration of ILP and	a. Interest of dwellers (number of	Riverine	***Built:*** Old, New, Refurbished ***Social:*** Society with and without flood	Hamburg Area, Germany

FLORETO	people participating) b-e. as for the ILP f. Possibility to apply FLORETO as a DSS during the process		experience ***Other:*** Role of the authorities	

5.1.1 Lake Lucerne, canton Nidwalden, Switzerland

5.1.1.1 Flood typology

The area around lake Lucerne in canton Nidwalden has suffered several flood events in recent years. The main flood events in the area took place in 1999 and August 2005. The event of 1999 corresponded to a 50 year flood with 434.93 m a.s.l. Although the event of the summer of the 2005 reached only a 30 cm higher water level (435.23 m a.s.l), it corresponded to a 300 year flood event (NSV, 2005)), causing a total damage of CHF 110 million in which damages to private and public houses reached the value of CHF 47 million[161]. The event of 2005 was a result of very intensive rainfall between the 19^{th} and 23^{rd} of August which reached 200 mm/m^2 (in some regions even 300 mm/m^2[161]). Heavy rain caused lakes and rivers to burst their banks, triggering severe flooding and showing the limits of the existing flood protection. The flooding caused interruption of daily business in the affected residential area for a week and especially affected tourism. An example of a building exposed to the flood of 2005 is given in Figure 5-1a. The study area is indicated in Figure 5-1b.

Figure 5-1 a) Flooding in Nidwalden in 2005 (courtesy NSV) b) the study area in the canton Nidwalden (map taken from https://www.google.de/maps)

The flood parameters considered for the study are given in Table 5-2.

[161] Internal documents NSV

Table 5-2 Flood parameters considered in the Lake Lucerne study area

Flood factor	Values
Flood type	Lake
Water depth h_j [m]	Given for each analysed building separately (provided by the insurance company NSV)
Velocity v_j	<2m/s
Duration d_j [h]	3days<d<14days
Oil content c_{oil} [g/m^3]	Given for each building separately (based on the presence of an oil tank in the building)

5.1.1.2 Sociotechnical system

<u>Social Environment</u>

Due to the recent flood events around lake Lucerne, people are generally aware of the flood hazard. Still, the motivation for active participation in flood management by undertaking measures on individual properties is rather low (NSV, 2006, Geissler& Manojlovic, 2006). At the same time, the potential for implementation of the resilience measures has been assessed as high[162] by the NSV, which calls for a detailed analysis of the present situation concentrating on the assessment of damage reported and the potential for its reduction through property scale resilient systems. Regarding the socio economic conditions in the area, it is a predominantly residential and tourist area with private housing as well as summer residences and recreation facilities indicating a high damage potential162.

<u>Built Environment</u>

The building fabric in the examined area, which has been assessed based on the survey and data collection performed by the insurance company NSV, predominantly belongs to that of buildings constructed in the period of 1960 to the present. The old buildings are generally in good condition and mostly refurbished.

<u>Other elements of the sociotechnical system relevant for the involvement of dwellers</u>

The dominant factor defining the institutional settings and shaping the behaviour and level of risk awareness of the local stakeholders in the area is the existence of the obligatory insurance system practiced through the Nidwaldner Sachversicherung (NSV). The policy of the insurance company in the past and including recent flood events was full reimbursement of the reported damage, without considering its justification. An example is the event of 2005. Also the insurance company NSV is willing to support the dwellers that are ready to implement flood resilient technology, reimbursing 10% of the overall costs.

[162] Personal communication with Mr M. Kohler, CEO NSV, June 2006

5.1.1.3 Objectives

This study area has been used for testing of the theoretical concept for the decision making process given in Figure 3-15, which is to be implemented within FLORETO (phase 1). The focus has been put to the step I- Flood risk assessment and given as follows:
O1: verification of the damage assessment method in terms of parameterisation of the damage functions both, functional and aesthetical. (I-1,2,3)
O2: assessment of the perceived damage and acceptable risk among the dwellers (I-4)

5.1.1.4 Research program

Based on the data obtained from insurance company NSV (Nidwaldner Sachversicherung), an analysis of damages has been carried out. The data provided were taken on site by the experts of the NSV or reported by dwellers. Data collection performed by the insurance company has been performed after the flood events 1999 and 2005. The most of data that was made available by the NSV dates from the year 2005.
This information has been extended to the data collected during the personal visits of the selected buildings.

O1:verification of the damage assessment method in terms of parameterisation of the damage functions both, functional and aesthetical. (I-1,2,3)
Out of the collected damage records, 37 residential buildings were selected and the damage which occurred to them investigated. The selection of objects depended on their type (only the private ones have been taken for study) and availability of good quality data and graphical material (plans, photos, drawings). Additionally, some selected objects have been personally visited (in total 25). The selection criteria for the onsite visits was the damage level and typology and the willingness and availability of the dwellers. The obtained and collected data has been anonymised and are given in a tabular form in Appendix 5.1.
This reported damage as stated in the documents provided by the insurance company NSV and collected onsite during the personal visits has been compared with the assumptions made to derive the physically based approach for damage assessment presented in Chapter 3 and implemented within FLORETO.

The system description together with the parameters to be verified at the case study area Lake Lucerne have been summarised in Table 5-3.

Table 5-3 System description (left) and parameters to be verified (right) in the Lake Lucerne area

Flood Typology	Lake
Sociotechnical	New/ old buildings

Verified Modules	Aspect
Decision making process	

system	Medium risk awareness High income society Insurance	Damage assessment method	- Parameterisation of the functional damaging functions - Assessment of the perceived damage and acceptable risk among the dwellers

O2: **assessment of the perceived damage and acceptable risk among the dwellers (I-4)**
The damage reported by the dwellers has been analysed and the main factors contributing to its extent assessed. The list with the main arguments as the motivation to report the damage reported has been developed, which feeds back into the analysis of the aesthetical damage functions analysed within O1.

5.1.2 Historic area of the city of Lauenburg, Germany

5.1.2.1 Flood typology

Lauenburg is a town situated in Schleswig-Holstein, Germany on the northern bank of the river Elbe, east of Hamburg (Figure 5-2a). It was founded in 1209[163] and nowadays its historic area is well known for its century timber framed buildings and the beauteous riverbank silhouette. The urban structure is rather dense, forming a tight front to the river Elbe and leaving small gaps between the buildings, so called "twiete" as shown in Figure 5-2.

Figure 5-2 a) The location of the City of Lauenburg b)The riverbank silhouette of the Lauenburg historic area with the corresponding plan view (highlighted buildings are affected by 25- year flood)

The recent flood events on the river Elbe in 2002 and 2006 reaching respectively 8,80 asl 9,10 asl considerably affected the historic area, devastating the historic building fabric and causing financial losses to the local economy, which is mostly based on tourism. Facing the situation

163 http://jubilaeum2009.lauenburg.de (last accessed: January, 2015)

of increasing probability of flooding on one side and willingness to preserve the historic area on the other, there is a need for immediate action incorporated into the changes of communal flood risk management, which opens room for the research on the appropriate flood resilient systems.

5.1.2.2 Sociotechnical system

Social Environment

Due to this proximity to the river, the old settlers of the historic area mostly have learnt to live with floods and this experience has been gained and collected through generations[164]. However, a number of new settlers have never experienced flood before and have rebuilt their houses and mainly basements

Built environment

The historic area of Lauenburg is mainly composed of the historic buildings located along the river Elbe as shown in Figure 5-2. A detailed study of the built environment is a part of the research program and will be presented in the section where the objectives have been presented.

Other elements of the urban system relevant for the involvement of dwellers

In the federal state Schleswig- Holstein, inland flood management has been given lower priority, pushing forward flood management along the coastline. In that sense, the financial resources for the large scale investments in the inland flood management are limited[165]. Apart from the limited resources, the case study area is located on the river bank as shown in Figure 5-2 and as such delivers additional motivation to explore the possibility of flood resilient systems at the property or neighbourhood scale as an alternative to the large scale flood defence structures.

5.1.2.3 Objectives

This study area has been used for testing of the theoretical concept for the decision making process given in Figure 3-15, which is to be implemented within FLORETO (phase 1).

O1: testing the impact of the building condition on the damage assessment and parameterisation of the damage curves (I-2)
O2: assessment of the perceived damage and the acceptable risk among the dwellers (I-4)
O3: applicability of resilient systems on different scales (II-1,2)

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[164] Personal communication with the local authorities- Planning department (Mr. Nieberg and Ms Manuel)

[165] Personal communication MLUR, December 2006

O4: verification of the key criteria of MCA for final selection of the resilient plan for dwellers (II-3)
O5: verification of the resilience parameters (III)
O6: testing the GUI for data collection (technical reliability, robustness, completeness

5.1.2.4 Research program

O1: testing the impact of the building condition on the damage assessment

1. The data describing the sociotechnical system (focusing on the built environment) following Table 3-19, has been collected by the "door to door" data collection procedure, according to the forms given in Appendix 5.2. Three team members (one research assistant - the author of this Thesis and two students) performed the data collection within 3 months. Data has been collected by means of personal interviews, photos and a visual assessment of the building fabric and its condition. The inventory data has been collected either by visual assessment or by interviewing the dwellers on the type and value of items in the house which could not be seen or due to their personal nature they were not willing to expose. The study area is given in Figure 5-3.

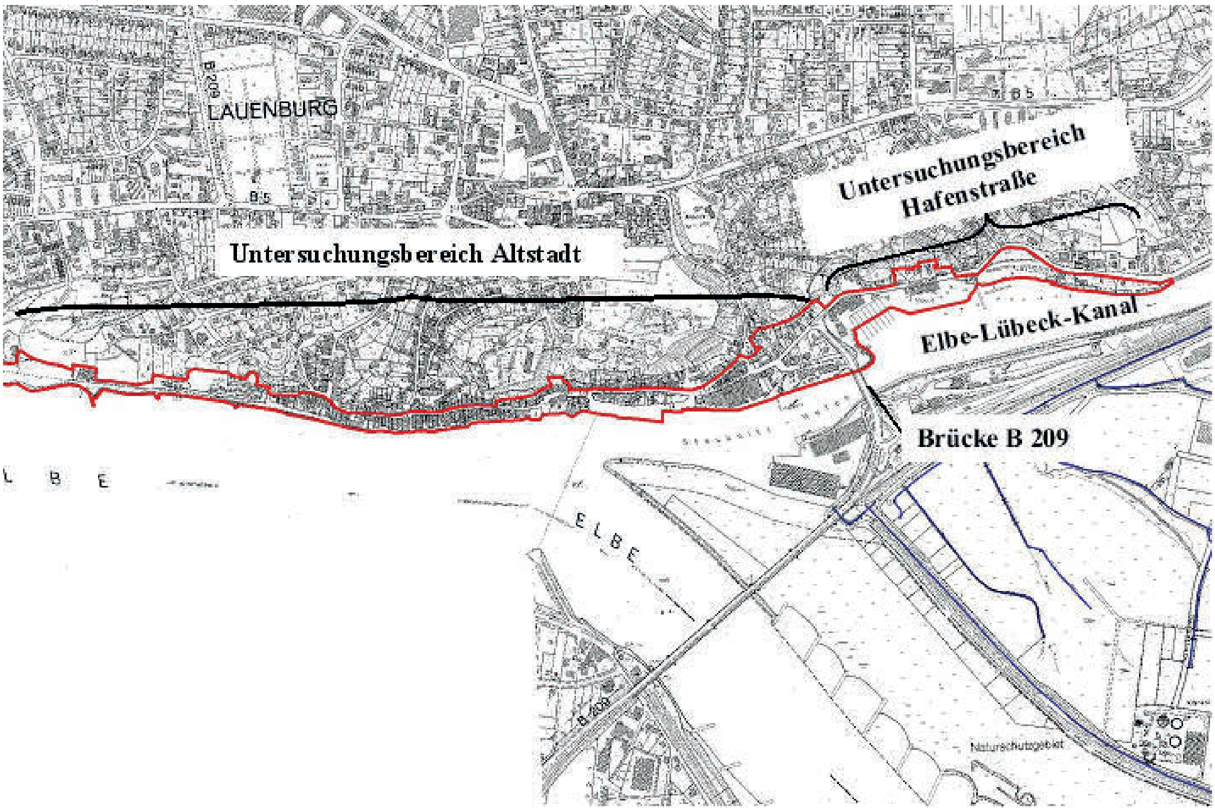


Figure 5-3 The study area in the historic city of Lauenburg (indicated as Untersuchungsbereich Altstadt)

The overall number of the buildings visited in the study area amounts to 123, which represents 90% of all targeted buildings. The buildings are stored in the FLORETO database.

During the data collection procedure, the buildings have been classified based on their condition (old, old-refurbished, new).

For the flood probability assessment, the data has been obtained from the Waterways and Shipping Office[166] and is given in Table 5-4. For the planning procedures the water level of 9,70 m asl has been selected, which corresponds to the 100 year flood event.

Table 5-4 Probability data for the City of Lauenburg (source WSA, 2006, personal communication)

a.r.i	1	2	10	20	25	50	100
Water level [m asl]	5,25	7,35	7,95	8,45	8,60	9,10	**9,70**

2. The damage has been estimated based on the onsite assessment of the necessary repair works and refurbishments which implicitly consider the building condition. The conclusions have been derived to which extend the building condition contributes to the final damage.

O2: Assessment of the perceived damage and acceptable risk among dwellers (I-4)

During the data collection procedure as given in O1, the dwellers have been interviewed about the refurbishments undertaken after the flood events and about the acceptable level of damage. The questions posed are given in Appendix 5.2.

O3: Applicability of resilient systems on different scales (II-1,2)

Different flood resilient systems (FReS) at the neighbourhood scale introduced in section 3.2.4 have been applied and their efficiency and cost effectiveness have been analysed. The relation between the FReS at the property and neighbourhood scale has been analysed. In order to define the resilient systems for the given built environment, six typical (representative) buildings have been selected based on the criteria as given in Table 5-5 for which the technical selection process has been performed.

Table 5-5 The key parameters describing the system which serve for the building type definition in the Lauenburg case study area

Parameter group	Parameter value
Terrain configuration/ Location	Riverside, hillside
Basement	y/n
Pathway of the flood water (considering the design water level as shown in Table 5-4)	Walls, openings in basement and/ or ground floor

O4: Verification of the key criteria of MCA (including CBA) for final selection of the resilient plan (II-3)

[166] http://www.wsa-lauenburg.wsv.de/ (last accessed: January, 2015)

The criteria defined in section 3.6.2 are ranked and rated, based on both, the expert knowledge and the dweller's perspective, assessed by the means of interviews, info sessions and questionnaires. The template of the questionnaire used for the interviews is given in Appendix 5.2. The costs and benefits have been calculated applying the approach presented in chapter 3. For the calculation of benefits, the results from the activities as stated in O1 have been taken. The considered costs are given in Appendix 3.4. The weighting scale applied for the MCA is given in Table 5-6.

Table 5-6 The weighting scale applied for the MCA

Value	Description
0	No relevance
1	Low relevance
2	Medium relevance
3	High relevance

O5: Verification of the resilience parameters (III)

For the defined buildings given in O3, the resilience assessment has been performed without any resilient systems and with different resilient systems. The relevance and completeness of the defined parameters have been evaluated.

O6: testing the GUI for data collection (technical reliability, robustness, completeness

The data collected in the Lauenburg study area following the forms given in Appendix5.2 have been entered in the FLORETO database utilising the GUI by an experienced researcher and two students. An example of the collected building data stored in the FLORETO database is given in Figure 5-4.

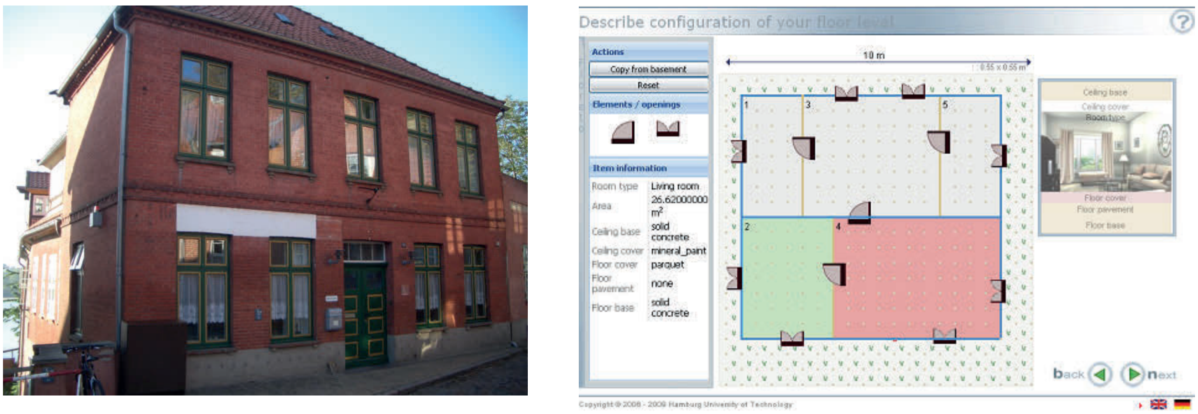


Figure 5-4 Data collection at the study area: a) an example of a building and b) its conversion in FLORETO

The data collected describe different types of buildings so that the GUI could be evaluated in terms of its completeness, technical realibility and roboustness.

5.1.3 Hamburg Area, Germany

The city of Hamburg is the second-largest city in Germany and the eight-largest city in the European Union[167]. It is located in North Germany at the Elbe estuary, about 110 km away from the North Sea (Figure 5-5). The port of Hamburg is the third-largest port in Europe, and the eighth largest in the world.

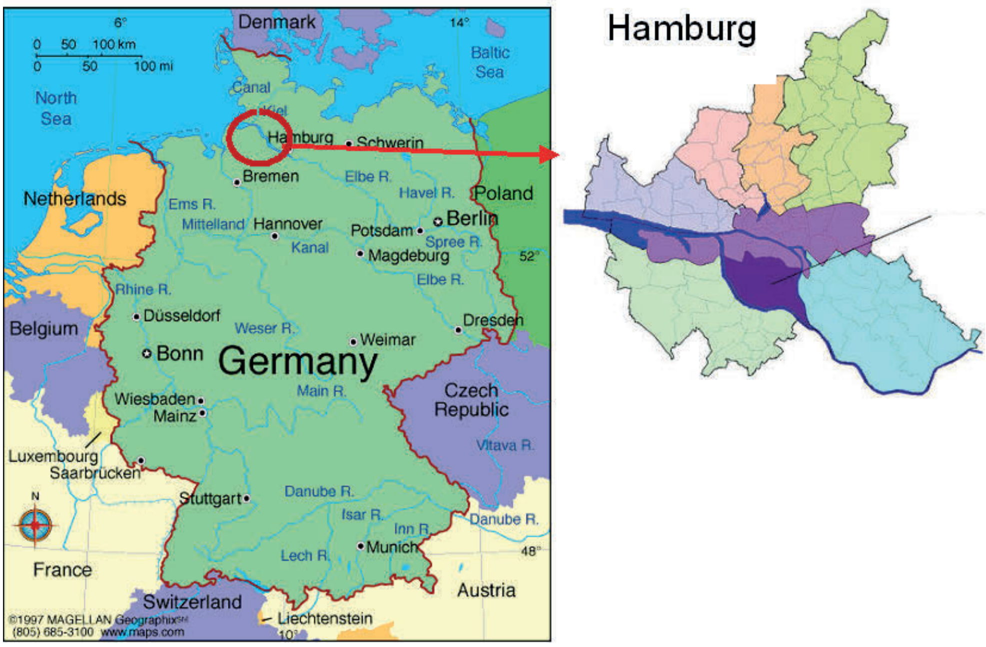


Figure 5-5 Location of the city of Hamburg (taken from Tadesse, 2010)

The spatial development activities of the city can be summarised under the long term overarching strategy "*the growing city*" set by the Senate in 2001 (BSU, 2007). Based on this concept, Hamburg should intensify its economic and social growth, constantly improving its image and the quality of living. Setting those goals as the key principles of future development, this strategy of "growing city" decisively shapes the urban development, causing constant changes in the existing urban landscapes and social structures. The areas with a high potential for development have been identified as summarised in Figure 5-6.

Development of those areas highly interacts with water regimes of the river Elbe and its tributaries as well as the watercourse network in the city. For example, the Hafen City and the Harbour area are directly located at the river Elbe, whereby the new city centre in Wilhelmsburg or urban infill in the northern part of the city interacts with the watercourse networks and their hydrologic regime. In Hamburg tide and storm surges have an impact on the flow regime of the river Elbe leading to a tidal range of 3.5 m. In order to protect the adjacent areas to the river Elbe, wide parts of the urban area are protected through a system of dikes and walls with a total length of about 100 km with the height between 7,6m to 9,0m above the mean sea level (Pasche et al., 2008a).

[167] http://www.citymayors.com/features/euro_cities1.html (last accessed: January, 2015)

In that sense, the urban development and flood management cannot be regarded separately.

The focus of this work has been put on the following issues related to the main flood typologies:

- The Hamburg area- general, covering the issues of the dwellers' perception of floods and the potential for their participation in flood risk management addressing the issue of storm surges
- Focus area 1: Kollau, small urban catchment
- Focus area 2: Wandse, small urban catchment

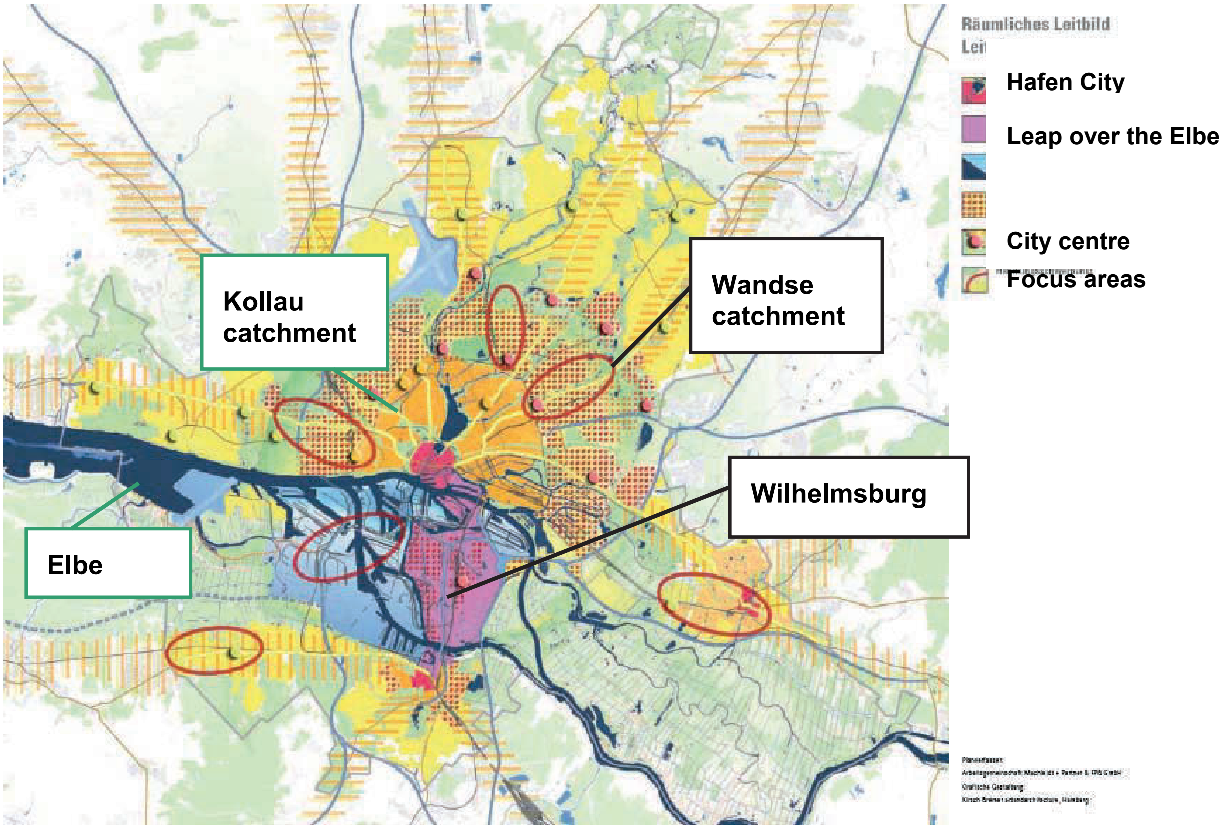


Figure 5-6 The focus areas for applying the "growing city" strategy in Hamburg (map: BSU, 2007)

5.1.3.1 Flood Typology

The City of Hamburg

The two main flood typologies in the city of Hamburg can be summarised as: storm surges of the river Elbe and the combination of pluvial and riverine floods in small urban catchments (BSU, 2007). Whereby the storm surges aspects have been analysed on a rather general level, assessing the perception of dwellers and the potential for their involvement in the flood risk management, the problems in small urban catchments have been analysed in more details addressing both, the decision making and the capacity building process.

The city of Hamburg has suffered from storm surges several times in the past. The most notable ones were the years 1825, 1855, 1962 and 1976 floods. There are even folklores dating back to the 14th century about the “great man drowning” (von Storch et al., 2008).
The storm event in the recent past with the strongest impact on the Hinterland occurred in 1962. Several dike breaches led to a catastrophe flooding which affected wide parts of Hamburg and especially the island Wilhelmsburg with more than 300 casualties and causing the overall damage of 350 Mio € in the whole area of Hamburg. This led to a dike enforcement program, in which a ring dike around the island has been raised twice in the last 40 years. Consequently, the higher storm surge in 1976 (see Table 5-7) did not cause any damages in Wilhelmsburg (taken from Pasche et al., 2008a)
After the disastrous event of 1962, the dike heights were increased to as high as +7.20m. The design of the dike was also modified. Currently, the design flood stage is 85cm above the highest recorded stage (Nehlsen et. al., 2007).

Table 5-7 -Storm surges in Hamburg NN (NN = “Normalnull”, corresponds to the mean sea level. The middle water stage reaches in Hamburg around 2,09m over NN) (Nehlsen et. al., 2007)

17.02.1962	NN + 5,70 m
03.01.1976	NN + 6,45 m
09.11.2007	NN + 5,42 m

Nowadays, Hamburg has a well-developed and organised flood management related to the storm surges with in total 103 Km of the defence structures (LSBG, 2012[168])
However, some areas are located in front of the dikeline. The most prominent example is the Hafen City area[169], which is either built on the dwelling mount or protected utilising flood resilient technology for individual buildings.
Also, even if the design figures are far larger than the maximum water stage, the high uncertainties associated with the climate change figures (IPCC, 2007) and the ever-increasing importance of the island, raise questions on how safe the defence structures are (e.g. Grossmann et al., 2006). Grossmann et al, 2006 estimate the uncertainty range of ±20 cm and ±50 cm for the scenarios 2030 and 2085 resp, which can cause the dike overtopping at certain locations, such as the ones in Wilhelmsburg and the vast damages associated with it. This calls for the capacity building activities even in the areas that are behind the dikes.

The floods in small urban catchments have been given importance only in the past years due to extreme events that caused high damages. The extreme flood events in summer 2002 that

168 LSBG, 2012: personal communication, June 2012

169 http://www.hafencity.com/en/home.html, (last accessed: Januaury, 2015)

are a combination of pluvial and riverine floods in small urban catchments in the city of Hamburg caused damage of more than €15 Mio (Pasche et al., 2008). Those floods have a rapid growth in reaction of an extreme local storm event that they are often compared to flash floods. This fast and intensive reaction is due to small drainage areas with high degree of impervious surface and a limited conveyance in a dense pipe network. At the end of these drainage area, a small open watercourse receives this overflow, which due to encroachment in small compact channels and culverting act like a bottleneck causing unexpected and underestimated flooding of urban environment. The specific conditions of the two studies small urban catchments are described in the following text.

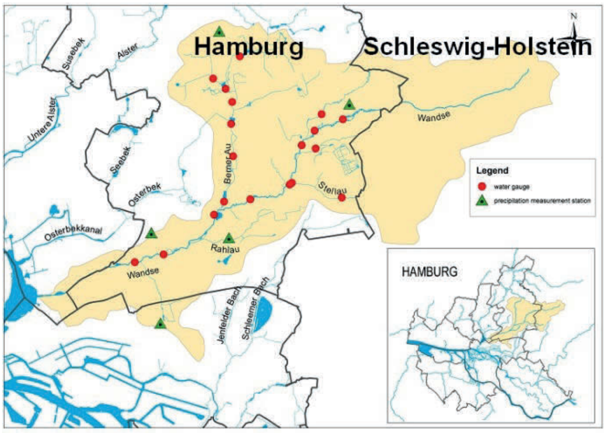
Focus area 1: The Kollau catchment:

Kollau is a small urban water course in the north of Hamburg with a total length of 7,3 km and with a corresponding catchment area of 34 km^2 (see also Figure 5-6). It is a densely populated urban area which has reached a population growth rate of 13,25 % for the period of 1987-2004, which is highly above the average rate in Hamburg (4,42%). Also, the new housing in the same period increased by 20,63% which is still higher that the average rate in Hamburg (10,30%) (Gätkens, 2007). Regarding the flood situation, the events of August 2002 caused considerable damage in the Kollau catchment, where during the flood event from 1st, August 2002, 26,82 mm of rainfall fell during a period of 2 hours and 16 min, causing blockage in the drainage system and damage to properties in the Kollau area as shown in Figure 5-7 (Pasche et al., 2008).

Figure 5-7 a) Kollau water course b) Kollau flood event 2002 (courtesy: city of Hamburg)

Focus area 2: The Wandse catchment:

Wandse is an urban catchment of about 87 Km^2, whereby 60 Km^2 is located in the Hamburg area. In terms of its topographic characteristics it is considered as a low-lying area (0-80 m as), spreading from the NW to SE. The upper catchment is close to the natural state dominated by farmland and nature protection area. Main urban area, located in the mid and lower catchment, is a high density residential area, dominated by detached buildings (23,85% out of all landuse types in the Wandse catchment). Industrial area is mostly located in the mid and lower catchment area, partly directly at the river (e.g. Yeast factory at the Km 4.500 or a commercial centre encroaching the river Wandse at the Km 12.162). 66,6 % of the catchment drains in the separate system, the lower catchment part to the combined sewerage system (LSBG[170]). The main characteristics of the Wandse catchment are summarised in Figure 5-8.



Topography:
- predominantly lowland
- 6-48 m a s l

Soil type:
- dominated by medium to light clayey sand

Urbanisation type:
- differentiated; upstream and middle part areas are closer to the natural state

Sewerage system:
- partly combined, two third of sewer system is of separate nature

Figure 5-8 Summary of the main parameters characterising the Wandse catchment (source: LSBG)

In terms of its flood typology, this catchment is characterised by a combination of pluvial and fluvial floods. An example of the flood hazard map for a 100 and 200 year flood events is shown in Figure 5-9. Also, due to the climate change, an increase in precipitation and the consequent flood events can be expected (KLIMZUG Project, Hellmers et al., 2013)

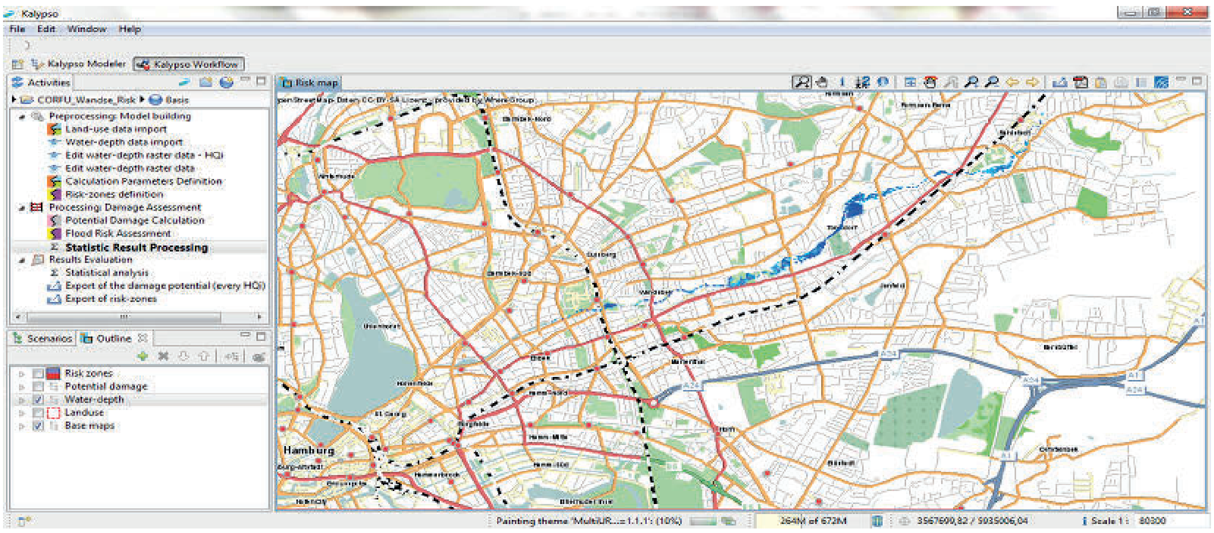


Figure 5-9 An extract from the flood hazard map for the river Wandse envisaged utilising the Kalypso-RISK module (source: Hellmers et al., 2013)

[170] The informaiton has been derived based on the GIS data provided by the LSBG and personal communication.

5.1.3.2 Sociotechnical system

Social Environment

The City of Hamburg[171]

Hamburg counts 1.783.975 inhabitants (Hussing, 2010), whereby the future projections indicate constant increase by 2020, exceeding the 1.8 Mio inhabitants. One fourth of the overall number of inhabitants has a foreign background (BSU, 2005), which exceeds the average national value of 19%. The majority of them is settled in suburbs, including the area of Wilhelmsburg (7,3%).

The area of Wilhelmsburg plays a decisive role in future urban development of the city of Hamburg. According to the urban development concept "Leap across the Elbe"[172] new urban zones should be developed or the existing redesigned which has as a consequence the creation of new homes for 30.000 to 40.000 citizens on this island and development of new commercial or business centres and facilities. Wilhelmsburg should become an area with attractive waterfronts triggering shift in construction style towards amphibian housing. In that context, the International Building Exhibition (IBA), has embarked on the largest developing the project in the area- New Wilhelmsburg Centre in the heart of the island (IBA[173]), which implies development of concepts and strategies for the existing housing and urban fabric.

Wilhelmsburg is considered as a socially deprived area with a high rate of unemployment (10,7%). Although only 3,1% of the overall inhabitants of Hamburg live in Wilhelmsburg, the number of people living on social welfare reaches 4,5% of the overall number of welfare recipients of the city of Hamburg. The area of Wilhelmsburg is characterised by a high rate of inhabitants with foreign background, that represent 34% of the overall inhabitants of Wilhelmsburg. Within the program "Leap across the Elbe" (http://www.sprung-ueber-die-elbe.de), the social situation in the area should be considerably improved.

In terms of flood management, the main aspects of the flood situation in Wilhelmsburg address risk awareness of the stakeholders behind the dikes. Therefore, the issue of stakeholders' attitude should be analysed in the light of relativising the safety and reliability of traditional measures that have been considered as absolutely safe for decades.

Prior to this work, the team of the RIMAX project- UFM composed of the TUHH[174] and HCU[175] researches has performed a survey and the Interactive Learning Group (ILGs) in the area, involving important players on the island- residents, authorities and emergency departments with the main objective to assess the risk awareness of the population in Wilhelmsburg and create mutual trust and transparent decision making process and initiate active learning among them (RIMAX Final Report, 2010). The experience gained during the

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[171] This analysis has been performed by the Author within the FP7 project CORFU.

[172] http://www.sprung-ueber-die-elbe.de, (last accessed: January, 2010)

[173] , http://www.iba-hamburg.de/

[174] Hamburg University of Technology http://www.tuhh.de (last accessed: January 2015)

[175] Hafen City University, Hamburg http://www.hcu-hamburg.de/ (last accessed: January 2015)

survey and the ILGs indicates the existence of champions that are eager to participate in the future oriented planning and are open to new ideas and paradigm. However, the methods that efficiently integrate them into participatory planning have been identified as a research need. Sophisticated strategies and tools are needed to support the residents in the decision making process and building capacity of the residents in Wilhlemsburg (Knieling at al., 2009).

Also, the people who have already experienced a tidal surge 1962 are organised in action groups (e.g. Pegelstand Elbinsel, Deichverband) and try to keep the issue of storm surges present in media and mindsets of new generations (through events such as fairs, public meetings). Also, the Authority for Internal Affairs organises an annual public event on disaster management in Hamburg, addressing the importance of risk awareness among the residents on Wilhelmsburg.

Focus area 1: The Kollau catchment:

As the Kollau area is regularly flooded, the key stakeholders are mostly aware of the potential hazard. The flooding problem is relatively well spread and known since the flood events of 2002. The flood problems have been reported several times in the local and regional newspapers and television (e.g. Hamburger Abendblatt, 6th, April, 2006 "Das erlebte ein Lockstedter"[176]), which, for a short time, raised public interest and awareness of such problems. The Hamburg authorities are initiating a communication process with the residents by providing them with relevant information about flooding in Kollau using different means of communication. Public presentations and discussions for the interested residents in the affected areas are organised, but the response strongly depends on the context and occasion. When the presentation aims at merely explaining the results of studies or general strategies for flood management, people show poor interest in it. This is partly explained by the poor trust in the authorities by the residents as well as their attitude that flood protection has to be completely covered by the authorities[177]. In the case that concrete problems are discussed and consultancy is being offered, the interest is considerably higher.

Realising the severity of the increasing flooding problems in the area, the resident are pursuing their activities within public initiatives and action groups. An example is the initiative NiKo e.V[178] which is devoted, among others, to raising the importance of the flooding problem in the Kollau area. But the actions of this group raise the gap between authorities and residents, confronting each other with the responsibilities, and in which each group has difficulties to accept its own. Mutual trust among the key stakeholders is not developed and the residents, although having already experienced flooding themselves, are not on the level to be able to understand and accept their role in a complex system such as flood risk management, indicating potential for systematic capacity building.

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[176] http://www.abendblatt.de/hamburg/article390184/Hochwasser-Das-erlebte-ein-Lokstedter.html (last accessed: January 2015)

[177] Outcome of the interview with the representatives of the city authorities of Hamburg, April, 2007-January 2008

[178] http://www.niko-ev.de/, (last accessed: January, 2015)

Focus area 2: The Wandse catchment[179]:

The concept of “growing city” influences the city planning in the Wandse catchment in two different ways; firstly, the fallow areas should be urbanised and secondly, the density of population on already urbanised area should increase. The extent that this further urbanisation would influence the flood situation in urban catchments can be only preliminary assessed. Although some area will be paved, some old housing will be pulled down, so that sealing/ unsealing rate will possibly be balanced. The problem occurs with further compaction of the sealed area, where the additionally created runoff can cause flood problems

The current strategy of development in the Wandse area, implies infill of the urban fabric in the catchment, but also directly along the river Wandse, “grabbing at the edges” as depicted in Figure 5-10.

Based on the data provided by the INFAS (Institute for Applied Social Sciences)[180] the population density of the study area has been assessed as 5700 Persons/km^2 and is given per postal code in Figure 5-11.

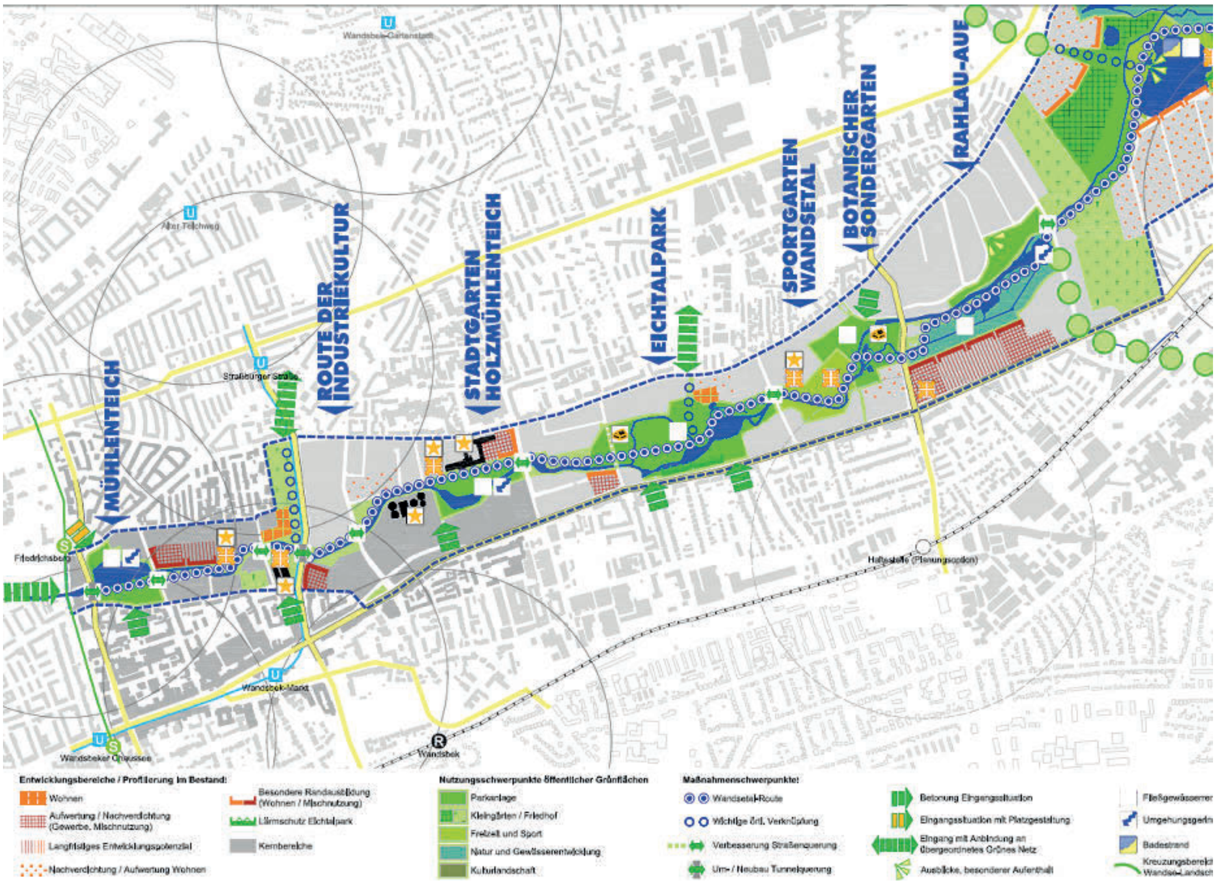


Figure 5-10 Current strategy of the urban development along the river Wandse (personal communication with the local authority- BA Wandsbek, 2010)

[179] This analysis has been performed by the Author within the FP7 project CORFU

[180] http://www.infas.eu/ (last accessed: January, 2015)

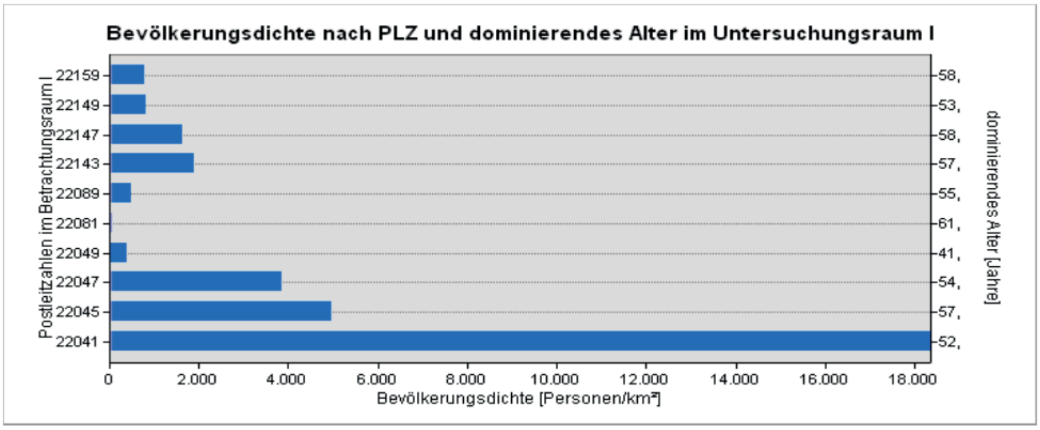


Figure 5-11 Population density and the dominant age in the study area, given per postal code; x axis-population density [persons/km^2]; y axis- postal code (Source: INFAS data given in Friese, 2014)

Flood problems in the Wandse catchment have been sporadically addressed within programs of diverse action groups acting in the Wandse area. It has been either integrated into the initiatives dealing with the watercourse as a whole or within urban planning strategies or the protection of natural areas. Some examples of such groups are Rahlstedt e.V (natural protection and river as a whole) or Kleingartenverein Am Berner Wald e. V (urban planning).

Built Environment

Hamburg has a rather heterogeneous built environment in terms of the construction year and styles (INFAS data accessed 2013). INFAS classifies buildings in Hamburg depending on their construction years in 10 classes (class1: before 1900 to class 10: after 2010). Within this work a detailed study of the building in the flood prone area of the river Wandse has been performed and will be discussed in the section describing the objectives.

Other elements of the urban system relevant for the involvement of dwellers

The Hamburg area:

The main aspects of the flood situation in Hamburg with the focus on Wilhelmsburg that shapes the research agenda are the flood management issues for the areas behind the dikes.

As the area of Wilhelmsburg is the are behind the dikes, flood management plans are reduced to contingency planning in case of extreme events such as in case of dike overtopping or dike breach.

Focus area 1: The Kollau catchment

The main aspect of the flood situation in small urban catchments that shapes the research agenda is the low priority given to problems in spite of the increasing risk to this type of flooding due to climate change and the rapid urbanisation of those areas. The small urban watercourses produce rapidly rising flood waves that are a result of both pluvial and fluvial flooding, often causing extreme damage. While policy and water experts are aware of the flood risk along rivers and large streams and have developed future oriented and sustainable strategies for their management 2007/60/EC, FCA, 2005), pluvial floods caused by exceeding flow in the storm water drainage system and small urban watercourses have been hardly considered so far and efficient strategies are still missing. Low awareness levels among both private and professional stakeholders and different attitudes leads to conflict situations and hinders efficient flood risk management in the area.

Focus area 2: The Wandse catchment:

The main aspect in the Wandse catchment decisive for the activities in this work, is the flood risk management plan in the sense of the EC Flood Directive (2007/60/EC) which has been developed within the EU INTERREG IVb Project SAWA, utilising the strategy for stakeholder involvement as presented in Figure 3-6 and implemented in a form of the Learning& Action Alliances (LAAs).

This planning procedure opened a question of the role of dwellers in flood risk management and in which way they can be efficiently involved. Currently, the municipality provides advices on measures and strategies that can be applied for the properties in flood prone areas[181].

5.1.3.3 Objectives

The complex flood risk management situation in Hamburg and diversity of the aspects have been used for verification of both, decision making approach and the tool (FLORETO) and the methods and tools for capacity building of stakeholders (FAC and ILP). In the final stage, the concept for participatory planning and the interest of dwellers to participate has been tested. The objectives of the single aspects with the corresponding focus areas are given as:

Objective	Description	CS
Phase 1: Decision making- concept and implementation (refer to Figure 3-15)		
O1	Damage assessment module as implemented in FLORETO (I-2)	Wandse
O2	Applicability of the resilient systems at the property scale	Wandse
O3	Applicability of the CI algorithms for the generic and specific flood and sociotechnical conditions (II-1,2)	Hamburg area, Wandse
O4	Relevance and applicability of the parameters defined for the assessment of the resilience performance (III)	Wandse
O5	Readiness to take decision on the resilience systems (II-4)	Wandse, Kollau
O6	Testing of the FLORETO modules in terms of - Operational time (BL) - Technical reliability (GUI)	Hamburg area, Kollau

[181] Personal communication with the responsible authority -LSBG, 2010-2014 (Mr Klugge, Ms Gönnert).

	- Robustness (BL, RDBMS)	Wandse
O7	Assessment of the acceptance of FLORETO - Is the tool easy to use? (GUI) - Is it assessed as useful? (all) - Are the dwellers willing to use it for own properties?	Hamburg area, Wandse
Phase 1: Capacity building of stakeholders		
O8	Testing of the Flood Animation Centre/Studio (FAC/FAS) method for flood awareness as presented in Table 4-5	Hamburg area
O9	Assessment of the acceptance of the FAC and its potential to motivate public stakeholders with the focus on dwellers to practice their role in the flood risk management	Hamburg area
O10	Verification of the concept of the ILP for building capacity of dwellers	Kollau
Phase 2: Framework for stakeholder engagement with the focus on the dwellers		
O11	Testing of the concept and the interest of dwellers to participate and get actively involved in the flood risk management activities by making use of both, tools for decision support and the capacity building	Wandse

5.1.3.4 Research Program

O1: Testing the damage assessment methodology as implemented in FLORETO

1. Data collection- data has been collected following the requirements on the FLORETO module in the Wandse catchment area (see also FLORETO Walkthrough available at http://floreto.wb.tu-harburg.de/welcome-to-floreto-tool/latest-version-floreto-walkthrough/). Out of the identified affected buildings located in the flood prone area, eight residential buildings have been selected which cover different building types in Hamburg (i.e. that belong to different building periods, with and without basement) and for which the data has been available. The required data that describe the building fabric and contents, has been collected in the following ways:
    i. On site visits
    ii. Interviews with the professionals being real estate agents, research groups (e.g. http://www.altbauatlas.de/), local authorities
    iii. Making use of the Internet resources (including Google Maps and Bing).
    iv. Commitment and inputs from the dwellers participating in the LAA- Wandse process (see O8)
2. Based on the collected data, damage has been calculated utilising the damage module as implemented in FLORETO
3. The verification of the obtained results has been performed by comparing the obtained results with medium scale methods for damage assessment currently used by the city

authority or if not available, the local experts have been consulted. Only in 1 case, the historic data and events were available and could be used (reported damage by one of the dwellers participating in the LAA-Wandse- Building ID7)

The list of the selected buildings is given in Table 5-8.

Table 5-8. List of selected residential buildings and a short description (Buildings with the ID3 and ID7 have been selected for the dwellers participating in the LAA-Wandse, see O8)

ID	Location	Type
1	LS 26	detached house, no basement
2	WS 103	multi-storey residential building, no basement
3	**StS 190**	**detached, single-story home, no basement**
4	AS 15	multi-storey, with basement
5	AS 14	terraced, no basement
6	V-E-S 16	multi-storey building
7	**BA 21**	**detached, two-storey, with basement**
8	EA 96	terraced, with basement

O2: Applicability of the resilient systems at the property scale and verification of the criteria for their selection

For the buildings selected in O1 (3,7), different resilient systems have been derived and discussed with dwellers during the participatory process LAA-Wandse as described in O11. They have been framed into the demo flood risk management plan being developed within the LAA-Wandse in the sense of 2007/60/EC.

O3: The potential to apply the CI algorithms for the resilient planning on the built environment

In order to test the potential to apply the CI algorithms for the resilient planning on the built environment, generic datasets and location specific datasets relevant for the Hamburg case study (i.e. considering the building types and flood conditions in the Hamburg area) have been created and are tested utilising the WEKA platform, either applying the 10 fold cross validation or split method. The process has been performed iteratively varying the number of key attributes, level of detail of the classes and number of datasets to be considered. The single steps of the research program are given as follows:

1. Generation of datasets utilising the data stored in the database in the following way:
    i. The real buildings have been surveyed based on the onsite analysis and the INFAS database.
    ii. Synthetic houses have been generated combining different materials for different elements of the building description that are to be found in the area of Hamburg.

iii. Each dataset has been assigned to a resilient system, which are technically appropriate for the given building description. The systems have been derived either based on the existing measures or based on the expert knowledge

2. Based on the AI model built in step 1. after performing the tests (cross validation and 10-fold), the initial dataset has been revised by varying the number of the key attributes as described in Chapter 3 and 4. The tests have been performed for different numbers of (key) attributes, being 62, 46 and 21. The selection of the attributes has been made based on the personal judgment and available experience. An example of the data set can be seen in Table 5-9. The DM model built containing the attributes (62, 46 and 21) with the associated measures is given in Appendix 5.3 (The data are given in the .arff format that is required for the testing in WEKA).

Table 5-9 An example of parameters defining the dataset for a building in the Hamburg study area

Description	Value	Type
Ground floor- wall type	masonry	Categorical
Flood depth	0.50	Numerical
CLASS ATTRIBUTE- Measures (result):	**C8: Wet proofing strategy of basement**: wet proofing of walls, openings and floors, elevating the inventory (not necessarily giving up the basement occupancy)	Categorical

The acceptability of the suggested resilient systems has been discussed in a form of semi structured interviews and utilising the feedback option of the FLORETO tool. Two groups have been used for this step- students of the environmental and hydraulic engineering at TUHH (in total 30) and experts from the city authority. Additionally, the representatives of TÜV (Technical Inspection Association) have been asked to assess the potential of the results to be used for the “flood proof certificate” to be issued for flood proof buildings protected by FRe technology. The homeowners of the assessed buildings were not willing to deliver any statements, due to the potential impact on their insurance premium.

O4: Relevance and applicability of the parameters defined for the assessment of the resilience performance for the resilient systems at the property scale

For the selected buildings in O1 and defined resilient systems in O3, a resilience assessment has been performed following the criteria/proxies given in Table 3-4.

O5: Readiness to take decision on the resilience systems

1. During the participatory process LAA- Wandse as described in O11, the semi structured interviews have been conducted with the participants-dwellers about their readiness to implement the measures for their properties.

2. The participants of the Klima Woche 2009 (see O7) that requested the access data to FLORETO have been asked whether they would be ready to implement the measures

suggested by FLORETO. Also they were asked to use the feedback option in FLORETO to communicate their opinion.

O6: Implementation of the decision making process- FLORETO

The technical performance of the tool has been assessed by an independent group of semi expert users (students) of the environmental and hydraulic engineering at TUHH (in total 30) following the testing protocol as given in Appendix 5.4. Additionally, the tool has been offered a number of professional users within the FP7 projects SMARTEST and CORFU and the German national project KLIMZUG, in total 10 and their feedback in a form of open interviews has been collected. 5 of the professional users have been given a training to use the tool and 5 have used the tool without any previous introductions.

O7: Acceptance of the FLORETO tool among dwellers

In order to assess the acceptance of FLORETO among dwellers, two main parameters have been assessed: the number of people that requested the access to FLORETO and the motivation to use the tool for own properties.

1. The concept and the demo version of FLORETO have been exposed to the participants of the ILP- Kollau (see also O10) and their opinion and suggestions have been collected in a form of open interviews. The outcomes have been used for the design of the final GUI version of FLORETO.
2. The Klima Woche[182] 2009 event, an one week event in Hamburg devoted to raising awareness of potential consequences of climate change and targeting the broad public, has been used for launching FLORETO. For demonstrating the features of the software, the focus has been put on Wilhelmsburg, integrating the flood inundation map of Wilhelmsburg via Web Coverage Service. The number of people requesting the access data to FLORETO has been counted.
3. During the event outlined in O5 and Table 5-10, the FLORETO tool, with its main features, was presented. A session where the participants could try and test it by entering their own properties followed the presentation. Their impressions have been determined after the session by means of questionnaires and interviews focusing on the issues:
    a. Easy to use
    b. Usefulness
    c. The willingness to use it for own properties

The questions used for those interviews are given at http://floreto.wb.tu-harburg.de/welcome-to-floreto-tool/feedback-on-floreto/ (password protected)

O8: Implementation of the concept- Flood training in FAC

[182] http://www.klimawoche.org (last accessed: June 2010)

The Flood Animation Centre has been applied to raise risk awareness of the dwellers in the Wilhelmsburg area. The dwellers have been contacted through the action group Zukunft Elbinsel Wilhelmsburg e.V[183] or through personal contacts. An one day event has been organised, with the "active flooding" in the flood animation as a part of it. The performed program is depicted in Table 5-10.

Table 5-10 Program of the event for capacity building of stakeholders in Wilhelmsburg

Nr	Activity
1	Introduction to the problems of flood management behind the dikes due to climate change
2	**"Active Flooding"- FAC/FAS**
3	Interactive session applying FAC "*How realistic is a flood hazard for my property?"*
4	Presentation and demonstration of flood resilient measures for the built environment and flood protection products: *What are efficient strategies for protection of properties? What can I do?*
5	Presentation of adaptive strategies (innovative resilient measures e.g. amphibious housing)
6	Interactive session- FLORETO
7	Discussion and wrap up

The flood training has been performed according to the procedure given in Table 4-5 varying the reaction phase as follows:

- Variant 1: The test persons were asked to select and pick up 3 items from the living room which they find most important
- Variant 2: The test persons got specific tasks to perform that were: to unscrew the computer from the monitor, to find the personal documents and to make selection either to take the item with the highest personal value (e.g. photos, souvenirs, toys) or an item that they will certainly need in case of evacuation (medicaments, emergency box etc.).

O9: The acceptance of FAC/FAS

Two tests have been used for achieving this objective:

1. The acceptance of FAC has been assessed by interviewing the dwellers on their impressions on the tool before and after the test described in O8.

In order to assess the learning effect of the training, both the test persons and observers were asked to fill in a questionnaire before and after the training. Regarding the observers (participants of the event) in the interviews before the training the objective was to assess the

[183] http://www.insel-im-fluss.de/ (last accessed: June 2010)

general profile of the participants, i.e. (a) previous experience, (b) level of information and (c) attitude towards new strategies and paradigms in flood management and towards uncertainties due to climate change. The questionnaires after the event had the objectives to assess (a) the impressions/associations the training evoked (b) their own reaction in such a situation and (c) the familiarity with the right response strategies and measures for private stakeholders. Additionally, the participants were asked to give their opinion about the event and express their readiness to take part in further capacity building activities in the area. The questionnaire applied is given in Appendix 4.4a.

2. The Flood Animation Studio (FAS) (the road show version of the Flood Animation Centre (see Figure 4-25)) has been used during the Klima Woche[184] 2010 event to assess the acceptance among the stakeholders- dwellers in the Hamburg area, following the procedure explained in Variant 2. The questionnaire applied is given in Appendix 4.4a.

O10: Implementation of the ILP concept

For building capacity of stakeholders-dwellers, the ILP was applied in its adapted/reduced form. The organised ILP sessions followed the implementation program presented in section 4.2.3 but the web based learning was just partly used, as at the moment of the application the system was in its development phase. Following the catchment specific conditions presented above, the following program that has been applied:

1. The session "*Concrete Experience*" has been combined with a public presentation that has been organised by NiKo e.V[178]. This event has been used for screening the participants for the ILP and polling the stakeholders' attitude towards flooding in the area. The FAC has been applied utilising the flood maps of the area, where the participants could interactively check their flood situation and visualise the water level by means of flood cylinders. Also, the main features of pluvial and fluvial flooding, that is the features typical for the area (e.g. rapid water level rise), were simulated and visualised.
2. The contribution of a narrator and visits of the affected objects in the *intermediate session "concrete experience to reflection*" were not applied as the participants experienced flooding themselves and already discussed the problems within the NiKo e.V. events.
3. Both local and city authorities were attending the "*reflection*" session and discussed the flooding problems and responsibilities with the residents. A detailed hydrologic study of the Kollau catchment was presented to the participants, demonstrating the complexity of flood management and serving as a basis for such a discussion.
4. The material presented was made available to the participants within the FLORETO Platform as given in section 4.3.3. It supported the *intermediate phase* "*reflection and observation to forming abstract concepts*". Onsite inspection of the buildings was performed for all participants' houses and the data collected according to the form

[184] http://www.klimawoche.org

given in Appendix 5.2 (see also Figure 5-12 a). Also, the facilities such as weir "Alte Kollau" or detention pond "Steinwiesenweg" were visited together with the participants and local authorities, demonstrating the complexity of the problems in the area.

5. In the session "*forming abstract concepts*" the presentation of measures for the resilient built environment as well as some of the examples were delivered to the participants. The collected data of the properties and their vulnerability assessment shaped the discussion and further analysis of the measures to be applied. Also, the participants were provided with the literature and material in a form of hard copied brochures.
6. The intermediate session "*forming abstract concepts" to "testing in new situations"* did not take place in its full extent and it has been merged with the session "*testing in new situation*". The reason was the fact that the participants had already been familiar with flood products, with some of them having already applied the products or having already visited such houses in the vicinity. Also, an intensive discussion during on site inspections of the properties and brochures and leaflets distributed in the previous session rounded the concretisation process and empowered the participants to test their knowledge on the individual cases.
7. Within the "*testing in new situation*" session, the participants applied their knowledge using paper and pan and trying to develop concepts for their own properties supported by the researches from the TUHH. (Figure 5-12 b)
8. The efficiency of the learning program has been assessed by means of the questions (formative and summative), before the ILP and immediately after the workshops and with one year time distance from the active phase of the ILP. The questionnaire is given in Appendix 4.4b.

In spite of those adaptations, the overall idea and structure of the concept is preserved and it can be considered as an application of the ILP concept presented in chapter 3.4 and 4.3.3. It provides one of the main advantages of this concept, which is its generic nature and robustness. The pace and single activities can be adapted to a specific group of participants, but while still keeping the overall objectives and applying the same concept and procedures.

Figure 5-12 ILP at the Kollau catchment, a) Vulnerability assessment within the intermediate phase "reflection and observation to forming abstract concepts" b) "applying knowledge to a concrete case" workshop

O11: The potential of the framework for the stakeholder involvement to include dwellers (phase 2)

The potential of the framework for the stakeholder involvement to include dwellers (Figure 3-6), the Learning& Action Alliances (LAAs) for the development of the flood risk management plan in the sense of 2007/60/EC has been made use of. The sessions have been designed in order to capture the relevant elements for the participation of dwellers- (1) supporting the decision makinf process at the property level and the capacity building methods. During the participatory planning process, the motivation, role, level of participation, and acceptance of the final FRMP by dwellers have been assessed.

A series of meetings (14 in total) over the two year time have been organised following the structure as given in Figure 3-6, supported by the online collaborative platform (http://laa-wandse.wb.tu-harburg.de/willkommen/, password protected) for information and opinion exchange (Manojlovic et al., 2012b).

A thorough stakeholder analysis preceded the planning process at the beginning of phase 1- *Scoping*. Table 5-11 outlines the main stakeholder groups considered for the LAA Wandse and the corresponding number of participants, in total 25. Out of total number, 3 participants represented the private stakeholders (dwellers) in the LAAs. They have been approached either directly (the action group representative) or on their own interest (2 dwellers their houses have been flooded in the past).

Table 5-11 The LAA- Wandse configuration/ per number of stakeholder group

Categories of Stakeholders	Nr
Strategic flood management	4
Implementation and maintenance	3
Urban development	2
Agriculture	0
Urban and landscape design	1
Environmental protection	3
Emergency services	1
Politicians	2
NGOs	2
Private stakeholders (dwellers)	**3 (2 private persons, 1 representing an action group)**
Economy and Industry	1
Research	4

The organised workshops have been designed as presented in Table 5-12, where the overall objectives and activities are given and the ones that focus on the dwellers (refer also Table 4-15). The questionnaires used for formative and summative assessments are given at: (http://laa-wandse.wb.tu-harburg.de/willkommen/, password protected)

Table 5-12 Activities of the LAA and the ones related to the participants- dwellers

LAA	Objective	Activities (all)	Activities related to dwellers (focus of this work)
1. Scoping	(Stakeholder analysis) Development of shared vision of the problem	- Scoping the flood problem in the Wandse catchment - Onsite visits to the critical spots - E lectures and presentations on flood risk (generic and specific)	- Participation in the experiment with the flood animation centre and assessment of its acceptance among dwellers - access to E Lectures and presentations on flood risk (generic and specific) - Assessment of the individual present and future flood risk utilising the KALYPSO and FLORETO tool (the assessed damage of the selected buildings is given in O1)
Assessment of the shared vision of the problem by the means of questionnaires. Additionally, semi structured personal interviews have been conducted. (Formative analysis)			
2. Understanding	Development of shared vision of where to get to (acceptable level of risk)	Overview of the measures to mitigate the flood risk via live presentations and e lectures	Overview of the measures for the resilient built environment obtained during the sessions and in a form of the e lectures via FLORETO-Inform (the lecture is available through the collaborative platform (http://laa-wandse.wb.tu-harburg.de/lern-und-aktionallianzen/sitzungen/sitzung-6-31-august-2010/unterlagen/, password protected)
Assessment of the achieved objectives (acceptable risk) by the means of questionnaires. Additionally, semi structured personal interviews have been conducted (Formative analysis)			

3. Experimenting	Formulate options of adaptive flood risk management by NSM	Hands-on development of the planning options to mitigate the flood risk to the acceptable level Simulation of the developed options by the means of KALYPSO and FLORETO	Participation in the development of the overall planning options for the Wandse catchment focusing on own properties Analysis of the strategies developed by FLORETO (Technical selection process, Option analysis, Cross-scale analysis) for the own properties
Assessment of the achieved objectives (developed planning options) by the means of questionnaires. Additionally, semi structured personal interviews have been conducted (Formative analysis)			
4. Evaluation and decision making	Adoption of the final FRMP	Conflict analysis and the agreement on the final plan	Participation in the decision making on the final FRMP
Summative analysis (questionnaires and interviews): Have the objectives been achieved- FRMP Suggestions for improvement of the process.			

5.1.4 Heywood, Greater Manchester, UK

Heywood is a town located in North West England (about 11.9 km north of the city of Manchester) within the Metropolitan Borough of Rochdale in Greater Manchester at an elevation of around 130 m above mean sea level. It has a population of around 28,000 (Schinke et al., 2013, see also Figure 5-13).

The main urban area is a high-density residential and industrial site, originally developed between 1750 and 1900. Since 1960 many open areas and brownfield sites, both within the town and on it southern margins have been occupied by new housing and new low-rise, large warehouses on a new distribution centre.

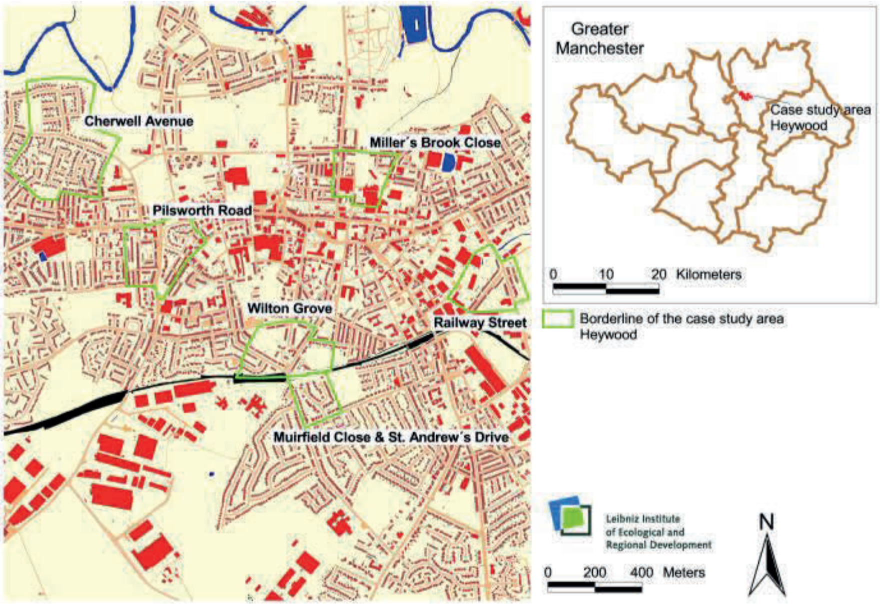


Figure 5-13 Heywood area; six locations potentially exposed to pluvial flooding (source: Schinke et al., 2013)

5.1.4.1 Flood Typology

The area of Heywood is prone to pluvial (sewer) and riverine floods. The streams in Heywood have been culverted and are some reaches of these streams are still part of a combined sewer system (Douglas et al., 2010). The major flood events in the recent history of Heywood date back to 2004 and 2006 (both events have been caused by summer storms on 3 August 2004 and again on 2 July 2006 resulting in severe sewer flooding). Both of these events affected the same six discrete areas of the town. In both 2004 and 2006, around 200 properties experienced flooding, with about 90 properties being flooded internally with up to 1 m of sewage contaminated water for up to two to three hours (Douglas et al., 2010). For the analysis a property from each of the six areas has been selected and are given in section 5.1.4.4.

A thorough hydrologic study of the flood probability has been performed by the ENPC within the SMARTEST project and has been taken as a reference for this work. A map indicating the flood prone area due to pluvial and riverine flooding is given in Figure 5-14.

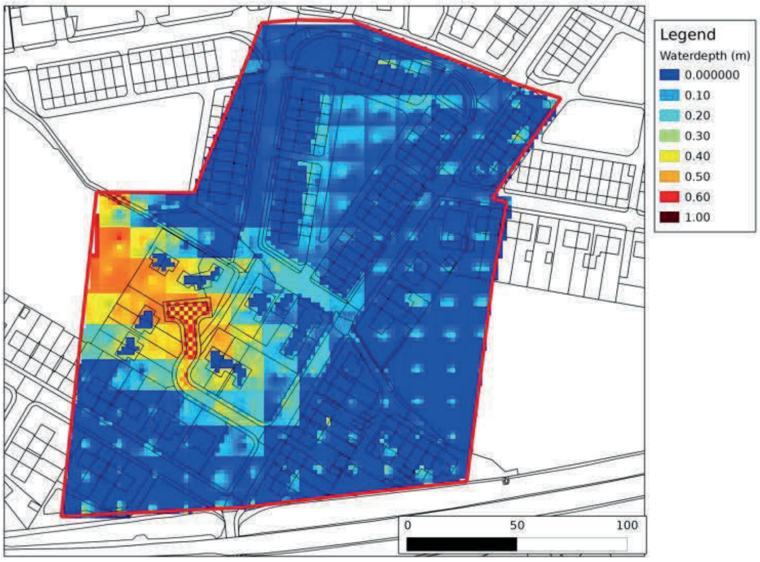


Figure 5-14 Heywood area; 'Wilton Grove'. Hydraulic modelling results (flood water levels) for a rainfall scenario based on Multi-Hydro simulations. Source: ENPC 2012, delivered within SMARTEST project

Based on the historic data provided in Douglas et al., 2010 and the performed calculations by the ENPC, the parameters considered for the damage assessment are summarised in Table 5-13:

Table 5-13 Flood factors considered for the damage assessment in the selected areas in Heywood

Flood factor	Values
Flood type	Pluvial and fluvial (culverted streams)
Water depth h_j [m]	Given for each analysed building separately
Velocity v_j	<2m/s
Duration d_j [h]	3days<d<14days
Contamination [g/m^3]	Dirty contaminated water (sewer)(up to 1m)

5.1.4.2 Sociotechnical system

Social Environment

Heywood residents were unaware of risk from flooding and were unprepared for the flood events of August 2004 and June 2006 (Douglas et al., 2010). They were ill-informed about how best to protect their properties. None of the agencies responsible for flood management has provided personal counselling or advice on flood mitigation methods to either the flood victims or the local community. Insurance companies have been efficient in providing reparation but have generally failed in communicating possible resilience.

Built Environment

The built environment is the study area has been assessed as homogeneous developed residential sites, dominated by three quantitative relevant structure types (Schinke et al., 2013):

- Low terraced houses
- Semi-detached houses
- Detached houses

whereby the terraced houses from Late Victorian /Edwardian era (1870-1918) have been identified as the most common and widespread type of high-density residential housing in this area, comparable with numerous other industrial districts in the United Kingdom (Schinke et al., 2013).

The damage to the homes in Heywood which experienced internal flooding was typically to all downstairs flooring, plaster, furniture, fixtures and fittings. In most cases, water entered the homes through doors, air vents and from under suspended floors. People generally are ill-informed about how best to protect their properties. Only 20% of Heywood homes flooded internally in 2004 and 2006 have actually taken some form of precaution against future flooding such as acquiring flood gates, retaining sand bags, improving doors and changing or blocking air vents. However, an additional 25% of those flooded would like to take preventative measures but do not know how to do so, or felt that there was nothing they could do to avoid being flooded (taken from White et al., 2012).

Other elements of the urban system relevant for the involvement of dwellers

The most relevant aspect for the performed research program has been the presence of the insurance which is provided only by private companies (White et al., 2012). White et al., 2012 outline the main aspects of the insurance in the UK and relevant for the Heywood case study as:

- The insurance industry provides for the renovation of property damaged by flooding and redress to flood victims.
- All insurance companies are independent and in competition. Therefore, adjacent properties with differing insurers can have vastly different responses/levels of premium/penalties if previously flooded.
- Insurance cover is often a condition of mortgage (financial loan) offers. Flood risk is usually covered as a standard part of business and household insurance.
- In principle, no difference between the insurance arrangements of an owner-occupied house and a rented house, but in practice the difference can be substantial due to different income and living standards. Generally, the property owner has responsibility for insuring the property with occupiers responsible for insuring contents.

5.1.4.3 Objectives

O1: to test the transferability of the damage module implemented in FLORETO

O2: to assess the acceptance of the tool among the dwellers of Heywood

5.1.4.4 Research program

O1: to test the transferability of the damage module implemented in FLORETO

In order to perform the damage modelling of the study area in Heywood, the following steps have been performed:

1. Based on the available flood maps provided by the University of Manchester and ENPC, six houses have been selected that belong to the flood prone areas of the Wrigley Brook catchment in Heywood and represent edifications that were actually flooded within the area in the events of 2004 and 2006 (Table 5-14 and Figure 5-13).

Table 5-14 The selected properties in Heywood for which the analysis has been performed

ID	Location	Type
1	29 CA	Private, detached, single-story house, no basement
2	1 MBC	Private, detached, single-story house, no basement
3	22 MC	Private, two-storey semi-detached
4	32 PR	Private, two-storey terraced home, with no basement
5	127 RS	Private, two-storey terraced home, with no basement
6	63 WG	Private, semi-detached, two-storey building, no basement

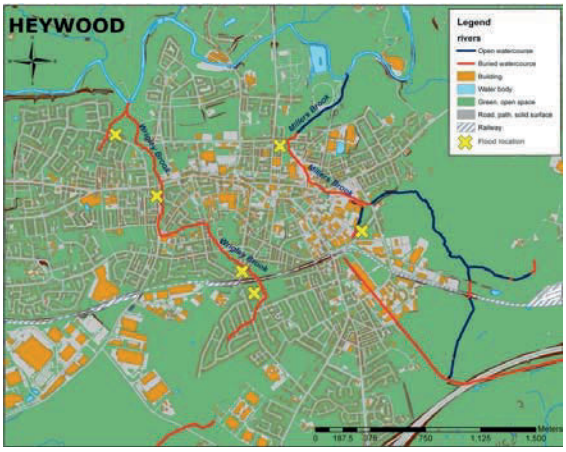


Figure 5-15 Localisation of the six different assessed buildings in Heywood reflecting the six hotspots of Heywood (Source: UNIMAN)

2. The available data have been evaluated. In addition, onsite visits of the selected buildings have been performed. The missing data has been obtained utilising the Google StreetView
3. The buildings have been entered in the FLORETO tool and the damage assessed. The costs available in FLORETO have be revised to fit the UK market, based on the personal communication and information provided ny the UNIMAN team within SMARTeST project.

4. The obtained damage has been compared with the reported damage which had been reimbursed by the insurance company. For comparison, the maximal values delivered by FLORETO have been used.

O2: to assess the acceptance of the tool among the dwellers of Heywood

In order to assess the acceptance of the tool, semi structured interviews with the homeowners have been conducted during the data collection and preparation of the buildings for FLORETO. The outcome has been compared with the results of the National Support Group-UK that has been founded within the SMARTeST project with the objective to assess the acceptance of the flood resilient technology, systems and decision support tools in the project partner countries (White et al., 2012).

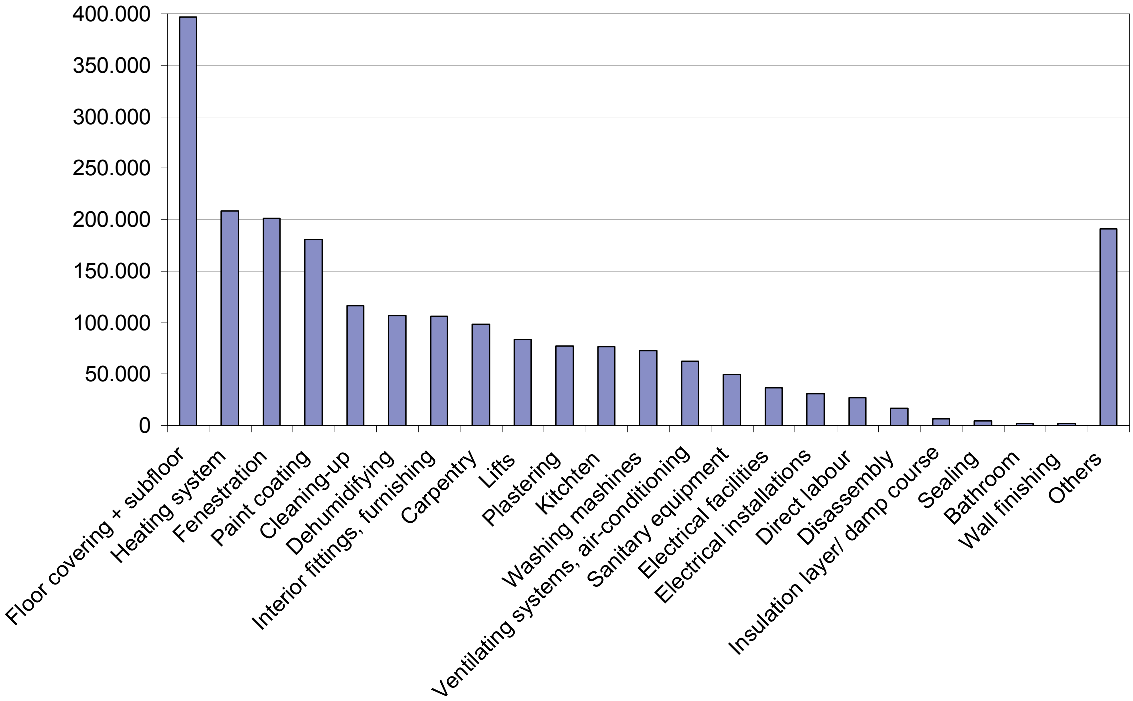
5.2 Results

5.2.1 Lake Lucerne, canton Nidwalden, Switzerland

5.2.1.1 Decision making process on the resilient built environment

Parameterisation of the damage functions:

The distribution of damages among different categories is shown in Figure 5-16[185].



[185] The result are summarised in Manojlovic in Geissler& Manojlovic, 2006 (in German) and in the project work of Pajak, J. (2006) (supervised by N. Manojlovic)

Figure 5-16 Distribution of the main damage categories reported damage over the building elements. The category “other” contains damages which were mentioned only in single cases, such as painting of the balcony or stairs or removing efflorescence spots.

It total 23 categories related to flood damages were identified causing a total reported damage in analysed buildings of CHF 2.167.586,65. Almost half of the damage (46%) has been assigned to four categories (floors, heating system, paint coating and fenestration), amounting to CHF 995.589,72. Individual damage amounts per building are summarised in Appendix 5.1.

<u>Floors</u>

The damages to floor were reported in 20 cases, what is more than a half of analysed buildings. Figure 5-17 includes data from 11 buildings.

The damage reported to tiles was indicative for the assessment of the reliability of the developed damage functions. Although damages to tiles were reported in only five cases, they comprised slightly more than 40% of the total cost of floor damage. It is caused by the fact that they are not only cost intensive (81 – 125 CHF/m^2), but also because they are used to cover bigger surfaces as they are considered to be flood proof materials. Even though tiles as such have a good resistance against water, it happened in some cases that adhesive and/or grout were not, and in consequence led to the damage which should be considered for the developed damage functions. More thorough analysis of the floor system (floor base and covering) indicated that those damage cases were reported at the floor base which has not been made of flood resistant materials (e.g. suspended floor). In that case it was necessary to remove the floor covering independently of its water resistance in order to dry the floor construction.

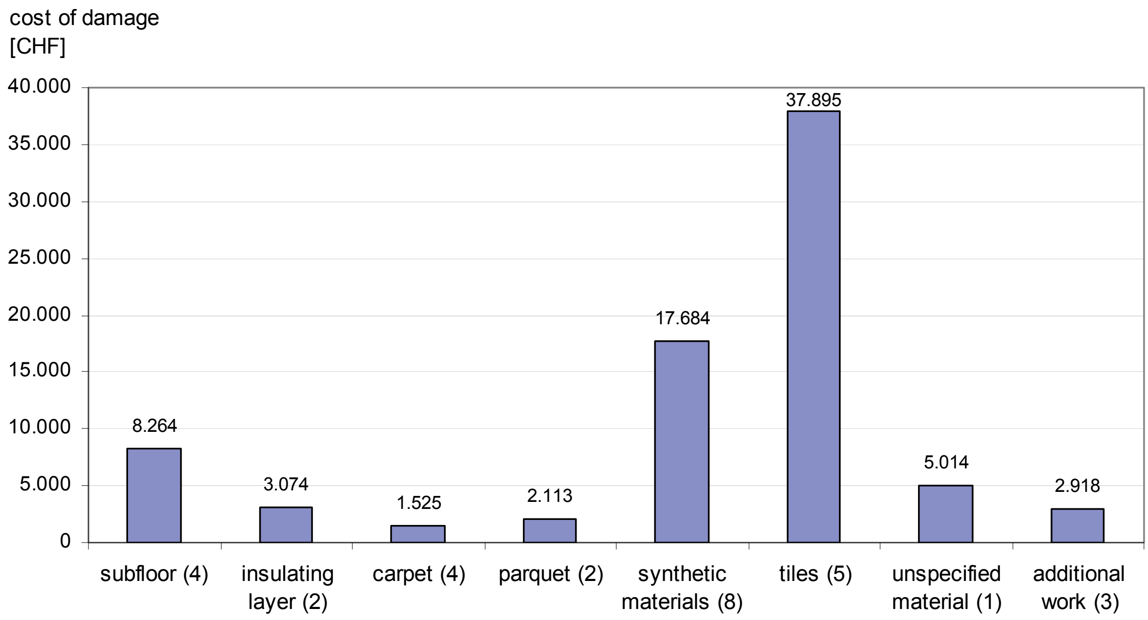


Figure 5-17. Total amount of damages to different kinds of floor covering, in parentheses number of incidences reported.

Walls

The damages to paint coating were reported most frequently, in 27 cases, in what is more than 65% of analysed buildings. The highest damages to paint coating were caused by damages to walls (CHF 35.116). Even though the cost of painting $1m^2$ of wall is relatively low (depending on the paint type and number of layers CHF 7-15/m^2), the area that needs to be painted is significant, and that is what mainly contributes to that amount. In 80% of the cases, the whole wall surface had to be repainted independently of to which extent it was affected by flood. The most often used kind of paint was colour dispersion, nevertheless in some cases also silicon resin paints were applied. A further increase of the overall costs were the expenses for preparing the wall, involving activities such as washing, levelling out and sanding of the wall.

Openings

Damages to fenestration were declared in 25 cases out of 37. Those damages constituted 8,9% of all documented damages, amounting to CHF 201.574,1. The majority of this sum (CHF 200.319,6) was caused by damages to doors with only 1,3% of this sum being assigned to window damages. Among the doors, damage reported to basement doors, with 9 reported cases amounting to 28.199 CHF, had the most significant contribution to the reported damage. It can be explained by their exposure to floods (location in basement, which is most frequently flooded) and the fact that in all reported cases they were made of chip -wood. This differentiation of doors per location (basement, external, internal) should be considered in the definition of damaging curves. The low extent of flood damages to windows can be explained by the fact that the examined frames are made of stainless steel or synthetic materials exposed to water pressure for a short time. In this case, there can be no need of replacing windows after the flood event. The reported costs to windows are mostly costs for cleaning and drying.

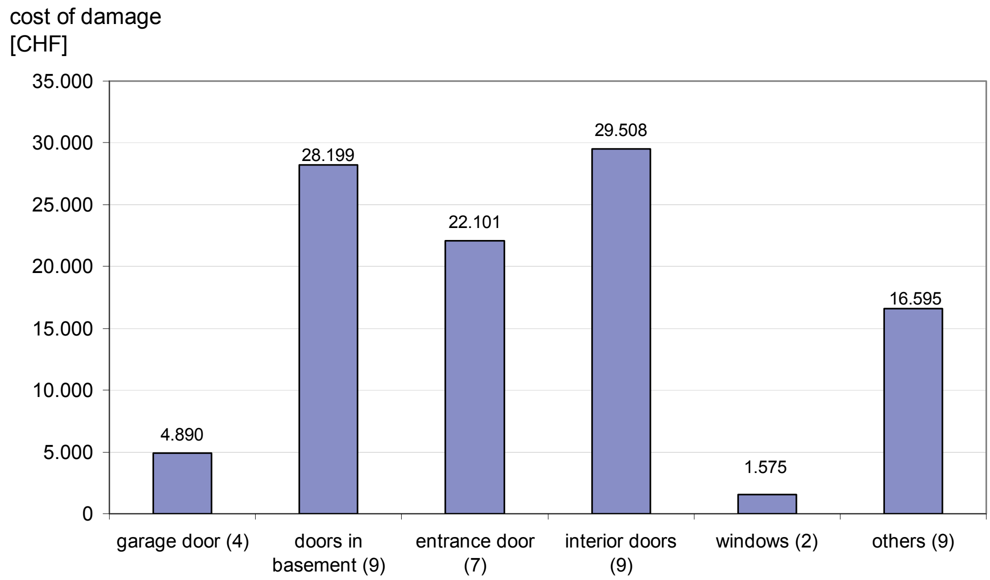


Figure 5-18. Total amount of damages to fenestration, in parentheses number of incidences reported

The highest damage was observed in case of interior doors, which was more than a third of damages presented in the graph (CHF 29.508). The main factor which contributed to this amount was the number of doors that had to be replaced, as usually new doors for many rooms were needed. Another point is that case of a future flood event, they will have to be replaced again, as in majority of cases they were made of wood.

Services:

The damages to heating system were reported in 23 cases. The total damage amounted to CHF 216.640; what comprises 10,27% of total damages. In this case, differences in damages amounts were lower than in case of damages to floor, probably because in every location similar heating system was used (i.e. with heating oil). The graph below contains data from 14 locations, where damages added up to CHF 132.387,75. For the remaining 9 houses only total damages to heating system were reported

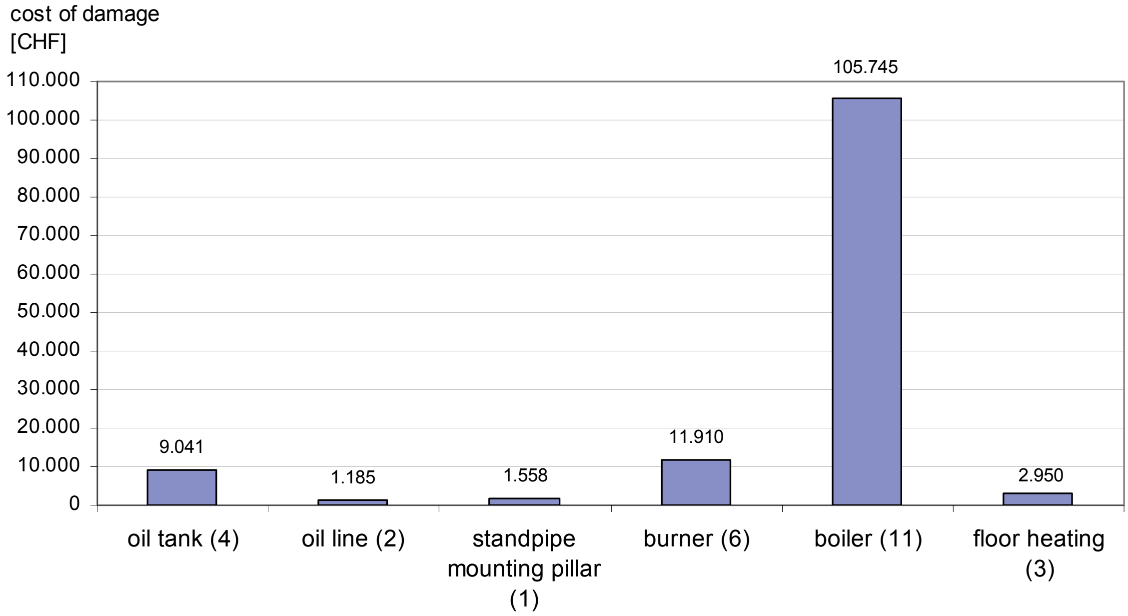


Figure 5-19 Total amount of damages to different parts of heating system, in parentheses number of incidences reported

Assessment of the perceived damage and acceptable risk among the dwellers (I-4)

Out of the open interviews with the residents and based on the damage data analysis presented above, the driver for reporting damages appeared to be lifestyle and living culture in the area. This can be illustrated as kitchen units were completely replaced in spite of being exposed to rather low water depths (approx. 10 cm) and the fact that their functionality had not been reduced. Following the lifestyle trends in the area, the kitchen has a strong component of social status and as such is given high aesthetic priority.

5.2.2 Historic area of the city of Lauenburg, Germany

5.2.2.1 Decision making process on the resilient built environment

Impact of the building condition on the damage assessment

Out of 123 examined buildings also stored in FLORETO database, 98 are assessed as historic buildings (built before 20th century). Out of 98 historic buildings 5 are not refurbished. The remaining 93 have been refurbished to a greater or lesser extent at a certain point of time. Out of those 93, 42 buildings have been assessed as partly or poorly refurbished.

An in-depth analysis has been performed on the historic buildings and the costs of repair needed for their refurbishment. The onsite analysis of the building fabric indicated that in the case of 50 buildings additional stability works were required in addition to drying and cleaning to bring the constructions in the original condition. The costs for the stability works contribute up to 45% of the overall costs of repair. This is to be considered when developing damage curves for old/historic buildings which are in a poor condition. The costs of repair per building are available in Pasche& Manojlovic, 2008.

2 buildings could not be used after the flood event (see Figure 5-21) and have been assessed as total damage. The results have been discussed with the local experts and the representatives of the local authorities.

Figure 5-20 An example of a building where additional stability works have been required- gaps and cracks in the foundation and the floor system (consequences of the buoyancy during the event of 2006)

Figure 5-21 The abandoned buildings after the flood event of 2006

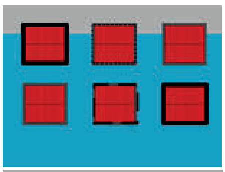
A detailed cost assessement of the examined buildings is given in the report (Pasche& Manojlovic, 2007)[186]

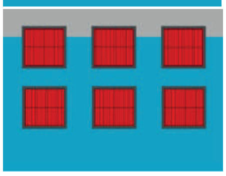
Applicability of resilient systems on different scales and verification of the selection criteria for the definition of resilient systems (II-1,2)

Based on the given conditions and the flood intensity, the resilient systems on the neighbourhood/district scale have been defined and used as boundary conditions to develop the resilient systems at the property for the six selected representative buildings. They are given in Figure 5-22.

Figure 5-22 The boundary conditions set by the resilient systems at the district-neighbourhood scale to the resilient systems at the property scale

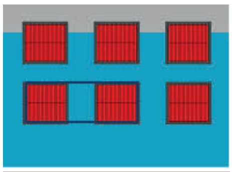
RS — Boundary conditions





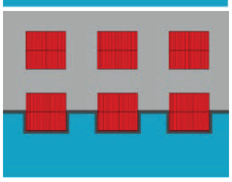
Protection of single properties separately for a non uniform design flood level D-RS1 and uniform design flood level D-RS-2)

- Accessibility of the buildings due to the topology (the buildings are very close to each other).
- Opening having a direct connection to the river Elbe
- Low elevation of a number of buildings
- As the frontline to the river Elbe is not closed, floodwater can reach the street side of the front buildings, so that the openings on the street side and buildings on the hillside also have to be protected.
- Apart from additional costs for these measures, floodwater on streets disables traffic and hinders access to homes.



Clustering of the adjacent buildings (neighbourhoods) (D-RS3)

- Topography in favour of this option (due to the intensity of urbanisation,
- Still, floodwater can reach the streets, creating the same problem as in D-RS1 and 2



Connecting buildings to the resilience frontline (D-RS4)

- The front buildings can create a chain closing the front to the Elbe by closing the gaps between the buildings with demountable barriers with sheet piling as shown in Figure 5-23
- the streets will not be flooded, but the water will be pumped out of

the basements and conveyed.

D-RS5 — Not considered due to the topography and proximity to the water course

Examples of the RS at the property scale for different RS at the neighbourhood scale have been illustrated in Figure 5-23.

[186] Also available at the link: http://www.lauenburg.de/download/stadt/gutachten-zum-hochowasserschutz.pdf (last accessed: January, 2015)

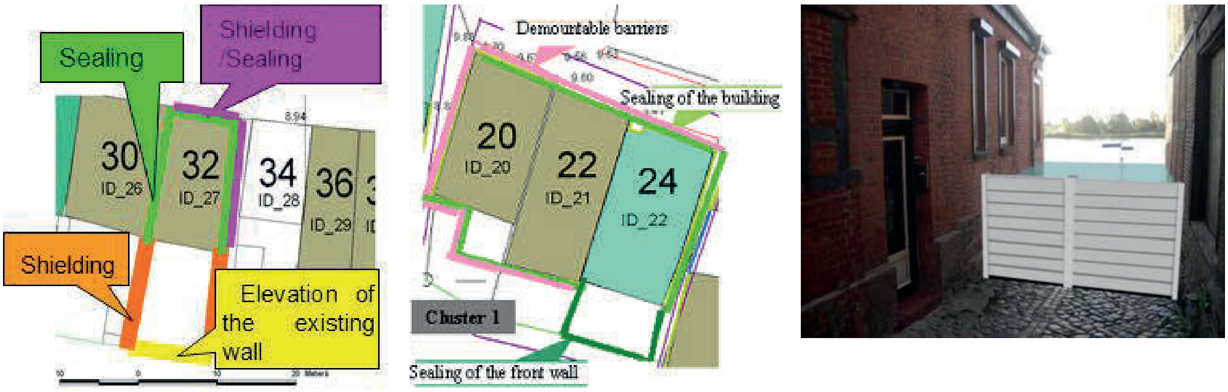
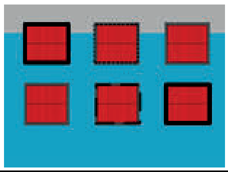
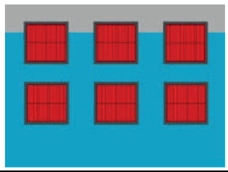
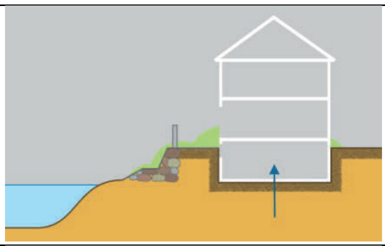
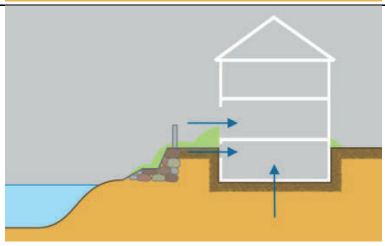
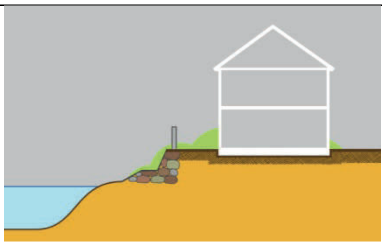
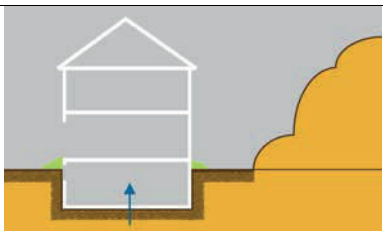
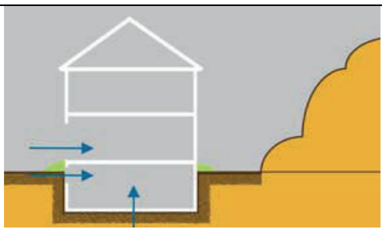
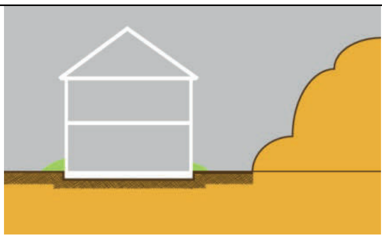


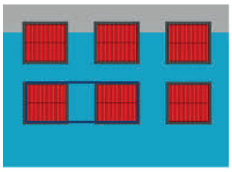
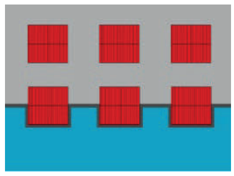
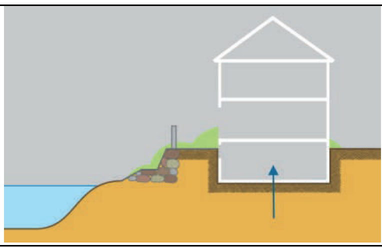
Figure 5-23 Examples of the RS at the property scale for different RS at the neighbourhood scale (from left to right: D-RS1, D-RS2, D-RS3)

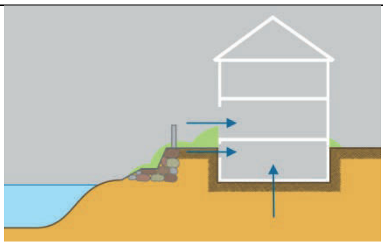
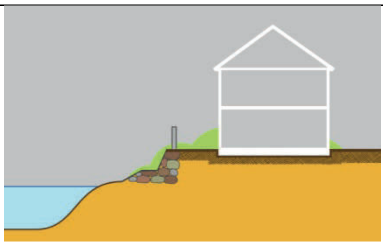
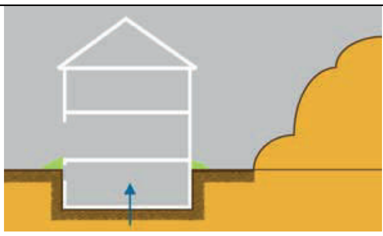
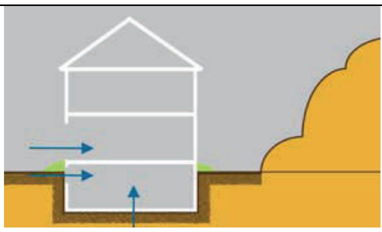
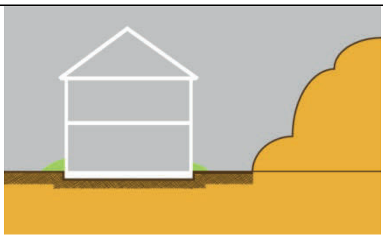
Table 5-15 outlines the resilient systems per representative building considered for different resilient systems at the neighbourhood scale.

Table 5-15 Resilient systems at the property scale developed as a part of the resilient systems at the neighbourhood scale for the six selected buildings (types) in Lauenburg,Germany

			D PRS-1 	D-RS-2 
B 1		Riverside Building with basement The water can enter only through the basement RS_wB_B	P-RS1 Controlled flooding of basement	P-RS1 Controlled flooding of basement
B 2		Riverside Building with basement The water can enter through the basement, groundfloor openings or walls. RS_wB_BGF	P-RS3,4,5 Controlled flooding of basement+ (3) sealing of the above ground floor (4) shielding of the ground floor (5) wetproofing of the ground floor	P-RS3,4,5 Controlled flooding of basement+ (3) sealing of the above ground floor (4) shielding of the ground floor (5) wetproofing of the ground floor

B 3		Riverside Building without basement The water can enter through the groundfloor openings or walls RS_woB_GF	P-RS-7,8,9, 10 (7) Shielding of the building (8) Sealing of the above ground floor (9) Controlled flooding of the above ground floor (10) wetproofing of the ground floor	P-RS-7,8,9, 10 (7) Shielding of the building (8) Sealing of the above ground floor (9) Controlled flooding of the above ground floor
B 4		Hillside Building with basement The water can enter only through the basement HS_wB_B	P-RS1 Controlled flooding of basement	P-RS1 Controlled flooding of basement
B 5		Hillside Building with basement The water can enter through the basement, groundfloor openings or walls HS_wB_BGF	P-RS3,4,5 Controlled flooding of basement+ (3) sealing of the above ground floor (4) shielding of the ground floor (5) wetproofing of the ground floor	P-RS3,4,5 Controlled flooding of basement+ (3) sealing of the above ground floor (4) shielding of the ground floor (5) wetproofing of the ground floor
B 6		Hillside Building without basement The water can enter through the groundfloor openings or walls HS_woB_GF	P-RS-7,8,9, 10 (7) Shielding of the building (8) Sealing of the above ground floor (9) Controlled flooding of the above ground floor (10) wetproofing of the ground floor	P-RS-7,8,9, 10 (7) Shielding of the building (8) Sealing of the above ground floor (9) Controlled flooding of the above ground floor

			D-RS3 	D-RS4 
B 1		Riverside Building with basement The water can enter only through the basement RS_wB_B	P-RS4 Controlled flooding of basement+ shielding of the ground floor	P-RS4 Controlled flooding of basement+ shielding of the ground floor

B 2		Riverside Building with basement The water can enter through the basement, groundfloor openings or walls. RS_wB_BGF	P-RS3,4 Controlled flooding of basement+ (3) sealing of the above ground floor (4) shielding of the ground floor	P-RS3,4 Controlled flooding of basement+ (3) sealing of the above ground floor (4) shielding of the ground floor
B 3		Riverside Building without basement The water can enter through the groundfloor openings or walls RS_woB_GF	P-RS-7,8 (7) Shielding of the building (8) Sealing of the above ground floor	P-RS-7,8 (7) Shielding of the building (8) Sealing of the above ground floor
B 4		Hillside Building with basement The water can enter only through the basement HS_wB_B	P-RS1 Controlled flooding of basement	P-RS1 Controlled flooding of basement
B 5		Hillside Building with basement The water can enter through the basement, groundfloor openings or walls HS_wB_BGF	P-RS3,4 Controlled flooding of basement+ (3) sealing of the above ground floor (4) shielding of the ground floor	P-RS1 Controlled flooding of basement
B 6		Hillside Building without basement The water can enter through the groundfloor openings or walls HS_woB_GF		

The results obtained from the interviews regarding the attitudes of the stakeholders towards resilient strategies and systems in Lauenburg reflect the assumption that the residents are generally aware of flood hazard and potential strategies to manage floods as depicted in Table 5-16 (42,86% opted for living with floods solution for Lauenburg i.e. for the application of one of the resilient systems).

Table 5-16 Survey of stakeholders' attitude in the historic area of Lauenburg

Attitude:	Nr. of answers:	Percentage [%]
Living with floods by application of resilience measures	**21**	**42,86 %**
Flooding is a matter of landuse management, building of polders	6	12,24 %

in the upper course of the River Elbe		
The Local Authorities should take over full responsibility over the flood management by rising dikes and walls	10	20,40 %
Do nothing- there is no solution for the city of Lauenburg	7	14,29 %
Don't know/ have no particular opinion	5	10,20 %

Total: 49 interviewees

Verification of the key criteria of MCA (including CBA)

The dwellers (49) have been interviewed during the onsite visit to rate the MCA criteria according to the scale given in Table 5-6, by directly asking them to rate those criteria. Additionally, as a reference, the representatives of the local authorities deliver their opinion in order to assess the potential for a dialogue and joint planning during the individual meetings with the representatives (3).

The results are given in Table 5-17. The performance of the measures as well as the loss of privacy even for the short time has been indicate as the key criteria by the interviewed dwellers.

Table 5-17 Feedback from the experts and dwellers (in total 49 interviewees) related to the relevance of the MCA criteria as given in Table 3-38 (0- no relevance; 3- high relevance)

Category	Criteria	Dwellers	Authorities
Technical aspects and reliability	Performance of the system during a flood event- e.g. effort for logistics	3	3
Cost effectiveness	Costs of investment Maintenance costs Cost-Benefit ratio	2	2
Social and Aesthetic	Changes in the building layout	2	2
	Impact on lifestyle	2	1
	Influence on the privacy, right of use	3	1
	Preservation of cultural heritage	1	3

The cost benefit analysis used for the discussion with the interviewees has been performed for the examined buildings and the results are given in Appendix 5.6b. In all analysed cases, the benefit cost ratio was unfavourable (0,37-0,42).

Verification of the resilience parameters

For selected six representative buildings, the resilience proxies have been assessed for the defined resilient systems on the property level considering different resilient systems at the neighbourhood/district level. The results for one represenative building are given in Appendix 5.6b.

Implementation of the decision making process- FLORETO GUI

The data collection via GUI of 123 buildings showed that it was possible to enter all detasets utilising FLORETO. However, it was not possible to directly enter some elements such as semi-floor, round wall elements or elements that are neither horizontal nor vertical. During the damage assessment, the problem of assessing the damage of the old abandoned, ruined buildings has been identified, which stresses the importance of considering stability of a building (i.e. damaging functions assigned to the building as a whole) in the FLORETO business logic.

5.2.3 Hamburg area, Germany

5.2.3.1 Decision making process on the resilient built environment

Testing the damage assessment methodology as implemented in FLORETO

For the selected eight edifications the results of the performed damage assessment by FLORETO is given in Table 5-18. The values are given for the minimal and maximal damage value based on the range of costs (ck,min -ck,max) and that for a 100-year flood event. The cost range depends on the categories of the materials and inventories assumed for different cases. Where vailable, the results have been compared with the medium damage assessment method that utilises standardised damage curves IKSE as implemented in KALYPSO-Risk and the results are listed in Table 5-18. The assessed damage utilising FLORETO for the selected buildings is given in Appendix 5.7a. The calculations utilising KALYPSO-RISK are given in Friese, 2014.

Table 5-18 Overview of the assessed damage (FLORETO- min, max, utilising the medium scale damage assessment as implemented in KALYPSO-RISK). Where the KALYPSO RISK data were not available, local experts have been consulted

ID	**Location**	**Water depth [m]- 100y**	**Damages [€ per property]**		
			Min.[€]	Max. [€]	KALYPSO-RISK
1	LS 26	1.0	17,096.00	65,000.00	Local expert discussion
2	WS 103	0.1	85,000.00	202,065.00	Local expert discussion
3	**StS 190**	**0.1**	43,200.00	93,600.00	~35,000.00
4	AS 15	0.1	100,000.00	195,000.00	Local expert discussion
5	AS 16	0.2	8,000.00	32,000.00	Local expert discussion
6	V-E-S 16	0.2	6,000.00	26,600.00	~1,200.00
7	**BA 21**	**0.2**	**11,200.00**	**48,000.00**	Discussion with the dwellers
8	EA 96	0.2	164,400.00	334,500.00	~49,000.00

The potential to apply the CI algorithms for the resilient planning on the built environment

The results of the data mining tests performed by WEKA are shown in Table 5-19 In Table 5-19 depicts the results obtained by varying the number of attributes from 21 to 46 to 62, and applying cross validation (CV) and split test (TS) on 308 data samples. The attributes considered are given in Appendix 5.3.

Table 5-19 Results based on the Cross Validation and Test Split on 308 data samples

	21 attributes		46 attributes		62 attributes	
Model/Test	**CV**	**66%TS**	**CV**	**66%TS**	**CV**	**66%TS**
PART	79.87	75.21	84.74	75.23	85.88	83.84
J48	**85.55**	72.21	82.66	80.00	**86.68**	79.04
NNGE	71.46	64.76	70.71	63.62	69.76	58.46
LMT	84.55	80.00	68.83	59.04	81.69	80.00
Logitboost	**86.36**	78.09	78.57	69.23	**85.06**	76.19
MLP	76.19	78.57	71.42	28.57	71.42	47.50

Table 5-20 Results on the Cross Validation and Test Split on 100 data samples

	21 attributes		46 attributes		62 attributes	
PART	76.79	75.00	75.19	28.57	76.19	25.00
J48	80.25	74.23	79.36	69.00	78.38	75.29
NNGE	80.95	78.57	71.42	55.14	71.42	62.50
LMT	80.95	78.57	76.19	28.57	71.42	37.50
Logitboost	76.19	78.57	80.95	71.42	76.19	87.5
MLP	64.65	55.38	55.38	50.76	41.36	45.38

In order to assess the sensitivity of the model, a smaller dataset containing 100 samples has been used. The results are given in Table 5-20. The models built using the dataset with 308 samples have been integrated in the current business logic of FLORETO. The results obtained are considerably better than the results obtained in the 100 samples dataset. The $M_{optimal}$ were in this case the Logitboost and the decision tree (J48) model. However it can be inferred from the actual test results that further refinements are necessary. The following iteration based on the increase of datasets (820) did not show any improvement, so that the balance between the key attributes, level of detail of the proposed resilient systems and effort for collecting and preparing the datasets still can be optimised.

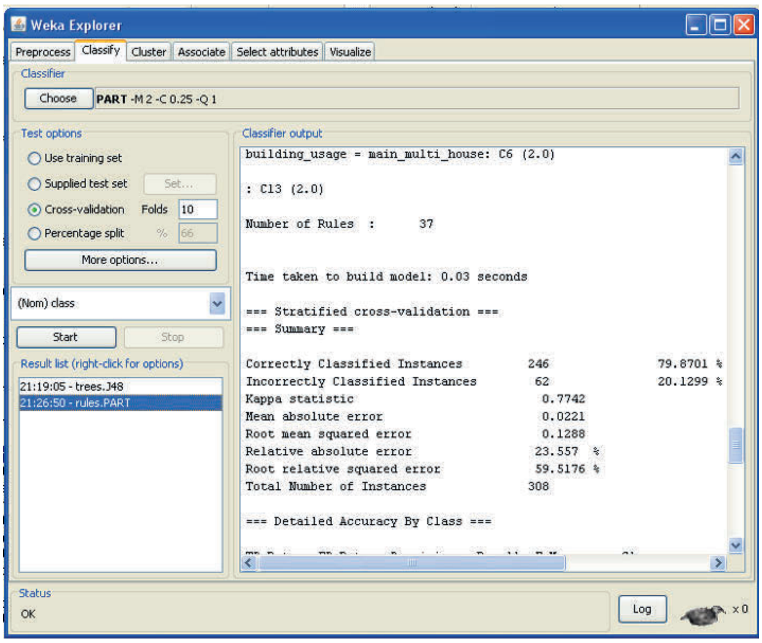


Figure 5-24 WEKA classification process in WEKA; here for classification of 308 with 21 attributes data utilising the PART algorithm, 10 fold cross validation. The result is 79.87% correctly classified instances.

Applicability of the resilient systems at the property scale and verification of the criteria for their selection

According to flood risk management plan (FRMP-Wandse, 2011, Manojlovic et al., 2012) that has been developed within the LAA-Wandse by all participating stakeholder representatives, the dwellers should undertake measures to protect their own properties. In that sense, the resilient systems suggested by FLORETO have been discussed with the involved dwellers. The open interviews and the discussions during the LAA sessions indicated that the decisive criteria for the dwellers has been to have a “dry homes”, giving less to the costs and the logistic requirements. For the Building with the ID 3 (StS 190), the difference between the suggested and preferred system is given in Table 5-21.

Table 5-21 The suggested and preferred resilient system by the dweller for the building ID3

Resilient system suggested by FLORETO	Preferred system by the dweller
Controlled flooding of the basement Sealing, shielding or wetproofing of the ground floor	Sealing of the basement and shielding of the building

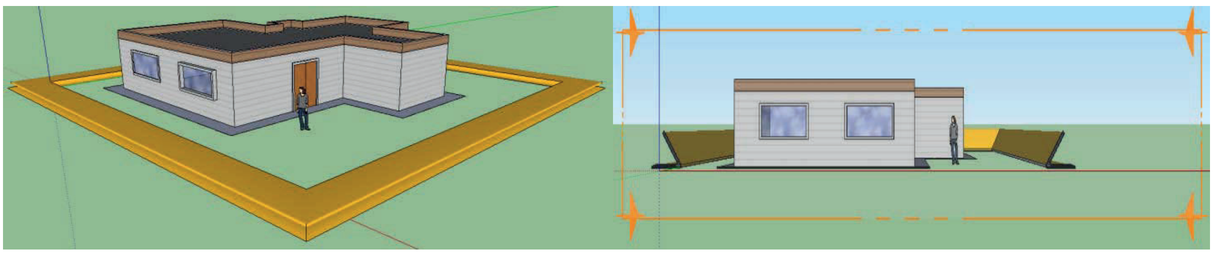


Figure 5-25 The preferred resilient system by the dweller for the building ID 3- StS 190 (source: students drawing supervised by N. Manojlovic)

Resilience performance

For the buildings ID3 and ID7 the resilient performance has been assessed for the present state, suggested and preferred resilient systems. The results are given in Appendix 5.7b.

Readiness to take decision on the resilience systems

Within the LAA-Wandse the delivered resilience systems have been discussed with the dwellers (2). Also the dwellers that requested the access data after the Klima Woche 2009 event (7 in total) have been contacted.

30% of the interviewed dwellers (3 in total) in Hamburg would follow the suggestion delivered by FLORETO, however further information and explications are required. However, 30% would not be ready to replace the advice of the experts with the tool under any circumstances.

Implementation of the decision making process- FLORETO

The outcomes of the testing according to the protocol given in Appendix 5.4 together with the feedback from the semi experts (students) can be summarised as given in Table 5-22.

Table 5-22 The summary of the feedback on the technical performance of FLORETO obtained from a group of semi experts (in total 30)

Technical performance of the tool:	**Feedback from the involved semi-experts (in total 30)**
Technical reliability (all modules)	-Overall good, minor bugs and inconsistencies found which could be fixed
Operational time (business logic module)	- Damage assessment module: strongly depends on the size of the building, number of the elements and the number of buildings, improvement needed - DM module: short response time (1-2 sec)
Easy access and use (all modules)	- Access is easy - Tool is easy to use and intuitive, no training needed
Robustness (all modules)	- It was easy to edit/add new damage curves in the database - some defficineces when entering data through GUI, options are missing

Acceptance of the FLORETO tool among dwellers

After the Klima Woche event and the launching of FLORETO, seven dwellers requested the access data to FLORETO and described properties in it. The users that requested access to FLORETO triggered by the Klima Woche event are listed in Figure 5-26.

During the event outlined in O5 and Table 5-10, the participants (in total 7) gave the feedback in an open session as depicted in Table 5-23. Additionally, during the session it has been made clear that additional explanations and support were necessary and not all items were self-explanatory and intuitive (drag & drop or drawing on the board). Also, for older people drawing was too demanding and hardly an acceptable option for the description of individual properties (3 out of 6). Based on the comments, more detailed and user friendly explanations of those actions have been integrated into the help menu of FLORETO.

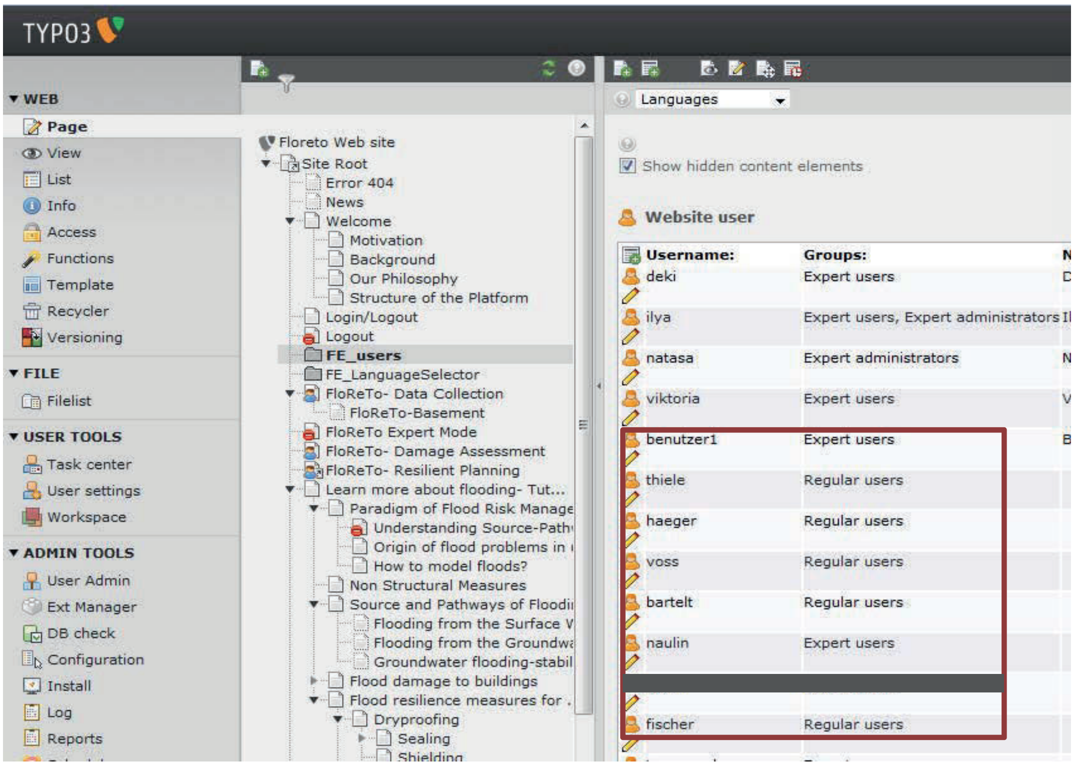


Figure 5-26 The users that requested access to FLORETO after the Klima Woche event are given in the red rectangular (here displayed in the FLORETO backend, 2 users requested to have an expert access rights)

Table 5-23 Feedback on acceptance of FLORETO

Aspect	Answer (in total 7 Participants)
Easy to use	Yes-3. No-3, I don't know- 1
Usefulness	Yes-6, No-1
The willingness to use it for own properties	Yes- 5 No-0, I don't know- 2
Feedback	Did not use the option

5.2.3.2 Capacity Building of Stakeholders

Tool for raising flood awareness- Flood Animation Centre/Studio (FAC/ FAS)

Implementation of the concept- Flood training in FAC

The application of the FAC to residents in Wilhlemsburg **(O6)** delivered different results depending on the variants applied. In the first round within the one day event in Wilhelmsburg[187], a group of 3 test persons (2 adults and a child) took part in the training according to Variant 1 (see section 5.1.3.4). In the second round, 1 test person participated in the flood training according to Variant 2. Two options have been considered: with and without observers.

Figure 5-27 Round 1: group of 3 test persons, Variant 1

Figure 5-28 Round 2:1 test person, Variant 2

Acceptance of the Flood Animation Centre/Studio among dwellers

[187] See Program in 5.1.3.4

a) Variant 1: In total seven observers have been interviewed. The results are given in more detail in Appendix 5.7c.

b) Variant 2: In total ten flood simulations have been conducted at the Klima Woche event 2010, visited by more than 200 people. 45 observers have been reached for the interview or for filling out the questionnaire after the flood simulation. The results from the questionanaires are given in Appendix 5.7d.

Interactive Learning Program

The applied concept of ILP has delivered the following results:

The participants' profiles (in total 6) have been assessed before the ILP based on the criteria given in Appendix 4.4b. Although encompassing a rather small number of people, the assessment indicates a variety of participants' profiles ranging from academia to semi-skilled manual workers. Most of the participants (5 out of 6) are owners of houses, which strongly contributes to their motivation for participation. Regarding the previous experience with flooding, the received answers indicate both no experience as well as occasionally facing flood water in their homes. The results are summarised in Appendix 5.7e.

Considering the main criteria for assessing the efficiency of the ILP the results are given as:

- Improvement of risk awareness and changing attitudes towards own flood risk

A detailed survey of affected households of participants and the questionnaires following the questionnaires and procedure given in Appendix 5.2 showed that the people are mostly aware of the flood problem, but at the same time the wrong implementation of measures shows a lack of knowledge and core understanding of the problem. In general, there is no systematic approach in the selection of appropriate measures. Risk awareness was not sufficient to be efficiently proactive, but the first step to it.

The introduction of flood hazard maps in combination with FAC has been evaluated as very important as useful, confirming the importance of flood maps for communication of flood risk.

- Acceptance of own risk- Improvement of the level of information and acceptance of own responsibility through enforcement of communication skills

Although people came with some prejudices and a rather negative experience in cooperation with the authorities, their presence was highly appreciated and a shift from "blaming the authorities" to "acceptance of self-responsibility" by the residents has been observed throughout the ILP. This shift was initiated by bringing together the residents and the authorities to a discussion table and by learning the aspects of the ILP. The feeling that they are not left on their own plays an important role.

- Improvement of the gained knowledge/ expertise

During the ILP, the participants showed an appreciable improvement in understanding the hydrological aspects and complexity of urban flood management, which was confirmed by the questionnaires before and after the program. However, for participants flooding has a strong local context ("my own property and neighbourhood"). The learning process from “reflection” to forming “abstract concepts” turned out to be critical. More examples and focused case studies together with the social science methods are necessary to achieve a higher level of generalisation. The participants reacted positively and highly appreciated the figures and facts. The presentation of the results of the hydrologic modelling in the catchment Kollau received a lot of attention and was appreciated by all participants. It was regarded as important for the understanding process.

- Proactive behaviour- Change of attitude and readiness to apply new knowledge

For most of the residents the application of measures means a certain change in comfort and additional responsibilities (e.g. in case of application of demountable barriers). The survey showed that the interviewed residents already had shown proactive behaviour before the ILP but the measures were mostly taken on an ad-hoc basis. Both good and bad examples were identified as depicted in Figure 5-29.

The inadequate measures as well as their wrong implementation show a lack of knowledge and core understanding of the problem by both residents and involved professionals. In general, no systematic approach in the selection of appropriate mitigation measures has been identified. The participants showed a high interest in the possibilities and techniques available for building protection. The main issues of concern were driven by their own problems and contained concrete questions such as “How can I protect my basement by applying waterproof concrete?”, which indicated their acceptance of the concepts and ideas presented within the ILP and their openness to apply the measures developed during the testing phase. Those protection concepts for individual properties were discussed with the participants (which are at the same time the homeowners), showing the most important criteria for their acceptance being financial, followed by the operability and the requirements for their maintenance. The feedback round after the ILP showed that the residents generally accepted the developed solutions for their own properties and demonstrated a readiness for their application. The interviews one year after the ILP showed that 2 participants followed the suggestions and took actions to protect their homes against floods.

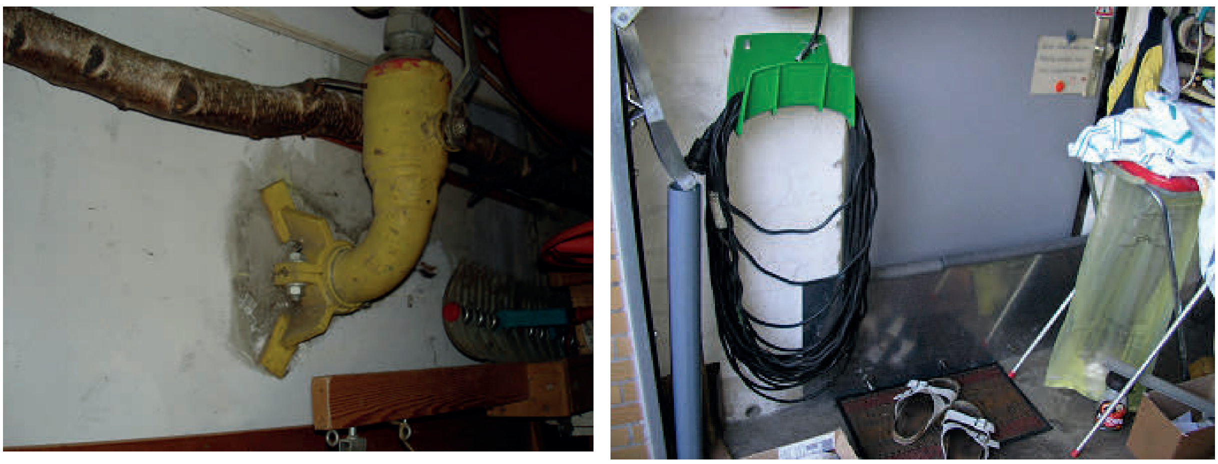


Figure 5-29 Good and bad examples of individual measures in the Kollau catchment; left: encapsulated fittings and services and waterproof concrete in the basement, right: : temporary barrier used as a permanent construction

Involvement of dwellers in a stakeholder engagement process

In total 14 sessions have been conducted with the participation of 3 representatives of the stakeholder group- dwellers. Table 5-24 outlines the main activities conducted related to dwellers as well as the summary of the feedback given by the dwellers during the formative and summative assessments. The full results are available at: http://laa-wandse.wb.tu-harburg.de (password protected).

Table 5-24 The main activities conducted and results obtained related to dwellers dring the LAAs

LAA phase	**Objective**	**Results- activities related to dwellers**
1. Scoping	(Stakeholder analysis) Development of shared vision of the problem	- The stakeholder analysis and the interviews during the session 1 indicated rather low interaction of dwellers with other stakeholders prior to LAA (see Figure) - The properties have been entered in FLORETO and the damage assessment obtained. However it was difficult to get the exact reimbursement costs of the flood event of 200y due to privacy issue or the data was missing.
Questionnaires and interviews (dwellers): - the flood risk could only partly be assessed - partly too technical explanations which are difficult to follow - still the delivered figures& facts (including maps and the simulation results) have been very helpful - the onsite visit with a group has been very useful - the possibility to discuss the issues with the authorities has been seen as very important		
2. Understanding	Development of shared vision of where to get to (acceptable level of risk)	The measures have been discussed with the dwellers. They have also made use of the provided e lectures.
Questionnaires and interviews (dwellers): - the discussion on the measures with other participants and the presented examples of the measures with the assessment of their potential effectiveness has been assessed as the most useful technique used		
3. Experimenting	Formulate options of adaptive flood risk management by NSM	Participation in the development of the overall planning options for the Wandse catchment focusing on own properties The suggested strategies by FLROETO have been discussed with the dwellers in terms of their technical performance, costs and benefits, and impacts on the system at the larger scale

Questionnaires and interviews (dwellers): - the discussion with other participants has been emphasised as the most important measure to develop a common strategy which also includes the resilient built environment		
4. Evaluation and decision making	Adoption of the final FRMP	The dwellers participated with in the decision making on the final FRMP, bringing the issue
Summative analysis (questionnaires and interviews with the dwellers): - overall impression positive - the topic had a personal relation with the dwellers, which created the motivation for the participation - still some of the presentations/lectures were too technical		

5.2.4 Heywood, Greater Manchester, UK

Transferability of the damage assessment approach

The damage assessment for the selected buildings has been performed by FLORETO and compared to the reimbursement of the insurance companies. The detailed analysis of the selected building in FLORETO is given in Appendix 5.8.

Table 5-25 Overview of the examined buildings and the obtained results by the means of FLORETO compared to the reported reimbursements by the insurance companies

ID	Location	Type	Damage FLORETO/ Insurance
1	**29 CA**	Private, detached, single-story house, no basement 	Water depth of the relevant event of 2006: 0.60m FLORETO: the estimated maximum damage amounts 29.000 EUR. INSURANCE: „Claims of circa £20,000[188]. No increases in premium”
2	**1 MBC**	Private, detached, single-story house, no basement 	Water depth of the relevant event of 2006: 0.80 m FLORETO: The estimated maximum damage amounts 29.000 EUR /per house INSURANCE: “Several claims of £45- 50,000 where flooded and varied increases in premium/excess”

[188] 1 £= 1,19 EUR

3	**22 MC**	Private, two-storey semi-detached 	Water depth of the relevant flood event of 2004: 1 m. FLORETO: The estimated maximum damage amounts 61.000 EUR INSURANCE:" £40,000 claim in 2004 where-after premium doubled but no excess."
4	**32 PR**	Private, two-storey terraced home, with no basement 	Water depth of the relevant event of 2006: 0.60 m FLORETO: The estimated maximum damage amounts 24.000 EUR. INSURANCE: "Received £8,000 contents and £23,000 structural + cost of living in hotel 6 months". "£2,500 excess now".
5	**127 RS**	Private, two-storey terraced home, with no basement 	Water depth of the relevant event of 2006: 0.40 m (2h) FLORETO: The estimated maximum damage amounts 10.000 EUR. INSURANCE: Paid out but excess now £8,000".
6	**63 WG**	Private, semi-detached, two-storey building, no basement 	Water depth of the relevant event of 2006: 0.25 m FLORETO: The estimated maximum damage amounts 8.000 EUR. INSURANCE: "£ 20000"

Acceptability of FLORETO among dwellers

The main comments received from dwellers can be summarised as:

- "Tool too complicated for individual use, we need an expert supporting and advising us"
- " The tool should be used and promoted by the local authorities"

This feedback is in line with the feedback received from the dwellers during the National Support Group meetings held in Heywood within the SMARTeST Project as given in White et al., 2012.

6 Discussion of Results and Conclusions

6.1 Decision Making Process for the Resilient Built Environment

The results from the case studies related to the decision making process have been analysed in the context of the objectives for verification as stated in sections 2.4 and concretised in section 5.1 and Table 5-1.

6.1.1 Methodology for decision making on the resilient built environment on the building scale

6.1.1.1 Risk (Damage) assessment

The developed model for damage assessment that considers the building elements such as walls, floors or ceilings as the basic units could be analysed and compared with the methods that consider the units at larger or smaller scales:

(1) larger scale: a medium-scale method utilising the standardised damage curves
(2) smaller scale: mere building materials

The results have been analysed for the study areas in Hamburg, Lauenburg, Nidwalden and Heywood and the main conclusions in relation to the parameterisation, transferability of the damage functions and the damage perception have been derived.

Parameterisation of damage curves

In the study conducted in Nidwalden, a difference in the assessed damages could be identified for the building elements and if the materials were considered separately. This phenomenon can be illustrated by the "tiles problem", where the damage reported on tiles considerably exceeded the theoretical values, in which tiles are considered as flood resistant and recommendable for the application in flood prone areas. The considerably higher values are mainly due to the fact that the tiles as an element of a floor or wall unit had to be removed depending on the underlying construction and its susceptibility to floods. In the case that the floor or wall construction have been damaged, the tiles, as a covering had to be removed in order to repair the construction beneath it.

The building condition can have a substantial role in the assessment of the damage as it could be appreciated at the case study of Lauenburg. In case the building is in a bad condition, either additional works should be considered or the building should be regarded as not usable and is to be abandoned. However, it is to assess to which extend those additional works are bringing the building to its initial condition (before flood), or it also delivers a certain improvement of the initial state.

It could be observed at the case of Heywood that the difference between insurance reimbursements and calculated damage utilising FLORETO differed partly due to the underestimation of the cleaning costs, which were needed to remove the dirty water coming from the sewer system. Further differentiation of the drying and cleaning costs has to be undertaken.

The method developed in this work introduces a matrix of the flood intensity that is mapped to different layouts of building elements. Still, a number of functions is missing, mainly related to the influences of the flow velocity to different elements of a building. A detailed study including lab or onsite experiments or reliable data from the real events are required to extend the existing database of damage curves. In that sense, FLORETO database delivers a good and robust base for extension (examples Heywood where the functions have been altered, mainly due to different costs, without changing the structure of the tool).

The parameters derived for this damage assessment method, enable the application for the buildings, which stability is not jeopardised due to floods, as a thorough consideration of the statics is not provided. It would be possible to integrate a static module which would be attributed to the building as a whole in the FLORETO database and improve the current approach.

The results obtained for Heywood and Hamburg indicate that the damage range is in some cases too high (up to 100% difference between min and max values). It has to be further investigated. A possibility would be the further refinement of the cost ranges per building element, item or material.

Assessment of the perceived damage and acceptable risk among dwellers

Individual perception of damage varies strongly among the stakeholder groups. A direct comparison of reported damage in studies in Lauenburg and Nidwalden (lake Luzerne) shows different levels of the reported damage, indicating a strong relation between lifestyle and perceived damage. Figure 2-11 depicts the differences in reported damage of the two areas. While Figure 2-11a shows considerable deterioration of the building fabric which has not been considered and reported as damage, the aesthetic damage of the kitchen unit in Nidwalden depicted at Figure 2-11b has been reported as fully damaged and replaced. Apart from the fact that insurance covered the damage, the lifestyle and importance of the kitchen as a “status symbol” in the area contributed to the high extent of the reported damage.

The differentiation between functional and aesthetic damage curves supports this difference in perception. However, functional alterations of the building element cannot be left to private stakeholders for a decision, as such damage destructs the basic functionality of the building elements and can cause health problems, and as such, has to be reported (which was the actual case in the example of Lauenburg).

Figure 6-1 Different damage perception of private stakeholders: a) Basement of a building in Lauenburg area not considered as damaged b) kitchen unit in Nidwalden reported as ful damage

Also, the data provided by the insurance company for the case study of the Lake Lucerne (Nidwalden) turned out to be a valuable input, however it should not be taken for granted. A detailed analysis and interviews with the representatives indicated that in some cases the damage was deliberately overestimated (e.g. reimbursement of an expensive audio equipment in basement) in order to avoid conflicts with the insures. Such deviations are to be considered when assessing the actual damage.

Transferability

Although the developed damage curves demonstrated a transferability potential (studies in Hamburg in Heywood), the specific construction styles of the region have to be regarded and this knowledge should feed into the (specific) damage curves. The regional aspects and construction styles should also be considered in the assessment as e.g. a subdomain in the database

6.1.1.2 Flood resilient plan for the built environment at the building scale

Validation for the parameters relevant for the definition of the resilient systems at the property scale

The developed set of resilience proxies that has been tested at the selected buildings in Lauenburg and Hamburg study areas contributed to a better understanding of the performance of the analysed resilient systems. The analysed systems exhibit different advantages in terms of the resilient level i.e. the shielding measures have high thresholds and lower time to recover than the analysed wetproofing and controlled flooding systems. However, they are more sensitive to malfunctioning and have less favourable damage evolution depending on the flood frequency. It is also to say that the proxies developed are not expressed in quantitative terms (i.e. they classify the performance of an analysed system rather then assigning weights to those classes), but can serve for development of the quantitative metrics. Also, the resilience parameters can be further become a part of an MCA, in particular, relating the costs of measures, willingness to spend or impact on the lifestyle, to the resilience performance of the measures. The results from Launeburg demonstrated that the resilience performance is scale dependent.

Cross scale analysis of the resilient systems

In terms of the cross scale analysis of different resilient systems, the case studies in Lauenburg and Hamburg- Wandse indicate high relevance and importance, where the resilience of individual building varies depending on the scale to be observed. The resilience at the property scale is to be seen in a broader context and should be embedded into the resilient systems at larger scales.

It also means that dwellers cannot make their own decisions when planning the measures without consideration of other buildings (neighbourhoods) or, if available, strategies defined on the community level.

This outcome also favours the idea of joint flood risk management planning (as conducted in the Wandse area within the LAA-Wandse), where other stakeholders should also be involved.

A knowledgebase, as developed for the resilience systems at the property scale can be beneficial, as it captures the main characteristics of different resilient systems and gives the initial hints on the potential of different measures and what to consider when implementing them.

Applicability of the CI algorithms for the technical selection process (accuracy of the models built)

Application of data mining for the selection of the flood resilient system showed an application potential. However, the results are to be discussed in terms of the effort to be invested to built the model vs. accuracy of the prediction algorithms and the sensitivity of the model to improve the accuracy when increasing or decreasing the number of datasets and the attributes. The results obtained considering the building types in Hamburg as summarised in Table 5-18 and 5-19 demonstrate rather comparable predicion accuracy of the applied algorithms, which leads to the conclusion that the key attributes for the selection of the measures are the same and are contained in all simulation runs (62, 46, 21 attribute sets). Also, further increase in the datasets did not bring any considerable improvements of the prediction accuracy.

WEKA identified the water depth, presence of the basement, wall base- basement and ground floor to be the decisive parameters for the selection of the appropriate resilient system.

However, this list is not exhaustive. The achieved accuracy of 87% (for the best fit CI model-$M_{optimal}$) in the initial dataset in Hamburg gives a good basis for further improvements.

As the method developed within this work, assumes that the models can be improved over time based on the experts' and dwellers' feedback, the real benefit might be expected in the future. In the next step, a possible research would be to increase the level of detail of the resilient systems to be applied and increase the number of instances in the dataset. For such a model, the key attributes, the sensitivity of the model, accuracy of the predictions and the effort to be invested to build the model should be analyses and compared to the model developed within this work.

It is also to mention that the effort to be put in advance for definition of the initial datasets is considerably high and in that sense it is also to consider developing subdomains (specific test areas), with the specific features which might increase the accuracy and more efficient optimise the number of the datasets needed to feed into this threshold accuracy.

Parameterisation of the MCA including CBA

The case study in Lauenburg shows that selection of the final resilience option can go beyond a mere monetary assessment. Although in most cases assessed as important (e.g. in the case of Kollau), the criteria other than economic are often decisive when deciding on the final strategy. The case of Launeburg indicated that the privacy issue was the decisive criterion for selecting a certain resilient system. This can cause conflict with the interests of the local authorities, who evaluated this criterion as rather irrelevant. Such conflicts are more likely to be solved within a joint participatory process (such as the LAA), than in a mere dialogue between the authorities and the dwellers, where the latter is the current practice in Lauenburg.

In Launeburg, a large number of the recent settlers is rather reluctant of accepting the fact that they have to adapt their lifestyle to flooding, putting the responsibility to the local and state authorities. A certain group of the residents is seeing the problem in Lauenburg only as a consequence of mismanagement of floods in the upstream Elbe course (12,24%). The regional institutions, as responsible, should solve the problem by constructing polders in the upper part of the river Elbe preventing flood wave reaching Lauenburg rather than managing floods in the city itself.

6.1.1.3 Implementation and review

Relevance of the parameters

As already concluded, the same resilient system can perform differently depending on the resilient system at the larger scale it is to be embedded in.

The verification of the defined parameters/proxies for the resilience performance (given in Table 3-4) has been assessed as useful and relevant by the interviewed experts. However, the analysis indicated that the flood resilient technology (FReT) used for the definition of the resilient systems has to be better explained and specified. FReT has a range of options and it is important to indicate from which side this measure is to be applied (inside of the building or from the outside). This parameter primarily influences the coping capacity (evacuation, accessibility) and should feed into the knowledgebase. This is of relevance for the dwellers when selecting the preferred measures, what could be observed in Hamburg.

The scope of the developed proxies is the building or property scale. They should be extended or embedded in the resilience analysis of the systems at larger scales and feed into a comprehensive methodology for the resilience assessment e.g. flood resilience index. One of the parameters should include the assessment on how a resilience system at the property scale impact the resilience level of the adjacent properties.

6.1.1.4 Feedback options

The possibility to integrate the feedbacks into the business logic

This aspect has been considered within the BL analysis.

6.1.2 Decision support tool- FLORETO

6.1.2.1 Technical performance of the tool and its components (GUI, BL, RDBMS)[189]:

Technical reliability (GUI, BL, RDBMS)

During the testing, the tool did not show any substantial bugs. However suggestions for improvements delivered by the professionals were related to the consideration of versioning. As the tool is online and directly communicate to the database, any change of the database entries (e.g. costs) has an impact on the calculations which has an impact on the previous calculated damages or costs.

Robustness (GUI, BL, RDBMS)

FLORETO has been assessed as robust by the experts as the required changes and entries into the database could be easily accomplished. In that sense it is possible to enter damage models and curves developed in other projects and for other regions and use them via FLORETO:

Completeness (GUI)

The tool delivers a rather comprehensive set of data collection items for describing the building and its elements. Still, during the data collection procedure some possible improvements have been identified. The main ones are given as: FLORETO accepts only

[189] As already stated, the technical implementaiton of the DM method (programming) has been beyond the scopeof this Thesis. However, the feedback on FLORETO's tehcnicla performance is given here as it might influence the adjustments in methodology for future development.

straight walls (horizontal or vertical; which is not always the case in reality; semi-floors are not considered for the FLORETO data collection.

Operational time (BL)

FLORETO's performance in terms of the operational time has been analysed considering two main aspects:

- retrieving data from the database and business logic (response time)
- time required to describe a building utilising GUI

In the case of one building with max 5 rooms (average), FLORETO has a response time of 1-3sec when retrieving the data from the database and running the models in the business logic, which has been assessed as acceptable by the interviewed users (professionals, semi experts). The main issue that could be observed, which hinders fast response is related to the high resolution damage module and the damage calculation time, which can considerably expand with increasing complexity of the object (high number of rooms, walls or building contents) or the number of objects analysed. Also, as FLORETO is an open source internet based tool available via a browser, the state of the art of the current web technology is a limiting factor.

6.1.2.2 Acceptance of FLORETO among dwellers

Easy and free to use

The interviewed users assessed the tool differently and their opinion could be related to the age and computer literacy. All interviewed dwellers above 60 years but 1 assessed the tool as difficult to use on their own. Approx. 80% of the interviewed professionals and semi experts found the tool easy to use. Also, the representatives from the technical certification agency TÜV assessed the tool as useful for the certification purposes, however it needs adjustments of the methodology and further research on how to involve the certification agencies and the isurance industry.

As the design of the user interface has been developed by consulting the dwellers' representatives (in the Hamburg-Kollau study area), it considerably contributed to the design and features to be available to the users.

As FLORETO is accessible via internet without downloading or installing any software or plug-ins, it can be considered as an easily accessible tool.

Due to data privacy protection, the users have to use their own login data, which is easy to get by contacting the administrator. There have not been any accessing problems reported.

Usefulness

The interviewed dwellers found the tool useful indicating the high sensitivity of the models and possibility to tailor the building description to own data as the most useful feature.

Willingness to use the tool for own properties

Although the tool has been assessed as useful by the majority of the interviewed dwellers, the appropriate end-users of the tool have been assessed differently.

The feedback from the users in Heywood indicates stronger reluctance to use the tool on their own, although it has been assessed as useful. It is argued that it is a complex issue and that a support from the experts is needed. The problem gains importance when addressing people that are less computer literate. For the future applications, it could be arranged that the experts perform onsite visits and together with the dwellers perform the assessment and input data into FLORETO.

In terms of the implementation of the resilient systems suggested by FLORETO, the obtained results (30% of the interviewed dwellers in Hamburg would follow the suggestion delivered by FLORETO and 30% would not be ready to replace the advice of the experts with the tool under any circumstances) indicate a room for improvement.

Also, the dwellers indicated different reasons for not following the advice, from poor trust in technology to disagreement with the suggested measures (e.g. prefer “dry homes” at any price, poor trust in resilient technology), which calls for the implementation of the MCA module in addition to the CBA. Also, 90% of the dwellers required more information about the measures to apply which should be supported by both, the experts’ advice and by the development of further teaching and info material with the corresponding explanations in FLORETO-Inform.

6.1.2.3 Transferability

The results from Heywood indicate good transferability of the FLORETO tool. Also, due to its modularity it is easy to update the database with the functions from different regions, without a necessity to change other modules.

6.2 Capacity Building of Stakeholders

6.2.1 Tool for raising flood hazard/ risk awareness- Flood Animation Studio/Centre

Raised risk awareness- Applicability of the method and variants and their comparison

In the first application phase applied at the case study are in Hamburg- Wilhelmsburg, it turned out that three people were too many for a box size of 2×2 m and the tasks assigned. Regarding the results of the questionnaires, out of the group of 10 participants 7 questionnaires could be used for evaluation.

The results indicate rather heterogeneous profiles of participants-observers ranging from experienced and informed residents to ones without previous experience and contact with the topic of flood management, but due to their active nature or “champions” attitude got interested in this event. The interviews after the training showed that the participants have a rather fragmented knowledge and general acceptance of the adaptive measures and resilient strategies for the built environment. Indicative is the opinion about the training procedure qualifying it as unrealistic in 50% of the cases, which opens room for further improvements of the method to make it more "real" and catchy. All interviewed participants answered positively to the question regarding their further engagement in similar events, showing interest in further programs for capacity building of stakeholders. Four respondents related the flood simulation to the previous experience, one of them to the big storm surge event took place in Wilhelmsburg in 1962. All participants found the tool useful. Five are interested in further events related to the capacity building.

In the second round, one person entered the box after having received rather brief instructions. The test person, a female in her early 30s, took part in the experiment according to variant 2, without observers. The observations during the training and recorded material showed chaotic and helpless behaviour, which increased with the increasing water level in the box (Figure 5-28).

The test persons, although they got defined tasks to accomplish, reacted confusedly, getting more helpless with the increasing water level. The interviews before and after the training indicated that even in spite of the previous flood experience the necessity for fast reaction and identification of "safe zones" within the living room with the increasing water depth caused the feeling of anxiety. Having multiple tasks to accomplish at the same time considerably contributed to this perplexed feeling and inability to react properly.

Motivation of dwellers to further participate in the capacity building process

During the Klima Woche event 2010, 90% of the respondents (out of 45) described the tool and the simulation as realistic mostly by comparing it with the experienced flood event (flooding at the river Oder or storm surge in Hamburg from 1962). 85% of the interviewees have seen no chance for structured reaction and assessed their potential reaction as chaotic or helpless without measures taken prior to the event. In 75% of the answers the interviewees expressed the readiness to participate in the further events and learn more about flood risk management and measures to protect their own properties, although 50% of the interviewed observers, had never thought about that before.

6.2.2 FLORETO-Inform

Acceptance of the tool among dwellers

FLORETO- Inform has been tested during the ILP process in the Kollau case study area and within the LAA- Wandse. It showed potential for non-presence phase.

Although the features of FLORETO-Inform have been evaluated as useful (mainly the e lectures) , the participatory process should be based on the face-to-face phases and the online aids used only to support the better uptake of the relevant information and knowledge. The dialogue and discussions during the workshops have been evaluated as one of the key aspects for a successful participation during and after the LAA-Wandse process.

6.2.3 ILP

The developed ILP, as a blended learning strategy, delivers an integrative framework for systematic capacity building of the private stakeholders. Considering the cycle of the ILP and the criteria for assessing the success of the learning process, the following results of different phases can be summarised as:

Raised risk awareness/ Changed attitude towards own flood risk
The example of Kollau showed that although the people were aware of the risk, they were not ready to change their behaviour in order to mitigate it. They still require information, or knowledge (expertise) on how to do it and motivation. For changing attitudes it is necessary to act on both the emotional and rational level and corresponding tools should be developed. FAC and especially the flood simulation contributed to awareness raising and changes of the attitude. This confrontation with the flood situation was decisive for breaking the illusion of controllability of the situation (i.e. own flood risk) (Musahl, 2009). Also, facts and sound information play an important role. This information should be provided in a form of flood maps, but their layout and contents have to be adapted to the targeted stakeholder group. The introduced approach of visualising flood maps by means of FAC showed a good acceptance among the private stakeholders, overcoming the problem of being too abstract to dwellers.

Acceptance of own responsibility
The participation of the authorities within the learning process has been assessed to be crucial in the case of the Kollau catchment, where the shift from "blaming the authorities" to "acceptance of own responsibility" has been observed. It can be achieved by an intensive dialogue of affected parties, expressing their own interests and presenting their own position. Speaking the same/right language is of crucial importance. Dialogue, i.e. communication, with the stakeholders is an efficient way to achieve it, but the stakeholders have to improve their communication skills.

Improved knowledge on flood risk management and flood resilient technologies and systems
Understanding hydrologic processes and the anthropogenic impact in urban catchments cannot be accomplished by standalone and fragmented sessions, but rather within a continuous process. The results obtained in the Kollau study area showed the improvement in terms of better understanding of the flood situation, but a comprehensive understanding of the processes has been assessed as too optimistic and not achievable.

Proactive behaviour
Clearly identifying own interests i.e. finding the motivation for the action turned out to be the most critical part. The results in the Kollau catchments indicate that the people tried to influence others to accept their own role and learn about their possibilities and obligations within flood management, but their own active involvement was on a rather low level.

Lessons learned regarding the implementation of the capacity building strategy

Regarding the implementation of the ILP, especially its face-to-face phase the following issues appear to be the key ones:

- The right selection of the participants is important, but difficult to achieve. Recruiting via an action group leads to selection of "champions" i.e. the active members of the stakeholder groups that are open to new experiences and changes. Although the scope of the targeted stakeholders is in this way reduced to the motivated ones, it is not seen as a drawback in the long run. Once they get and accept the key message, they can spread it over a larger population group (starting with neighbourhood or family) and initiate interest in flood related issues, as indicated in the results from the Kollau catchment.
- Facilitation of an independent and competent institution (such as academia) plays an important role. They should have an excellent command over the subject and knowledge of the area (supported by scientific results or models).
- Although not compulsory, it is recommended to conduct the sessions in the study areas, using the local facilities. Apart from being logistically convenient, it gives a familiar feeling to the participants and makes them feel "at home", supporting personal identification with the topic. To keep the continuity of the program and keep the topic present, one session per month turned out to be appropriate.
- For optimal management of the group, 6 to 12 participants should be considered. They should include a variety of different social and economic backgrounds.

The ILP concept showed some deficiencies, with the main ones identified as:

- *Resources issue*: Although the outcomes of the study at the Kollau catchment showed that a systematic approach is necessary in empowering the stakeholders, this process is time intensive and requires corresponding infrastructure and resources, which usually cannot be provided. The intermediate sessions are especially time and effort intensive as they involve coordination and agreement of various actors. If possible some of the sessions can be grouped and organised together with face to face sessions. For example, an experienced narrator that belongs to the intermediate phase 1-2 can be included in the "experience".
- *Transferability issue*: Due to a small group size dominated by champions the statements can hardly be generalised and used for any statistical analysis or extrapolated to all members of a group.
- *Novelty issue:* Although the original idea of the learning cycle is that it can be repeated if necessary, the question of its practical applicability has to be raised. Experience at the Kollau catchment showed that people expect new and more attractive contents which are to be supported by tools such as FAC. They have to be improved by enhancing their visual performance as well adding new contents and aspects (such as visualisation of groundwater flooding or combination of fluvial and pluvial flooding).

- *Transferability issue*: Due to a small group size dominated by champions the statements can hardly be generalised and used for any statistical analysis or extrapolated to all members of a group.

Table 6-1 outlines the main methods developed and applied in during the ILP process for the relevant case studies.

Table 6-1 Overview of the capacity building – active learning phases and corresponding methods developed/applied within this work

Phases of ILP	Learning Goals (steps of assessment of resilience performance)	Capacity Building Methods	Tools developed/applied within this work	Testing/Verification Case study areas
1	Raised risk awareness/ changed attitudes towards own flood risk	Methods appealing to emotional level, breaking the illusion of controllability Confrontation with the facts	**FAC, Flood Training** Flood maps	Hamburg area-Wilhelmsburg, Kollau,
2	Acceptance of own responsibility	Providence and confrontation with the facts	Presentation, delivery of the facts about flood situation in the area based on scientific results/ models, dialogue	Kollau
3	Improved knowledge	Learning out of provided materials in form of texts, presentations, E learning, concrete examples	**FLORETO-Inform**, presentations, field trips, hands on tools and methods	Kollau,
4	Proactive behaviour			Kollau

Here ,it is also to compare the results with the outcomes from the interviews in Lauenburg, which is a community with a flood experience. Still, in general, 53% of the interviewees miss relevant information and need more instructions and support from the authorities, whereby 65% support the idea of having internet as one of the primary information and communication media. Interesting is that this idea has been supported not only by younger residents, 40% of the interviewees above 65 found the idea good, which opens room for web based systems and tools. The results from Lauenburg show that flood awareness is not enough to be efficiently proactive. Also, the results from the interviews as given in Table 5-16, indicate than in total 22 out of 49 interviewees, either think there is no efficient strategy for Lauenburg, have no opinion, or find that the responsibility is fully on the municipal side, show that there is a lack of problem understanding. Also, it indicates a gap between differnet stakeholder groups, which is likely to be overcome in a dialog or a participatory process supprorted by a method such as the ILP.

6.3 Engagement of dwellers within a stakeholder involvement framework towards flood resilient cities

6.3.1.1 From the decision making process (FLORETO) to participatory planning (LAAs)

The analysed case studies addressed both cases that are (1) the application of the decision making method and the tool without considering the overall context and other key stakeholders' roles, interests and level of affect (Launeburg, Heywood) and (2) embedding the decision making process for dwellers into a participatory planning method (LAA-Wandse).

In Lauenburg, a decisive difference in assigning ranking to different criteria in MCA between dwellers and authorities caused an unbridgeable gap between the preferred resilient plan of the two. This situation indicates lack of communication and understanding of each other or lack of capacity building process supporting the decision making process. The interviews conducted with the dwellers in the case study area showed that they possessed rather little or no information about the possibilities and limits of the other stakeholder groups (local and regional authorities as well as emergency services) as well as on tasks of flood risk management including their own tasks as also given in section 6.2.3.

Those examples clearly indicate the limits of mere decision making process, which calls for activities and actions that involve joint planning.

The joint planning activities as implemented in LAA-Wandse could indicate the acceptance of own role of the involved dwellers and of the resilient measures to be applied at own houses which should be in accordance with the overall planning activities in the area and should not, even if locally, increase flood risk at other locations in the catchment.

6.3.1.2 From the capacity building concepts (ILP) to participatory planning (LAAs)

In the analysed case study areas, both cases have been conducted being (1) mere application of the tools for flood risk awareness (Hamburg-Wilhelmsburg, Hamburg area) and ILP (Hamburg-Kollau) and (2) embedding the capacity building process for dwellers into a participatory planning method (LAA-Wandse).

Although the results obtained in the Kollau study area indicate a certain level of improvement of the dwellers' capacity to practice their role in FRM (see section 6.2.3), a limited understanding and appreciation of the roles and interests of other stakeholder groups which are relevant for flood risk management planning could be observed.

The participation of the authorities within the learning process has been assessed to be crucial where the shift from “blaming the authorities” to “acceptance of own responsibility” has been observed, which again emphasises the necessity to have a joint planning process.

However, the example from Hamburg-Wandse showed that different levels of knowledge has been a problem throughout the LAAs. The involved dwellers evaluated some explanations and presentations as too technical and partly complicated for ‘non experts’. Even the offered e lectures could not fully solve the problem. At the same time, the dwellers highly appreciated the possibility to communicate and discuss the relevant flood related issues with the other stakeholder groups, mainly the authorities. Also, the dwellers recognised and acknowledged the necessity to have a holistic perspective when developing flood risk management strategies.

For the future stakeholder participation framework it has been assessed as recommendable to keep the dwellers in the decision making process but defining sub structures in the stakeholder groups (e.g. experts non experts) and offering the intermediate workshops adapted to their level of knowledge and interests. Those additional sessions would mainly have an objective to further build capacity of the dwellers and prepare them better for the decision making process and the joint sessions.

6.3.1.3 Embedding dwellers participation into a holistic flood risk management framework

The work performed in all case study areas indicated complex interactions and interrelatedness between dwellers and other elements of the urban system and other stakeholder groups, mainly the authorities, which are often a function of a range of factors, out of which the following could be identified:

- current policy towards flood risk management (Lauenburg),
- level of risk awareness (Hamburg)
- previous experience with floods (Nidwalden, Hamburg, Lauenburg)

Also, it has been assessed throughout the studies conducted in Hamburg (Kollau and Wandse) that dwellers acknowledge the importance of the relations and contacts with other stakeholders mainly authorities.

Also, the multi-scale assessment conduced in Lauenburg and Hamburg case study areas shows interdependences between strategies and systems at different scales and the clear need to consider them in a combination.

The holistic approach as defined in 3.1 offers a framework to study those complex causal loops and analyse how behaviour of different actors, such as dwellers can contribute to the change in the flood risk or the resilience level of the overall system.

Referring to the initial research challenges summarised in Figure 2-19 and given in section 2.4, the following interrelations and interrelatedness of the dwellers and the built environment towards flood resilient cities have been derived based on the testing results and are illustrated in Figure 6-2. It indicates that the problem of the dwellers engagement in the decision making process in UFM goes far beyond the linear links between the authorities, consultancy and dwellers or the built environment and dwellers as assessed and illustrated in Figure 2-19.

Also the research on the capacity building and decision making is not to be piecemeal when talking about the dwellers' engagement as it is the dominant way of dealing with it as illustrated in Figure 2-19.

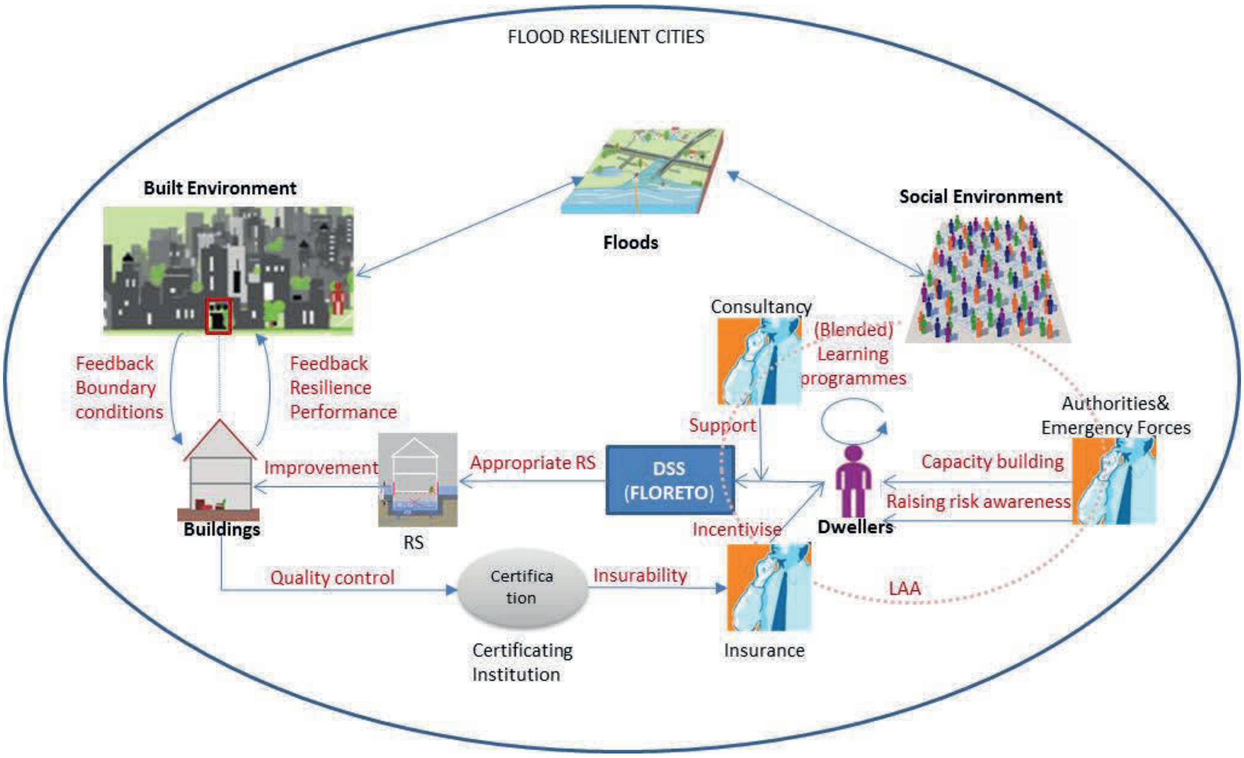


Figure 6-2 The interrelations between the elements of an urban (flood resilient) system focusing on the dwellers that have been derived from the test areas referring to the main research questions stated in Chapter 2

6.4 Key conclusions

The following key conclusions regarding dwellers involvement in flood risk management towards flood resilient cities have been derived:

1. The flood resilient cities, as a notion, is likely to be implemented utilising flood resilience strategies that are composed of a sound combination of different flood risk management measures such as early warning or landuse planning (as *inter alia* stated in 2007/60/EC). Flood resilient built environment is a substantial part of the resilient strategies.

To assess the extent to which the measures improved the resilience level of the cities and put it into tangible metrics (e.g. quantitative level of resilience), a set of proxies can be defined that considers different elements of an urban system at different scales.

Due to the complexity of the selection process of different measures at different scales, a knowledge base, as a context based repository of measures, is likely to be a way to go. Within this work, such a concept has been developed and its application has been demonstrated at the example of the measures for the resilient built environment.

2. Involvement of dwellers goes beyond mere assistance and delivery of tools and a linear connection between the authorities, dwellers, consultancy and the affected built environment. A sound combination of the capacity building and decision support methods and tools tailored to dwellers' needs is required to empower dwellers to participate in FRM and practice their role.

3. Dwellers and the built environment are a substantial part of s sociotechnical (urban) system and interact with each other and with the other elements of an urban system. Those connections go beyond linear and standalone ties between different actors and elements as given in 1). They should be regarded within a holistic framework to capture all relations, interdependences and behavioural patterns that lead to changes of the flood risk. This work delivered a contribution to this approach by analysing the dwellers and the built environment at the property scale.

4. Consideration of various scales is required to analyse the resilient systems at the property scale. Resilience as a system characteristic varies depending on the scale of observation which is relevant for the dwellers participation. The systematic analysis of the resilience performance of different resilient systems for the given conditions should be a part of a knowledgebase of measures and strategies.

5. High resolution physically based approach based on both functional and aesthetical damage curves is required for the assessment of potential damage at the property level and the acceptable risk. It should consider both, general information about the building fabric and regional and local specific construction styles. A clear differentiation between the functional and aesthetical damage has to be made, so that functional damage cannot be considered as aesthetic alteration of the built environment.

6. The Computational Intelligence (CI) models can be a useful aid to support decision making process on resilient built environment, however the time and effort for building models should not be underestimated. Also, the consideration of the systems at larger scales should be considered as stated in 3.

7. Decision support systems (DSS) for dwellers involvement can be a useful tool, but the findings of this work indicate that their application should be coordinated with the resilient planning at larger scales. The assistance from professionals (consultancy) in operating the tool can also be considered as a potential practice for further activities, which is supported by the

results from the test areas. In that sense, the connection between the dwellers , DSS and the built environment should be extended by an additional actor- experts. Web based open source tools offers a range of advantages such as free and easy access.

8. The methods and tools for raising risk awareness and capacity building should address the dwellers both emotionally and rationally by providing a hands-on experience on floods and delivering figures and facts. Flood maps are a substantial part of the raising risk awareness strategy and deliver facts. They should be embedded into blended strategies for capacity building. The methods should be further developed to support the multiscale resilient planning also including different key actors.

9. The Learning& Action Alliances (LAAs) following the 4-steps of the stakeholder engagement (1-*scoping, 2-understanding, 3-experimenting, 4- evaluation*) proffed to be a possible framework to involve dwellers into the planning towards flood resilient cities and to embed the strategies for the improvement of their participation both related to the decision making and capacity building. In this way, it is possible to operationalise the multi-level and - stakeholder resilient planning. The heterogeneity of the actors and their interests, abilities and level of affect requires tailoring of the methods to their needs, which could be observed in the test area within this work.

7 Summary and Outlook

7.1 Summary

Following the paradigm shift in flood management from traditional to more holistic approaches, one of the main emerging tasks of flood managers becomes the development of (flood) resilient cities. This new mind set and legislative framework in managing floods (EC Flood Directive, 2007/60/EC) set challenges to the stakeholders in urban flood prone areas, causing a rethinking of the current attitudes and practices. Substantial changes are imposed as regards the dwellers, who are given the right to be informed about relevant flood related issues (e.g. in Europe 2007/60/EC Article 10 (1)), but at the same time are challenged to contribute adequately to FRM. Thus, they have to recognise the problem, understand their role in FRM and acquire the required knowledge to accomplish their tasks.

The role of dwellers should be observed in a broader, holistic perspective analysing their role and responsibilities, requirements and underlying abilities as well as their interrelatedness and interactions with the other elements of the system, the main one being the built environment.

Special attention is to be paid to urban areas, as the uncertainties of future development will have major implications on the future layout of cities, individual properties and the building environment as well as for the residents (Zevenbergen et al., 2008). The cities, as systems, should develop the capacity to fight with the current and future perturbations. Such capacity can be explained applying the *resilience* principle.

Within the work a method and the associated tools supporting participation of dwellers in the development of resilient cities has been developed. It includes definition of the framework of the resilience cities in the context of FRM, and the strategy and tools to provide required knowledge to dwellers and strategies to build their capacity to efficiently apply this knowledge. Required expertise includes risk assessment and development of a flood resilient adaptation plan for the built environment.

Theory

The resilient built environment is one of the main aspects of flood resilient cities and one of the layers in the multi-layer approach. The single techniques for its achievement are mostly well established and fall under the banner of dry-proofing and wet-proofing strategies. Those strategies have some shortcomings when applied solely, so that they are mostly used in combination referred to as resilient system. Defining an appropriate resilient system should be performed within the ***decision making (DM) process*** as depicted in Figure 3-10. This process encompasses flood risk assessment and a flood resilience adaptation plan for the built environment followed by the implementation and review of the adopted solution. It is very knowledge intensive and requires a high level of expertise. The availability of this knowledge is difficult to achieve *ad hock* so that methods and decision support tools are required to support this process.

For risk assessment a physically based approach has been developed for damage estimation considering the susceptibility of building material and contents and ex post analysis of the previous floods. Supporting the individual perception of damage, two types of curves have been developed: *functional* and *aesthetic*, enabling the possibility to define a range of damage scenarios (minimum or maximum price for repair or cleaning of functional or aesthetic damage). Functions are developed for both the building fabric and inventory based on the physical analysis of the materials and experience from real flood events in the past. The functions are defined not only for single materials, but also for combinations of them for different flood conditions. For each item/building part, a range of functions is set, depending on the aspect being considered. In this way high a resolution damage assessment and resilient planning on the building level is enabled.

For supporting flood resilient adaptation planning, a data mining approach has been developed and used, overcoming the deficiencies of the conventional expert systems, being the knowledge acquisition bottleneck and the robust learning limitation bottleneck (Owotoki, Manojlovic et al., 2006). The key problem of the technical selection process is the matching of the input parameters (X) describing the stakeholders' property to the technically appropriate measures (y) for given designed criteria. It is realised with a mapping function defined as:

$$y = M(X): \quad y \in Y, \quad X \in X^{\infty}$$

The input parameters consist of vectors of categorical and/or numerical attributes, which constitute the design criteria describing the property and the floodwater parameters of the specific location. This approach incorporates the knowledge of experts in the constructed Computational Intelligence model but overcomes the knowledge acquisition bottleneck by supplementing any available expert knowledge with more objective knowledge extracted from databases. There are many possible matching functions, but the objective is to find and use the $M_{optimal}$, which returns the most appropriate flood mitigation measures for the stakeholders. It mostly depends on the domain and amount of data available as well as the number of attributes/classes. Finally, the set of measures are processed within the cost benefit analysis.

Capacity building of stakeholders should support the private stakeholders in all the facets and stages of the decision making process, depending on their role and level of acting. Surpassing simply awareness and mere delivering of flood related information, it should focus on interactive learning by means of face-to-face and web based learning, training courses or collaborative platforms (Pasche et al., 2008).

Implementation

The theoretical concept has been implemented within a web-based three tier advisory system (FLORETO) devoted to support DM for the resilient built environment supported by implementation of the ILP. FLORETO is a 3-tier web based systems composed of user interface, business logic and database tiers. As an outcome of the system, the mitigation scenarios for improvement of the built environment are obtained, based on the technically appropriate measures tailored to the user's own property data and local flood conditions. It enables a high-resolution risk assessment and supports resilient planning. Regarding its performance, FLORETO is easy accessible via web browser without downloading the software or installing plug-ins. The three-tier design of FLORETO, composed of *User Interface- UI, Functional (business logic) Module and Database* has many advantages, the chief one being its modularity, enabling modification and replacement of one tier without affecting the other ones. An innovative approach has been developed to collect data from the key users, private stakeholders, using a graphical interface rather than standardised forms. A blended learning strategy, the *Interactive Learning Program (ILP),* has been developed with the main objective of building the capacity of the stakeholders to be proactive within their role in FRM and contributing to the resilient built environment. It is based on the learning cycle of Kolb& Fry 1975 (adapting the approach of Geissler 2006), dividing the learning process in four steps from concrete experience through reflection followed by the abstraction of the concepts learnt, to testing the acquainted knowledge in new situations. Within the ILP the learning cycle is regarded as a continuous process with smooth transitions between the learning phases. Apart from the face-to-face sessions that follow Kolb's cycle, this learning concept involves intermediate phases composed of onsite events and the autodidactic learning, supported by the web strategy *KalypsoInform.* It contains the modules with tailored access to the information depending on the users interest and knowledge level that are: Tutorial, Knowledge Base and Virtual Trainer (Pasche et al., 2006). The continuity and combination of different learning tools strengthens the motivation of participants and improves the pace and dynamics of the learning process. The developed tool for raising hazard and risk awareness, the Flood Animation Centre (FAC), (Pasche et al., 2008) is used not only to increase awareness, but to give a local context and relevance of flood problem by using local flood maps and giving the possibility to participants to have a "hands-on" approach to the local flood situation. They can be used as a standalone application or as a part of the ILP.

Verification on case studies

The developed methodology and tools (FLORETO and ILP) have been applied to case studies in Germany (Lauenburg-L, Hamburg-HH), Switzerland (Nidwalden-N) and UK (Heywood-HW), considering different flood typologies and sociotechnical conditions.

Data mining algorithms performed at ~87% (for the M_{opt}) on initial testing based on datasets from HH, still leaving room for improvement. The ILP concept showed considerable improvement of the capacities of dwellers in the area HH based on the interviews and questionnaires. Although single applications have proven to be efficient, maximal utility has been achieved by the integrated application of both tools from the initial planning and DM phase within the LAA approach.

The DM process and tools for the resilient built environment, as a key to resilient cities, should be integrated with the strategies for building capacity of stakeholders to apply them. The single applications of FLORETO and ILP have delivered the results as presented in this work, but higher utility can be achieved by integrated application of both tools from the initial planning. The integration of FLORETO and FLORETO-Inform showed the first benefits of the integration.

The problem of the dwellers engagement in the decision making process in UFM goes far beyond the linear links between the authorities, consultancy and dwellers or the built environment and dwellers. The research on the capacity building and decision making should support this holistic way of thinking and not regarded in isolation.

7.2 Outlook

This work aimed at the contribution to the improvement of the dwellers engagement mechanisms in urban flood risk management. Still, the work has indicated a range of open research questions and needs for further investigations, which can be summarised under the following sub-research domains:

- Further research on the improvement of the methods for decision making and the corresponding tools
- Further research on the methods for capacity building of stakeholders including the raising risk awareness strategies
- Further research on the methods to improve the combined application of the decision making process and the capacity building of stakeholders in the context of flood resilient cities- a holistic approach

7.2.1 Further research on the improvement of the methods for decision making and the corresponding tools

The process of decision making:

Within this work a method for the decision making on the resilient built environment that regards the present situation and the property scale has been presented as summarised in Figure 3-15. Due to the increasing importance of the uncertainty of future development, the aspect of adaptability and flexibility of measures should be considered for the definition of risk mitigation strategies and consequently, the decision making process should be further developed by consideration of climate change projections. As the first step, risk assessment according to the EC Flood Directive, 2007 has to be performed. For definition of the Flood Risk Management Plan, possible options for flood risk mitigation have to be considered including adaptation strategies regarding climate change and their potential to cope with future risks is to be analysed. An adaptability index of strategies should be defined to assess their potential for application within climate change adaptation strategies. As a next step, this extended process of decision making should be implemented within the FLORETO Platform.

Also, resilient systems on all scales (property to community) should be developed and their performance assessed. This can further contribute to the scalability of the approach.

Scalability of the approach:

One of the requirements on decision making methods and tools is their scalability, i.e. the possibility to consider decision making options on different scales from the property to community/urban system level. The detailed assessment method performed on the property/building scale developed within this work and implemented in FLORETO, can be further enhanced to support and refine the vulnerability and damage assessment and resilient planning on the urban system level, by the definition of the feedback modes and connections between the parameters and their level of detail at different scales.

Damage assessment method

The developed physically based damage assessment method aims at a comprehensive understanding of the origin and mechanisms of the flood damage in different building elements for a range of the flood parameters. Still, the knowledge gaps could be identified especially when analysing the impact of the flood duration, velocity and contamination.

In that sense, it is required to enhance the knowledge on these impacts either by the laboratory and on site tests on materials and building compounds for different flood conditions or by an in depth analysis of the real flood events and their consequences to the built environment.

The damage matrix should also encompass the analysis on the behaviour of the typical construction style of different regions EU wide. In parallel to this research, the damage perception of dwellers in those regions should be systematically studied and integrated into the damage assessment methods.

Algorithms for selection of appropriate resilience strategies

Although the measures for the resilient built environment are considered as traditional and already well-established in the flood risk management practice, there is still room for improvement and further development. Especially emergent are the new materials and technologies for wetproofing as well as automatic flood abatement and aperture systems (e.g. Garvin et al., 2012) for the homeowners. It should also be kept in mind that the measures for the flood resilient built environment and systems are a subset of a larger group of measures and strategies, that are resilient strategies. Also deployment of those measures can have an impact and interactions with the physical, social or institutional environments. Therefore, the methods on the development of FReS at larger scales are required to encompass different measures for a range of social, legislative or physical factors. The developed structure for a knowledgebase can serve as a starting point for a development of such a methodology.

The development of such resilient systems can be pursued in several steps starting with the extension the measures for the built environment to other resilience strategies (e.g. flood forecasting, insurance).

The factors shaping the efficiency of resilient systems should be extended by additional aspects, the main one being the operational time, which also has to be integrated into the business logic. Also, standards on resilient building and repair, once they are developed, should be implemented into the selection procedures of the business logic.

Development of a multiscale metrics for the flood resilience assessment

The developed metrics for the resilience assessment at the property scale could be used for the assessment of the resilience performance of the developed resilient systems for the given conditions in the test areas. Still, they reflect only one element of the sociotechnical system- the built environment. Following the requirement on the multiscale system approach (e.g. Fiksel, 2006) the metrics for the assessment of the resilience performance, are to be extended to cover all resilience aspects of an urban system. The method of a Flood Resilience Index (FRI) can be considered for that purpose (e.g. Batica et al., 2013)

7.2.2 Further research on the methods for capacity building of stakeholders including the raising risk awareness strategies

The developed methods attempted to integrate different aspects of the awareness and the capacity building process and mechanisms summarised in the *Postulates of raising risk awareness* and in the blended learning strategy based on the Kolb's learning theory. Those were implemented as the FAC and the ILP and tested at different test areas. The results indicated a need to further investigate the audio visual representation of the FAC components, their sound integration as well as to further explore different didactic concepts to improve the blended learning method.

The outcomes also indicated that the methods for motivating participants are still a research need. Although the idea of contacting action groups and champions brought positive results, it should be tested in different cultural and social settings.

This work, although it utilised the methods of the social science research (such as learning theories, questionnaires or interviews) did not aim at the development of a comprehensive methodology for the evaluation of the learning performance or the in-depth phychological analysis on the motivation for action.

The work aimed at the establishment of the liaison between the engineering and the social science research, as they are dealing with the fields of research (built and social environment) which are hardly to be separated when dealing with the urban flood management. Further reseach directed in the social science field can be performed to extend the capacity building method developed in this work.

7.2.3 Further research on the methods to improve the combined application of the decision making process and the capacity building of stakeholders in the context of flood resilient cities- a holistic approach

Integration of the decision making and capacity building methods and tools

The results of the combined application of the two processes within the LAA method, indicated the advantages for the dwellers involvement mainly related to their better awareness of the overall flood and urban system and of the roles and interest of other key stakeholders. Still, it is in an initial phase and should be further researched.

Also, the integration of the tools should be further explored. A better integration of the developed tools towards a combined application can be achieved by the connection of the Flood Animation Centre to FLORETO. In this way, the results of mathematical models (i.e. inundation depth) for a certain region can be directly visualised and potential damage for selected objects assessed. FLORETO should be more actively used as a part of ILP as the outcomes from the test area could indicate.

Integration of dwellers and the built environment as an element of the sociotechnical system- a holistic approach

Dwellers and the built environment, as the constitutive elements of a sociotechnical/urban system, have complex interrelations with each other and with the other elements of an urban system (e.g. other stakeholders, building blocks). This work contributed to a better understanding on their mutual dependences and ties, however opened a range of questions related to

Methods should be developed that can capture, understand and analyse all complex interactions between different elements of an urban system in respect to flood risk. This calls for the holistic approaches focusing on those complex interactions shaping the flood risk and the corresponding flood response strategies.

The agent based models, which enable combinations of heterogeneous agents (i.e. elements of the urban environment) are likely to enable such a holistic approach to urban systems and flood risk and should be explored in this context (Vojinovic, 2015).

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[70] UN-UNITED NATIONS

[71] UNCED- UNITED NATIONS CONFERENCE ON ENVIRONMENT AND DEVELOPMENT

[72] UNCHS- UNITED NATIONS CENTRE FOR HUMAN SETTLEMENTS

[73] UNDP- UNITED NATIONS DEVELOPMENT PROGRAMME

[74] WASSER- UND SCHIFFFAHRTSAMT LAUENBURG http://www.wsa-lauenburg.wsv.de/

[75] WMO- WORLD METEOROLOGICAL ORGANISATION

List of Appendixes

9 Appendixes

Appendix 3.1 Overview of the flood risk mitigation measures including the measures for flood resilient built environment

Table 9-1 Measure to reduce flood probability and/or improve the threshold capacity to floods of an urban system (adapted from Pasche et al., 2008, Vojinovic 2015, Batica et al., 2012)

FPRM	Type of measure	Description	Scale
Fluvial Flood Protection Measures	Give rivers more space	daylighting or deculverting of watercourses, flood plain restoration	Water-course
	Holding back water	flood polder, small detention reservoir	
	Embankment (structural measures)	dikes, walls	
	Capacity enhancement of rivers	dredging, deepening and widening of the watercourse, bypass	
Coastal Flood Protection Measures	Embankment (structural measures)	sea dike, sea walls, tidal barriers, dunes	Coastal reach and estuaries
	Coastal Management	coastal realignment, drainage of the hinterland, offshore barriers, beach nourishment, cascading compartments	
Pluvial Flood Protection Measures	Conventional urban drainage systems	open channels, closed conduits, storages	Drainage network
SUstainable Drainage Systems (SUDS)	Source control	green roofs, rainwater reuse, permeable pavements	Allotment scale
	Infiltration techniques	filter trenches, filter drains, strips, sokaways	
	Detention structures	swales, bio-retention area, detention basin, pond, wetlands	Allotment to city
Controlled surface conveyance	Conveyance and storage structures	diversion structure, multi-functional space, conveyance structures, dual drainage	Street to city

Table 9-2 Measures to minimise flood impacts and reduce vulnerabilities (adapted from Pasche et al., 2008, Vojinovic 2015, Batica et al., 2012)

FPRM	Type of measure	Description	Scale/Effect
Capacity building of human resources A:Awareness	Information	flood maps, info material (brochures, public presentations, internet portals etc)	All scales/ Reducing vulnerability
	Education-Communication	face-to-face learning, web- based learning. training, collaborative platforms	
Landuse control A: Avoidance	Spatial Planning	flood risk adapted landuse embedded in policies and regulations	Catchment or urban system scale/ Reducing vulnerability
	Building regulations	building codes, zoning ordinances	
Flood alleviation measures A: Alleviation	**Flood proofing of buildings**	**wetproofing, dryproofing, amphibious housing, floating homes, buildings on stilts, relocation, elevation, flood proof infrastructure**	**Building scale/ Minimisation of impact**
	Flood action plans (local scale)	building and infrastructure maintenance	
Contingency measures A:Assistance	Financial preparedness	insurance of residual risk, reserve funds, financial incentives or fines	Local / Minimising impact
	Disaster preparedness and Emergency response	evacuation and rescue plans, emergency regulations, forecasting and early warning services, real time control system, providence of emergency response staff, technologies for intervention	
	Emergency infrastructure	allocation of temporary abatement structures, telecommunications network, transportation and evacuation facilities	
	Recovery	disaster recovery plans, pecuniary provisions of government	Strategic/ Minimising impacts
		care for victims, decontamination technologies, repair and clean-up	Minimising impact

Appendix 3.2 Flood resilient systems at the property scale (please also refer to Table 3-4 and Table 3-5.)

Resilient system (P-RS) 1: Controlled flooding of basement

Description: In the controlled flooding system, the water level is kept below the critical load by a pump in a sump and is regulated by pressure sensors. In the flooded building parts waterproof materials are applied in order to minimise the damage to building fabric. The targeted water level in basement should not reach the level of the electrical appliances or power sockets, as it can cause power blackout and further damage. To assess the critical water level, it is necessary to analyse the building fabric and its occupancy, elevation and configuration of the basement and compare it to the design flood level. In general, the difference between the water level outside the building fabric and inside the building should not exceed 1,5 m, due to stability issue caused by strong buoyancy forces. Controlled flooding can be considered as one of the basic resilient systems and is used in a combination with the other measures for definition of the other ones.
Resilience level: In terms of resilience performance, it has been assessed high for this system. Referring to the criteria given in Chapter 3 the system in general improves resilience level of the building (I). Applying the controlled flooding system, the damage is being minimised as the building fabric and services are wet-proofed meaning that materials are selected that remain undamaged when exposed to flooding. After being exposed to flooding, the controlled flooding system can return fast to its initial state. The time is needed for cleaning and drying of the building fabric. In case the inventory has been elevated, the additional time is needed to return the inventory to the initial state. In the systems where controlled flooding of the basement has been applied, the upper floors are not affected. In that sense, vertical evacuation is not an issue of concern. As services and fittings are either encapsulated or wet proofed the continuous supply at the property level is enable. Regarding the range of the applicability of this system, if the difference in water pressure outside and inside the building exceeds 1,5 m the system should be redesigned. However, if the water level reaches the ground floor this system and be extended in either P-RS3, 4 or 5. In that sense, the system is just extended, making use of the previous system and not redesigned losses are minimised. In that sense, the adaptation of this system to a range of flood situations can be assessed as high-medium.
Critical parameters: Although assessed as highly resilient, this system has some critical factors, which can hinder its optimal performance. They are given as:

- Time for elevation of the inventory items in the basement is needed
- Effort for operating the equipment is necessary (critical in case of vulnerable groups such as old people, disabled etc.)
- If the flood level is higher than the terrain, it is difficult to reach the building, damage can still happen

Resilient system (P-RS) 2: Sealing of basement

Description: In this system the basement is dry proofed by the sealing measures. They are either based on application of waterproof concrete or polymer bituminous sealing. Here the water is not allowed entering the interior of the building, but the fabric (walls, floors, ceilings and staircases), openings and services and prepared in a way to resist flooding forming one closed system. In this system, the connection between different elements are crucial for its efficient functioning. The services should be encapsulated and openings sealed either permanently or temporary using products for sealing of the openings.

Resilience level: Resilience performance of the system has been assessed medium. Referring to the criteria given in Chapter 3, the system improves resilience level of the building (I). Applying this system, the damage is being minimised as the building fabric is dry proofed together with the services and fittings. After being exposed to flooding, the controlled flooding system can return fast to its initial state. Floodwater does not even reach the building interior, the time needed for return to its initial state is reduced to cleaning of the building exterior . In the buildings where this system is applied, the upper floors are not affected. In that sense, vertical evacuation is not an issue of concern. As in this system services and fittings are encapsulated the continuous supply at the property level is enabled. The critical issue of this system is its adaptability i.e. the domain of attraction is rather low. In case that the external water pressure to building raises, the system can suffer considerable stability problems and as such has to be redesigned as soon as the critical value of difference between external and internal water level has been exceeded. This redesign is bound with considerable effort and possible redesign options are either to remove sealing and apply controlled flooding (P-RS1)or to apply additional enforcement of the construction to withstand water pressure.

Critical parameters: This system has some critical factors, which can hinder its optimal performance, the main one being the stability of the building that can be jeopardised either by static or dynamic pressure of flood water.

Resilient system (P-RS) 3: Controlled flooding and sealing of the ground floor

Description: This system represents a combination of the RS1 and additional sealing of the ground floor. Here basement is protected by the controlled flooding system at the same time the ground floor can be used as flood water is prevented from reaching the building interiors by sealing measures. At the contact between the building levels, horizontal sealing measures are required in order to prevent capillary rise from the basement into upper floors.

Resilience level: Regarding the resilience performance, the assessment performed for the system P-RS 1 is applicable to this case with the extension regarding the sealing of the upper floors. The system as a whole contributes to improvement of the resilient level of the building, where no permanent damage is caused . The system returns to its initial state fast as in case of the system P-RS 1 and as the upper parts of the building are sealed, no additional effort in needed for cleaning of interiors, time is only needed for cleaning of the exterior face of external walls. Vertical evacuation within this system is conditionally enabled, only in case more than one upper floors are available vertical escape routes can be created in this system. However, as the building is sealed, this is only in exceptional cases required. Continuous supply of services is guaranteed with this system. The main deficiency of this system is the range of flood conditions it can be applied. In case the difference of the water pressure outside and inside exceeds the threshold value the system has to be redesigned. This redesign can be either into direction of P-RS 4 or P-RS 5, depending on the building fabric and expected flood conditions. A possible redesign option towards P-RS 4 has been depicted in Figure 9-1.

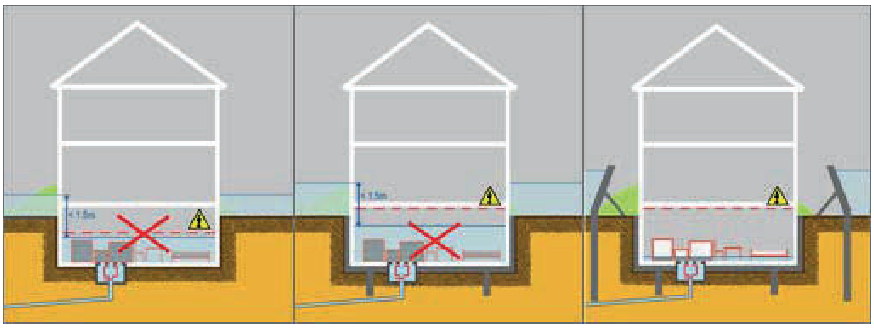

Figure 9-1 Redesign possibilities of the system P-RS 3

Critical parameters: In addition to the critical parameters of the system RS-1, here the issue of availability of the upper floors for vertical evacuation has to be brought. Also, the stability of the exterior walls on the ground floor can be endangered due to high horizontal pressure.

Resilient system (P-RS) 4: Controlled flooding and shielding of the ground floor

Description: This system combines controlled flooding of the basement (P-RS 1) and shielding techniques of the building.

Resilience level: Considering the criteria introduced in Chapter 3, the resilience performance of this system is assessed as high-medium. The general resilience level of a building is improved by application of this system, where no damage is expected. After being exposed to a flood event, the system returns fast to the initial state requiring time for cleaning and drying of the basement as in case of the system P-RS 1. Vertical evacuation within this system is in conditionally enabled i.e. only in case more than one above ground floors are available vertical escape routes can be created in this system. However, as the building is shielded, this is only in exceptional cases required. Continuous supply of services is guaranteed with this system. Regarding the range of flood conditions, the system shows high-medium adaptability level as after exceeding a threshold value of flood water pressure to the system (of approx. 1m), it has to be redesigned, either into P-RS 5 (medium-low effort) or in an extreme case, the P-RS 13 (high effort) should replace it.

Critical parameters: For optimal performance of this system, in addition to the critical factors for the case of P-RS 1, the time for erecting the temporary barriers have been assessed as critical factors for optimal performance of the system P-RS 4.

Resilient system (P-RS) 5: Controlled flooding (basement) and wetproofing (ground floor)

Description: This system combines controlled flooding of a basement and wetproofing of the building fabric in the above ground floors, usually ground floor. This is also combined with adaptation of the occupancy of the building and preparation of the inventory to be easily removed in case of a flood event.

Resilience level: The system's resilience performance is assessed high due to the fact that it improves the overall resilience level of the building and permanent damage is not expected as wet proof materials are applied and susceptible inventory elevated. As such the system can recover fast and time needed is as in the case of P-RS 1 for cleaning and drying of the building fabric. Vertical evacuation is enabled only in case more than one above ground floor is available. Continuous supply of services is enabled. The potential of the system to adapt to a wide range of flood conditions is assessed as high. In the final redesign phase the system can be replaced with the P-RS 13.

Critical parameters: Critical factors for optimal performance of the building are as in the case of P-RS 1 extended to the issue of limited occupancy of the ground floor.

Resilient system (P-RS) 6: Sealing of the basement and sealing of the above ground floor(s)

Description: This system combines controlled flooding of a basement and dryproofing of the building fabric in the above ground floors, usually ground floor.

Resilience level: The system's resilience performance is assessed high due to the fact that it improves the overall resilience level of the building and permanent damage is not expected as due to the dryproofing measures. As such the system can recover fast and time needed is as in the case of P-RS 1 for cleaning and drying of the building fabric. Vertical evacuation is enabled only in case more than one above ground floor is available. Continuous supply of services is enabled. The potential of the system to adapt to a wide range of flood conditions is assessed as high. In the final redesign phase the system can be replaced with the P-RS 13.

Critical parameters: Critical factor for optimal performance of the building is the threshold value of the dryproofing measure.

Resilient system (P-RS) 7: Sealing of the basement and shielding of the ground floor

Description: This system combines controlled flooding of a basement and dryproofing of the building fabric in the above ground floors, usually ground floor.

Resilience level: The system's resilience performance is assessed high due to the fact that it improves the overall resilience level of the building and permanent damage is not expected as due to the dryproofing measures. As such the system can recover fast and time needed is as in the case of P-RS 1 for cleaning and drying of the building fabric. Vertical evacuation is enabled only in case more than one above ground floor is available. Continuous supply of services is enabled. The potential of the system to adapt to a wide range of flood conditions is assessed as high. In the final redesign phase the system can be replaced with the P-RS 13.

Critical parameters: Critical factor for optimal performance of the building is the threshold value of the dryproofing measure.

Resilient system (P-RS) 8: Wet proofing (basement)

Description: This system represents a simplified version of the RS 1. Building fabric is prepared according to requirements for wet proofing of building fabric combined with elevation and protection of services and fittings. Building contents are selected in away to enable quick evacuation and the occupancy of the building interior has been adjusted to flood conditions.

Resilience level: Resilience level of this system is assessed as high, see assessment for RS 1. As a redesign pathway, by increasing of flood intensity the system an be replaced by P-RS 1.

Critical parameters: The critical parameters for optimal resilience performance are related to time for elevation of building contents and unfavourable terrain configuration disabling access to the basement.

Resilient system (P-RS) 9: Shielding of the building

Description: This system disables water reaching the building by applying demountable barriers at a certain distance from the building or directly in front of the construction. Depending on the flood intensity, they might have to be anchored in the ground or can be used as a free standing barriers.

Resilience level: Resilience level of this system is assessed as medium as this system improves overall resilience of the building without permanent damage, enabling vertical evacuation (if necessary) and returning rather fast to the initial state. However, the system shows rather low adaptation potential. In case the water pressure to flood barriers exceeds the threshold value, the system has to be redesigned either P-RS 11, 12 or exceptionally P-RS 13, where considerable effort is required.

Critical parameters: As a main critical parameter, the time required for erecting barriers is assessed. An extension of this system is seen in its connection to flood forecasting and warning system that would diminish the critical factor of the time available.

Resilient System (P-RS) 10: Sealing of the ground floor

Description: This resilient system implies that the above ground elements of the building are sealed against flood water. Walls and floors are protected applying waterproof concrete of polymer bituminous seals, openings and services applying opening barriers and anti-flooding devices for sewerage protection respectively as explained in chapter 3.

Resilience level: Resilience level is this system is assessed as medium-low. Although the system generally improves the resilient level of the building, disabling damage occurrence providing constant supply of services and fast return to the initial state after being exposed to flooding, the system shows low adaptation level. This means that the adaptation capacity of such a system can be exhausted rather fast, and the system has to be redesigned.

Critical parameters: The main critical parameter of this system is related to the stability of the building, especially of the exterior walls.

Resilient System (P-RS) 11: Controlled flooding of the above ground floor(s)

Description: In the controlled flooding system, the water level is kept below the critical load by a pump in a sump and is regulated by pressure sensors. Similar to the P-RS 1, in the flooded building parts waterproof materials are applied and services and fittings kept out of the reach of water. In general, the difference between the water level outside the building fabric and inside the building should not exceed 1,5 m, as in the case of the system P-RS 1.

Resilience level: Resilience level of this system is assessed as high-medium as in the case of P-RS1 and the parameters coincide to the assessment of the P-RS 1. Regarding vertical evacuation, it is necessary in this case, as the ground flood is being flooded. It is possible only in case that the building has further upper floors. Regarding the range of the applicability of this system, if the difference in water pressure outside and inside the building exceeds 1,5 m the system should be redesigned. In that sense, the adaptation of this system to a range of flood situations can be assessed as high-medium.

Critical parameters: Although assessed as highly resilient, this system has some critical factors, which can hinder its optimal performance. They are given as:

- Time for elevation of the inventory items is needed
- Effort for operating the equipment is necessary (critical in case of vulnerable groups such as old people, disabled etc.)
- Accessibility to ground floor during flooding is limited
- Limited occupancy of the ground floor

Resilient System (P-RS) 12: Wet proofing of the above ground floor(s)

Description: This system represents a simplified version of the P-RS 9 and is corresponding to the P-RS 6. Building fabric and contents are prepared according to requirements for wet proofing of building fabric and adjustments of the occupancy.

Resilience level: Resilience level of this system is assessed as high and all assessment of resilience criteria can be applied to this case. As a redesign pathway, by increasing of flood intensity the system an be replaced by P-RS 9.

Critical parameters: The critical parameters for optimal resilience performance are related to time for elevation of building contents and limited occupancy of the ground floor.

Resilient System (P-RS) 13: Relocation

Description: In case the building suffered considerable damage in the past or future scenarios are forecasting unbearable condition without considerable effort, the building should be elevated (vertical relocation) or removed to another area (horizontal relocation).

Resilience level: The resilience potential of this system is low as the building is not returning to the initial state but establishing new equilibrium. This system also implies considerable input from the other resilience strategies summarised in the 4As such as assistance reflected in financial incentives.

Critical parameters: The most critical issue related to this system are not technical, but of economic or social nature, especially in the case of "horizontal" relocation. New area where the building has to be relocated has to be made available, as well as the resources. Those process has also to be accepted by private stakeholders.

All presented systems imply a certain number of intermediate states, which usually coincide with the implementation phases. For example, for the RS 8 (Sealing of the ground floor) different system intermediate states can be defined, one being sealing of all openings in the ground floor. In that case, water can still enter through the walls or floors, but as majority of flood water enters building through openings, resilient level of the property has been improved. As damage can still occur, the implementation should be proceeded up to achievement of the final resilient system.
For the scope of this work, only final stages have been considered and their resilience performance assessed.

Appendix 3.3 Flood damage matrix

Appendix 3.3a- Intensity assessment: factors and their impact to the built environment

I)Physical Factors

Water depth (h)

Depth of floodwater is the main flood parameter for the damage assessment of buildings (e.g. Penning Rowsell, 2003, Mayer et al., 2006). It defines the level of flood water which comes directly into contact with the building fabric. Floodwater that is pushing the walls and other vertical elements (e.g. staircases) exerts lateral hydrostatic pressure. Also, together with the water that has saturated the soil under the building, the water exerts buoyancy forces which push up on the floor.

For parameterisation of the damaging functions, water depth should be made available either for defined probabilities of occurrence (in form of hazard maps), for extreme (historic) events or for the generated scenarios.

Flow velocity (v)

Flow velocity is predetermined by the type of a flood event and topography of the local area, and is one of the key factors for parameterisation of damaging functions.

The velocity vector changes depending on the location around the building, causing different pressures against the building (FEMA, 2005, Kelman, 2004). At the building scale, the velocity shows a different impact on directly, laterally or indirectly exposed elements to the flood stream. As water flows around the house, it pushes against the upstream side of the house (that faces the flow). As it flows past the sides of the house, it creates friction that can tear at wall finishes. On the side of the house that faces away from the flow the water creates a suction that pulls on walls. In some situations, the combination of these forces can destroy one or more walls or even sweep the house away (FEMA, 2005). Flowing water also contributes to erosion and scour. Both can weaken the structure of a house by removing supporting soil and undermining the foundation (FEMA, 2005).

High resolution hydrodynamic models combined with digital terrain models are required in order to analyse changes in velocity over the building surface. For the scope of this work, the classified impact of velocity on flood damage, in the form of a matrix derived for the construction type in England, (Kelman, 2004) has been adopted as an orientation:

flood velocity v [m/s] flood depth X flood velocity v [m2/s] type of damage
< 2 < 3 inundation damage
> 2 3 – 7   partial damage
> 2 > 7 total destruction

However, those values refer to a specific building style with a regional context, and can be taken just as an orientation. A thorough analysis involving hydrodynamic models and tests onsite is still a matter of research and has been beyond the scope of this work.

Velocity is given as:

where the v takes the following values: <2 and >2

Flood duration (d)

If the house is flooded, duration is a factor that determines how long the structural elements (e.g. the foundation, walls or floors), service equipment (e.g. furnaces, hot water heaters), and building contents will be affected by flood waters and in consequence what the extent of damage will be (FEMA, 2002).

This parameter can be obtained as a result of hydrodynamic models or is estimated based on the experiences from events in the past. Also, different flood types have some orientation values that can be used for the pre-assessment (e.g. flash floods often last a couple of hours or days whereby riverine floods of large rivers or dike overtopping can take several weeks EMDAT, 2010). Even if the flood duration in the area can be determined, it does not imply that all buildings and building elements are equally exposed to water in terms of duration. It further hinders a reliable damage assessment for different building elements. Also, the threshold values, defining different resistance levels of different materials, are to be defined. "Flood-resistant material" can be defined as any building material capable of withstanding direct and prolonged contact with floodwaters without sustaining significant damage. The term "prolonged contact" means at least 72 hours, and the term "significant damage" means any damage requiring more than low-cost cosmetic repair. (FEMA, 2002). The duration of 14 days has been taken as a maximal duration from the examined flood events taken form the EMDAT database (reference).

d 0-12 h
d 12h-72 h (3 days)
d 72h- 14days
d 14days-

Further physical parameters that are not discussed in detail:

Rate of rise and rate of fall (t)

The rate of rise and rate of fall describes the changes in hydrostatic pressure during a flood event. When flood water rises rapidly, water may not be able to flow into a house quickly enough for the level in the house to rise as rapidly as the level outside. Conversely, when flood water falls rapidly, water that has filled a house may not be able to flow out quickly enough, and the level inside will be higher than the level outside. In either situation, the unequalised hydrostatic pressures can cause serious structural damage, even to the extent where the house collapses (FEMA, 2002). The term "slow-rise" implies that there is no large hydrostatic pressure difference between inside and outside of a building (Kelman et al., 2004).

For consideration of this factor for parameterisation, the water depths outside and inside of the building should be known. Additionally, the time required for the equalisation of the hydrostatic pressure should be known, which is usually not the case. This parameter will not be discussed further in detail.

Debris load (LD)

Debris are objects carried by the flood water. Even when flow velocity is relatively low, large objects carried by flood waters can easily damage building elements.

For consideration of this parameter for the vulnerability assessment, the dynamic forces acting on the building should be known. Not all building elements are equally exposed to debris load. It considerably affects the external elements such as doors or walls and as in the case of flow velocity, due to changes in the velocity vector, it affects the direct and lateral sides of the building differently. The parameter describing debris load is usually not available or is difficult to quantify and is not being further considered within the scope of this work.

II) Chemical Factors

Flood damage due to chemical factors occurs when water in the liquid state or in the form of water vapour contacts the building. The chemical impact of flood water to the built environment is multi fold and can occur due to its basic characteristics (e.g. presence of water inside building materials enhances frost-thaw effect, reducing the material strength or initiating hydration reactions causing hydration pressure, what can lead to cracks), content of inorganic materials (e.g. aggressive salts) or organic substances (e.g. heating oil) (e.g. Thieken et al., 2009). Long-lasting action of contaminated water adversely affects the building materials and leads not only to physical changes but to chemical and biological as well.

Inorganic materials (c_{IN})

The content of inorganic materials is mostly related to the presence of harmful salts in water. They can be acid (KHSO4), neutral (NaCl) or alkaline (Al(OH)2Cl). The most important harmful salts belong to group of chlorides and carbonates and are given as: (Buss, 2007)

- Chloride: NaCl and CaCl2 6H2O
- Carbonate: Na2CO3 10H2O, K2SO3 and CaCO3

Flood water can already contain those salts, but they also can be products of reactions of flood water with the building fabric. In order to assess the impact of those salts to building fabric and consider this parameter for the flood factor matrix, the concentrations of those substances in flood water have to be known. This parameter is not further discussed in detail within this work.

Organic Material (Oil content coil)

Among the organic materials that can cause damage to the building fabric when contained in flood water, heating oil is one of the key organic contaminants that can be spread during a flood event. It is a petroleum product consisting of mixture of petroleum-derived hydrocarbons in the 9- to 20-carbon atom range used to fuel furnaces for household space heating. The heating oil has a density lower than that of water (max 860 kg/m3, 15°C, DIN EN ISO 12185). Apart from the direct damage caused to the building fabric, oil can cause odour pollution even several years after the exposure to oil. Even at the concentration of 500 mg/kg (dry matter) the odour is very strong and cannot be ventilated. It considerably affects the quality of life in the affected buildings (LGA, 2000). Heating oil can be carried by flood water or the presence of an oil heating system in the building indicates the probability that flood water can be polluted by heating oil.

For consideration of heating oil for the flood factor matrix, its concentration in flood water should be available. Still, as even low concentrations can cause damage, an approximation can be made because in case of the presence of heating oil in the water it can already cause damage.

III) Biological Factors

Biological factors for alteration of functionality of the building components are related to the content of microorganisms which thrive in damp conditions, such as moulds and fungi. Favourable conditions for fungi growth are: mass humidity in the range of 20-25%, presence of air and temperature from 18 to 35ºC (Matkowski et al., 1998). Those conditions are often encountered in buildings affected by a flood event. Those factors have a strong impact on living conditions and health and as such will have an impact on the indoor climate in the building.

For consideration of those parameters for the flood matrix, the data should be directly available or based on the conditions in the building they can be estimated. This parameter is not further discussed in detail within this work.

Considered physical, chemical and biological processes

Flood actions based on the selected flood factors acting on the built environment can be considered mainly as physical, chemical or biological phenomena. Those processes are initiated by flood water coming into contact with the building fabric. Also, those processes often occur together, making it difficult to assign a given damage to only one kind of a mechanism, which should be taken into account while modelling flood damage. In the following text the main processes considered for the scope of this work are given.

Water absorption (Moisture transport)

Water absorption is a process of water up-take by a building material. It is one of the key parameters assessing the performance of thermal insulation and living conditions (odour, humidity) as the air that is normally contained in walls is replaced by water, which is 20 times more heat conductive than the air (Buss, 2004). This process can occur by transporting water either in a liquid or vaporous (gaseous) form, depending on the given conditions in the medium. Figure 9-2 depicts possible processes of water transport in the building fabric depending on the pore radius (Willelms, 2003). In reality, the transport mechanism of water depends not only on pore radius, but on their distribution and shape (Reul, 2005).

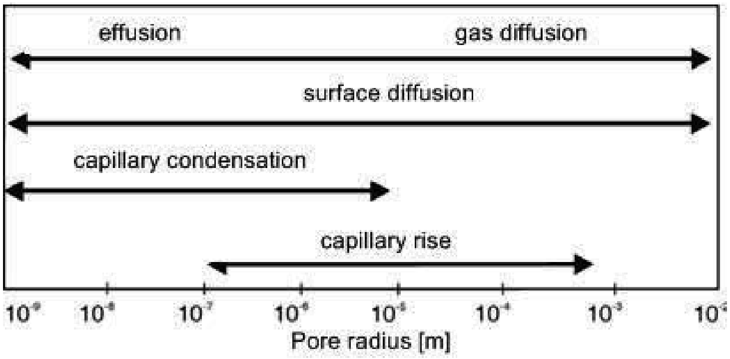

Figure 9-2 Moisture transport through building fabric depending on the pore radius (Willelms, 2003)

Capillary rise

Capillary rise is the process of water suction in the pores of a solid material. The rate of suction *v* is the ratio of the suction length and the time [h].

The rate of suction is much higher in macro-pores than in micro-pore systems. In general, it is a function of porosity, capillary radius and moisture content in the building element. The maximal capillary rise depends considerably on the radius of the pores in the material, and the maximal theoretical rise for water can be calculated as (Buss, 2004):

$$H_{max} = \frac{15mm^2}{r}$$, where

H_{max} maximal capillary rise of water [mm]

r- pore radius [mm]

In practice, the range of $10\mu m < r < 50\mu m$ is relevant for the process of capillary rise. In this range belong, for example, the pores of masonry units and render. 0.45 m is considered as an approximate upper limit for capillary rise following a flood event, depending on the building materials (Buss, 2004). The impact of capillary rise varies. Often when a building is flooded with water containing organic contaminants, it generally has to be refurbished entirely, irrespective of how high the water rose above the flood depth. In such a case, damage from chemical processes would surpass damage from capillary action (Kelmann, 2003). Still, capillary rise is one of the main processes for the assessment of the impact of flooding on the building fabric. It must also be mentioned that, along with its negative impact, it also has a positive one, which is the acceleration of drying procedures in building fabric.

The parameter measuring the absorption of capillary water by a building material is called *capillary absorption W* per unit area and can be expressed as (Homann, 200):

$$W = w \times \sqrt{\tau}$$, where:

W - capillary absorption W of a building material per area unit [kg/m^2]

w - water absorption coefficient [$m^2\sqrt{h}$]

$\sqrt{\tau}$ - square root of the process time [$\sqrt{h}$]

This parameter is important for the assessment of resistance of the facade to dampness and is determined by the coefficient w as (Homann, 200, Buss, 2004))::

a) water retaining if $w \geq 2.0kg/(m^2\sqrt{h})$

b) water hindering if $w < 0.5kg/(m^2\sqrt{h}) < 2.0kg/(m^2\sqrt{h})$

c) water resistant if $w \leq 0.5kg/(m^2\sqrt{h})$

In Germany the requirements on quality in terms of water absorption are regulated within the standard DIN 4108.

Depending on the rate of the water uptake the materials can be divided in four groups as:

1. low rate of water uptake and low rate of water release (e.g. solid concrete)
2. high rate of water uptake and high rate of water release (e.g. gypsum or brickwork)
3. high rate of water uptake and low rate of water release (e.g. cellular concrete)
4. low rate of water uptake and low rate of water release

Condensation

The process of condensation is closely related to the relative air humidity. The absorption capacity of the air is dependent on the air temperature. In the case that the dew point is exceeded, it leads to condensation of water vapour. The water vapour can then diffuse through porous solid construction materials. The resistance of the construction materials to this process is expressed as diffusion resistance number μH_2O and is defined for different materials (in Germany in DIN 52615).

In practice the equivalent values of the air layer s_d are being used expressed as the thickness of the air layer with the same diffusion resistance as the observed material.

This value is given as (taken from Buss, 2004):

$s_d = \mu \times s$ with

s_d equivalent air layer [m]

μ resistance coefficient [-] (to be taken from standard tables)

s thickness of the layer of the building material [m]

For external walls the value s_d decreases moving from internal to external side, which means that condensation will occur at the contact of the wall and environment.

One building element is considered as dry if the s_d value exceeds 0,2 (Zimmermann, 2006).

For values between 0,2 und 1500 m the diffusion is being hindered whereby for the values above 1500m the layer is considered to be tight in terms of its diffusion potential. For proofing these criteria for different building components, both on site measurements as well as simulations programs are used (Zimmermann, 2006).

The condensed water can be harmful for a building element if it leads to the corrosion of metal elements or causes moulding in a building.

A special process of condensation is capillary condensation. In very fine pores (of diameter 10^{-3}-10^{-7}m), condensation already occurs when the saturation moisture has been reached.

Diffusion of water vapour

The diffusion of moisture through building materials is a natural phenomenon. It is a movement of gas and liquid molecules following Brown's law, in which water vapour migrates through the construction material due to a difference in vapour pressure from the area with the higher to the area with the lower vapour pressure. In most of the cases diffusion takes place from the inside to the outside and it is not

dependent on the heat flow. It has significant effects on the comfort conditions in the built environment.
This process is more intensive in porous materials, but in general the type and structure of materials determines the rate of the process. The resistance to diffusion is defined by the water vapour diffusion resistance factor (commonly called μ -factor [-]), that is given for different materials (e.g. DIN EN 12524). It is a dimensionless value defining the ratio between the resistance of the material and the air layer of the same thickness as:

$$\mu = \frac{\delta_a}{\delta}$$, where

δ_a - water vapour diffusion conductivity coefficient of the air

δ - water vapour diffusion conductivity coefficient of building material

The lower the μ factor, the more water vapour migrates through the building element. Still as in case of capillary rise, for materials with open pores a low μ value can be favourable as the in this way the drying procedure can be accelerated. In practice, the ranges for the μ factor are set defining different diffusion characteristics of the material as depicted in Table 1 (Ib-Rauch[190]).

Table 9-3 a) Definition of materials depending on the μ factor and b) equivalent air layer (Ib Rauch)

a) μ factor	b) Equivalent air layer
$\mu = 10$ very good diffusion	Sd < 0,5 m diffusive,
$\mu = 10-50$ - medium diffusion	0,5m < Sd = < 1500 m restricted diffusion
$\mu = 50-500$ - restricted diffusion	Sd > 1500 m no diffusion
$\mu = 500-15000$ - highly restricted	
$\mu > 15000$ - no diffusion	

This factor shows the ability of water vapour to diffuse in a building material in relation to air. It is, however, not applicable to water in the liquid state, as water molecules are larger than the pores of the materials and in some cases can not pass through them. This has to be kept in mind when discussing the diffusion features of building fabric.

In practice the equivalent air layer s_d is being used, defined as the thickness of the air layer that has the same diffusion resistance coefficient as the analysed material (as depicted in Table 9-3 b).
As the diffusion of water vapour takes place from inside to the outside, the diffusion resistance of the wall layers should decrease from inside to the outer side. In order to avoid condensation of water vapour, the resistant materials should be placed on the warm side (i.e. interior side) and conductive materials on the outer side. The rate of the transport of water in the liquid state is higher than that of the water vapour. This enables a much faster drying of a construction material.

Sorption
Sorption is a process that describes the storage of moisture (adsorption) on the pore walls in the hygroscopic materials through uptake of the water from the air. The adsorption power depends on the inside surface of the pores and layer thickness (Homann) The higher the relative air humidity, the higher moisture of the material. Reversely, by lowering relative humidity, the material releases moisture through the process of desorption. Both processes are summarised as sorption. The sorption isotherm is given for different materials and defines the dependent relative air humidity to moisture content of a material for the given temperature. By means of the sorption isotherm, it is possible to

[190] http://www.ib-rauch.de/bautens/formel/diffwidst.html

assess the equilibrium moisture of a material, based on the relative air humidity without consideration of the transport mechanisms (Homann).

Water uptake under pressure
Pressurised water increases the water uptake rate by the capillary pores of materials. Additionally, the pores, that under normal conditions can not absorb water pressure (such as air pores), can be filled with water if exposed to pressure. In the case in which all pores are filled, the saturation point has been reached.
The water uptake under pressure follows Darcy's law, given for the mass flow:

$I = k \times \frac{d_p}{d_x}$, with I - mass flow [g/s], k - material specific value (given in tables), d_p - pressure difference of the water [N/m^2], d_x - thickness of the layer of building material [m]

Lateral pressure
The water stage during a flood event exerts lateral pressure to the building and its vertical components. There are two types of lateral pressures, hydrostatic and hydrodynamic.
The former one is a pressure exerted by a depth of water against a building. It can be expressed as: (Kelman, 2003):

$$\Delta P = \rho_w \times g \times (f_{diff} - y) = \Delta P_{hydrost, y=0} - \rho_w \times g \times y \text{ for } h \le y \le f_{diff}$$

$$\Delta P = 0 \text{ for } y > f_{diff}$$

with

f_{diff}	flood depth differential [m]
g	gravity [9.81 m/s^2]
ΔP	pressure difference [Pa]
y	distance upwards from a set reference point [m]
y = 0	the base of the building
ρ_w	density of water [kg/m^3]

as depicted in Figure 9-3.

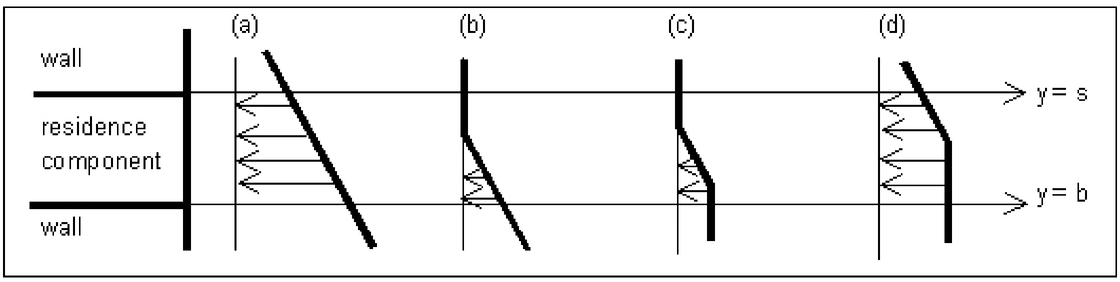

Figure 9-3 Lateral pressure to building components (Kelman, 2003)

Pressure distribution depends on the water depth and its relation to the building component. Kelman, 2003 differentiates four basic cases being:

(a) Water covers the entire residence component on one side yielding a linear pressure over the entire residence component.

(b) Water rises partway up the residence component on one side.
(c) Water rises partway up the residence component on both sides, but to different y-values on each side.
(d) Water entirely covers the residence component on one side and rises partway up the other side

These lateral pressures have high a relevance to the damage outcome from a flood as they can cause the structural failure of a building (Kelman et al., 2004). Within this work, this phenomenon will not be further investigated but taken as a general aspect and factor for assessment of potential damage.

Buoyancy force
The buoyancy force is an uplift force which is exerted to a building or its components. In combination with hydrodynamic or hydrostatic actions the floating building or its parts can be displaced and can what potentially lead to damage, destabilisation or even complete destruction. This force is a function of the submerged volume of the building and can be calculated as:
$F = \rho_w \times g \times V$, where the volume V equals the volume of water which the residence (with the cross section A) displaces, resulting in $F = \rho_w \times g \times A \times h$.
The relevance of buoyancy depends on the kind of building. A timber building may float if it is not anchored properly, which is usually not the case for masonry or concrete buildings (Kelman, 2003). Still, high buoyancy forces can cause cracks and gaps in the foundation slab, depending on the material and possibility of water migration through the building element and as such has to be considered for each building and flood scenario.

Impact on heat transport
Heat conductivity is one of the main processes to be considered for the assessment of potential damage to the built environment due to flooding. It determines the functionality of the building elements related to one of its key functions, heat insulation. The contact of flood water with the insulation material can degrade the insulation functionality and cause damage. The main parameters determining the heat conductivity process are given as:

Heat conductivity λ
Heat conductivity is one of the most important parameters describing the features of heat insulation. It encompasses overall heat exchange in a solid material through heat conduction, convection and heat radiation. It is given in [$\frac{W}{m \cdot K}$]. This coefficient depends on the physical parameters of the material, the main ones being: (Buss, 2004)

- Material density: the higher the density the higher conductivity it performs.
- Porosity: the higher porosity and the smaller the pores are, the lower the heat conductivity.
- Dampness of material: the higher the water content in the material, the better the heat conductivity

The following parameters are of relevance for the assessment of the changes in the insulation function of the building elements (Buss, 2004):

Heat conductivity coefficient Λ
represents the heat that is conducted through a $1m^2$ cross section area of the examined material with a thickness d, if the temperature difference between those two sides reaches 1K.

$\Lambda = \frac{\lambda}{d}$ where

Λ heat conductivity coefficient [$\frac{W}{m^2 \cdot K}$], λ heat conductivity [$\frac{W}{m \cdot K}$] and d layer thickness [m].

Heat resistance R

is a parameter that describes the performance of building materials in terms of heat insulation. It is a reciprocal value to heat conductivity and is given as:

$$R = \frac{d}{\lambda} \; \frac{m^2 \cdot K}{W}$$

In the case that the building component is composed of several layers, the overall heat resistance can be calculated as

$R = \sum_{i=1}^{n} \frac{d_i}{\lambda_i}$ where d_i [m] is thickness of single layers with heat conductivity λ_i

R is the relevant value for the evaluation of the performance of the building elements regarding their heat insulation. It is based on the temperature difference between the surfaces of the layer of the thickness d. Those surfaces are in contact with the air temperature either from the interior or exterior side, which is easy to measure. The rate the heat is transferred between the surface of the building element and the air temperature is determined by the heat transfer coefficient h or its reciprocal value defined as heat transfer resistance R_s.

Those values are given for different materials depending on the side of the building element (interior, exterior) or direction of heat flux (Schulz, 2004).

For a practical calculation of heat transfer processes in the building elements such as walls or floors, the heat resistance coefficient can be calculated as:

$R_T = R_{si} + R + R_{se}$ [$\frac{m^2 \cdot K}{W}$], where the heat transfer coefficients between the interior/exterior and surface of the building component are given as R_{si} resp. R_{se} and R is heat resistance of the building material.

The reciprocal value to R_T is defined as the heat transfer coefficient U (also called U-value) given as:

$$U = \frac{1}{R_{si} + R + R_{se}} = \frac{1}{R_T} \; [\frac{W}{m^2 \cdot K}]$$

The smaller the U-value is, the lower the heat loss in the building element. For the scope of the assessment of the potential damage, the values for damp building components are relevant.

The U-values are defined for different building components (e.g. walls, fenestration, ceilings). Especially critical points are, for example, fenestration joints. Maximal U-values are defined by standards (in Germany EnEV, 2001).

For practical purposes those coefficients are applied to assess whether existing or planned insulation is sufficient, as given in Schulz, 2004.

This procedure can be applied before and after flooding for different building elements in order to assess the loss in functionality due to floods.

Regarding the main function of the heat insulation, the question arises of how damp can the building elements be. They are either known (in Germany DIN 4180) or can be calculated (e.g. after Clammerer "assessment of the impact on dampness of construction materials to heat conductivity") by applying so called saturation curves of heat conductivity. In general the influence of moisture in a material can be calculated based on the heat conductivity of dry materials corrected by the coefficients b and c. It differs for organic (weight related) and inorganic (volume related) materials and is given as (Buss, 2004):

Organic: $b = \frac{\Delta\lambda_{\mu}}{(u_m \lambda_n)}$ (weight related)

Inorganic: $c = \frac{\Delta\lambda_{\mu}}{(u_m \lambda_n)}$ (volume related)

These equations result in the heat conductivity for damp building materials as:

$\lambda_{um} = \lambda_{tr} \times (1 + b \times u_m)$ for organic materials

respectively

$\lambda_{uv} = \lambda_{tr} \times (1 + c \times u_v)$ for inorganic materials

In practice, the assessment of moisture content in the material and its influence on the heat conductivity is given as an estimation. As an orientation for the material density from 300-800 kg/m^3, the coefficient b is constant and reaches 0.037% (Buss, 2004). Values for different materials can be obtained from graphics (e.g. Buss, 2004 p 265) and are given depending on the porosity of the materials. In practice the minimum requirements for heat protection are defined by standards (e.g. DIN V 4108).

Absorption characteristics of masonry wall can be discussed in terms of its absorption coefficient as depicted in Table 9-4. As a comparison, the coefficients for gypsum boards and synthetic dispersion coatings are given.

Absorption is less relevant in case of calcium silicate units, but pore structure affects resistance to frost damage. Clay units tend to expand in service whereas calcium silicate units shrink. Water absorption accelerates destructive processes in masonry walls of flooded buildings. In the winter period, the masonry wall can be damage as a result of water freezing inside walls, because it increases its volume by around 9%.

Table 9-4 Absorption coefficient w for selected building material

Building material	Absorption coefficient w [$m^2\sqrt{h}$]
Cellular concrete	4-8
Solid brick	20-30
Sand lime brick	4-8
Cement plaster	2-3
Gypsum board	35-70
Synthetic dispersion coating	0.05-0.2

Cement render $\mu = 20$ water vapour but at the same time, it hinders water molecule migrating through the material, as water molecules are too large for the pore size of material. Water vapour molecule with its radius of 0,14-0,16 nm is considerably smaller that the air molecule 0,2-0,28 nm. The water molecule with 0,28 nm

The same is valid for synthetic-cement or dispersive paints. In contrast to loam or brickwork that conducts both water vapour and water molecules. The μ value can be determined in lab experiments and are summarised in standards and norms (in Germany DIN 4108-3).

There are materials with similar behaviour during heat and moisture conductivity. For example, cork hinders both heat and moisture conductivity whereby brickwork or gypsum conduct both heat and moisture very well. Concrete conducts heat very good.

Figure 9-4 presents distribution of mass humidity before and after the flood, on inside walls in the building drying out in the natural way, without vertical and horizontal moisture insulation.

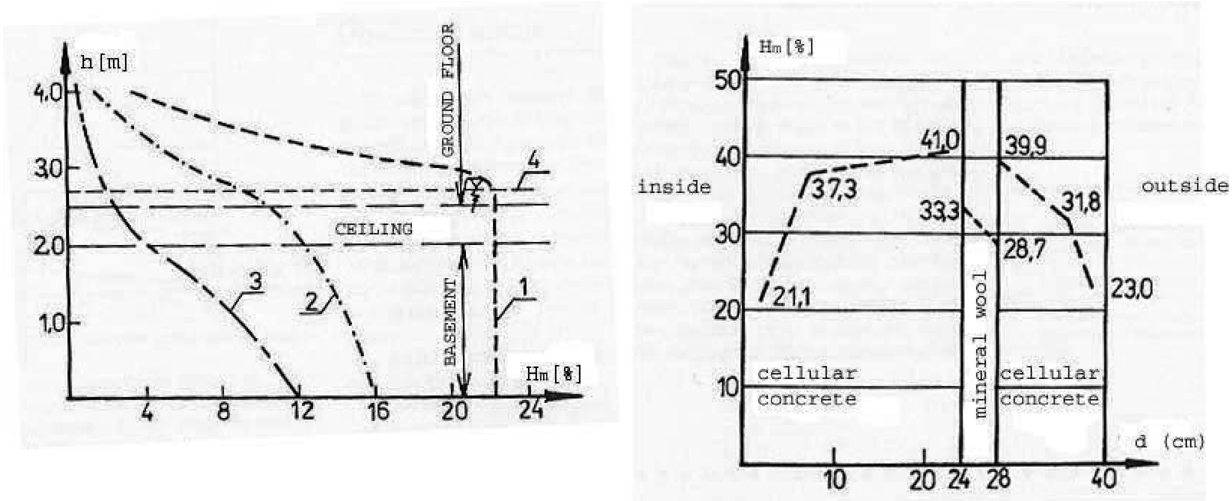

Figure 9-4 left: Distribution of mass humidity (Hm) at the height (h) of inside walls, made of ceramic brick in basement and ground floor: 1– during the flood, 2 – 9 months after the flood, 3 – before the flood, 4 – maximum level of flood water in the building. Right: Distribution of mass humidity (Hm) in the thickness (d) of 3-layer wall, 4 months after the flood

9 months after the flood mass humidity of walls up to 0,5 m above the floor was higher than 5%. Such humidity is too high for plastering.
Figure 9-4 right shows distribution of mass humidity on the 3-layer wall, 4 months after the flood. The wall is the outside one, on the ground floor, in the building without cellar, with moisture insulation. The flood water level was 1,8 m above the ground floor. The walls were dried by airing the building. After 4 months, cellular concrete was still highly damp, 40% inside walls and 21 – 23% at the surface. Those values are 2 – 3 times higher than acceptable mass humidity of this material in utilized buildings.

After the flood in Wroclaw (Poland) in July 1997 the drying out process of cellular concrete in building was investigated. For the first time the humidity was measured 6 weeks after the flood event and then 12-15 weeks later. The typical course of the drying out process in the plastered and the non-plastered building is shown in Figure 9-5.

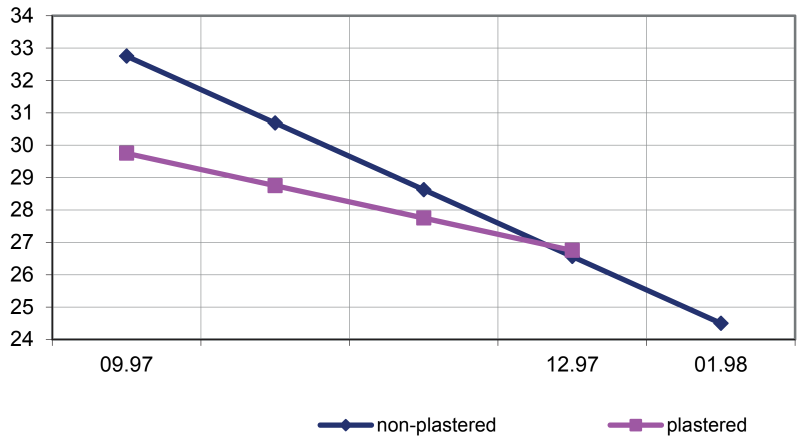

Figure 9-5 Drying out of cellular concrete walls (taken from Pajak, 2006)

In the non-plastered building, the humidity of a wall decreased by 8,3% between September 1997 and January 1998 (from 32,8% to 24,5%). In the plastered building the decreased was significantly smaller, from 29,7% to 26,7%. The lower humidity in the plastered building was caused by the fact that it was intensively aired before the investigation started. Also the thickness of walls was lower. Nevertheless, looking at the graph, it can be concluded that non-plastered buildings dry out faster.
The distribution of humidity in cross-section of a cellular concrete wall is presented in Figure 9-6.

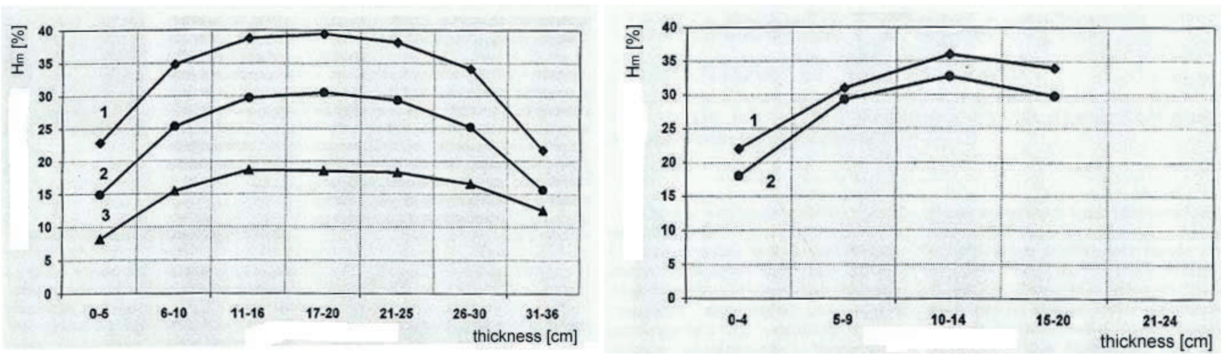

Figure 9-6 Distribution of humidity in non-plastered wall, thickness 36 cm, 1 – 09.97 (6 weeks after the flood), 2 – 01.98, 3 – 06. 98 right: Distribution of humidity in plastered wall, thickness 24 cm, 1 – 09.97 (6 weeks after the flood), 2 – 12.97 (Bodzak et al., 1998)

Heat conductivity
As a result of increased heat transfer coefficient, heat losses in rooms are higher and the temperature on interior surfaces of external walls is decreased. Heat transfer coefficient for wet walls made of ceramic brick is higher by around 150% and for walls made of cellular concrete – 185% in comparison with dry walls. Contribution of external walls to total heat losses in residential buildings is about 40%. Therefore expenses for heating of not dried buildings can be significantly higher in first heating seasons after the flood events. In intensively heated rooms relative air humidity often reaches values above 80% due to water evaporation from walls. Decreased temperature on interior surfaces of humid external walls adds to the probability of water vapour condensation on those surfaces. The result is that the minimum relative air humidity for condensation of water vapour in such a room is reduced (Matkowski et al., 1998)

Water as a chemical agent:
Water as a chemical agent can interact with the materials, causing reactions that can alter the quality of building components. The main processes related to the presence of water in building materials are given as:

1. reactions of water as a solvent agent with building materials, causing two main types of reactions being:

acidic reactions: e.g. $SO_2 + H_2O \rightarrow H_3SO_3$
alkaline reactions: e.g. $CaO + H_2O \rightarrow Ca(OH)_2$
chemical and electrochemical corrosion: e.g. $2\ Fe + H_2O + O_2 \rightarrow Fe_2O_3 + H_2$

2. transportation of the aggressive salts

Water in the building material transports aggressive salts that crystallise on the surface of the materials and cause efflorescence. Also, the presence of salts in water and their interaction is responsible for more intensive moisture transport in the material as the salts adsorb water. The presence of salts can hinder the capillary rise in the materials, increasing the water vapour diffusion resistance (μ -value). The salts can be already contained in the building material (sulphate: gypsum, mortar containing gypsum), brought from an external source e.g. adsorption from the soil, or groundwater due to insufficient horizontal sealing of the building or insulation. During a flood event those processes can get intensified as there is enough water available as a solvent.
Examples of harmful salts for building fabric are given as:

- Nitrates: calcium–nitrate $Ca(NO_3)_2$, magnesium- nitrate $Mg(NO_3)_2$
- Chlorides: calcium-chloride $CaCl_2$, sodium chloride NaCl
- Sulphates: magnesium sulphate $MgSO_4$, gypsum $CaSO_4$, sodium sulphate $Na_2\ SO_4$

In most cases, the dominating process for transport of salts is hygroscopic, depending on the type of salts and their concentration. The hygroscopic process starts if the relative air humidity is for sulphates >85%, chlorides >70% and nitrates >50%.
For a better understanding of the processes involving salts it is necessary to understand the environment in which these processes are taking place. The soil surrounding the brickwork contains water with dissolved salts. Through capillary transport, these salts reach the building component and are transported depending on the pore size and evaporation capacity. The system reaches equilibrium when the amount of penetrating water equals the amount of evaporated water. In the evaporating zone, the concentration of salts increases as water can only evaporate and the amount of salts is increasing through capillary transport. At a certain concentration level (depending on the salts), the hygroscopic process begins, which destroys the existing equilibrium state. In order to recreate it, it is necessary that more water evaporates, causing an extension of the evaporation zone (and consequently the moisture area on the building element). As it is a dynamic equilibrium, this process shifts the equilibrium into the direction of the hygroscopic process. The estimation of salts transport in the walls is being researched and published for different salts and material (e.g. WTA Bulletin in Germany).

Acidic Reactions
Acidic attack is caused by the presence of the acidic solution in flood water. Its severity depends considerably on the solubility of the formed calcium salt. Solutions of hydrochloric acid HCl and nitric acid HNO3 are considered to be highly aggressive media, as the solubility of their calcium salts is very high, 46.08 and 56.0 wt.% respectively. The velocity of flowing water can influence the severity of the attack because dynamic conditions contribute not only to the transport of the aggressive species into the pore system of the solid material but also to the washing out of the decomposition products as well (Zivica et al., 2002). Still, this process has its positive aspects. In case of formation of insoluble calcium salts such as calcium oxalate and fluoride, a thick insoluble layer is formed contributing to the protective effect of acidic attack. This characteristic can be used in practice for the protection of the solid materials.

Efflorescence

Efflorescence is a chemical process in building materials that appears as a white and thin foggy salt deposit on the surface of porous building materials, most often on the masonry facades made of brick or concrete blocks (Brocken&Nijland, 2004). Although efflorescence is considered to be an aesthetic phenomenon, the underlying mechanism, causing thick crust-like surface deposits on masonry components or crypto-efflorescence (deposits of crystallizing alts within pore near the surface), may result in the exfoliation of spalling and as such indicate functional damage on buildings (e.g. loss of binding agent). The causes of efflorescence are sulphates (approx. 70%) and chlorides (Brocken& Nijland, 2004). The most common efflorescence occurs on brickwork. In the case where wall moisture is in a reaction with the building material and nitric oxide, light dissolvable nitrates are created. Efflorescence becomes visible when wet walls dry and salts dissolved in the pore solution accumulate near the surface.

The water that has been uptaken from the soil by the capillary forces, contains salts and dissolve salts already contained in the building materials. While a part of the water evaporate, the salts remain and crystallise and as such can destroy the masonry. Also, the presence of salts increases further water uptake.

In this process water dissolves components of the efflorescing salt and to transports them between brick block and mortar joint and finally to the masonry surface. Efflorescence on masonry is generally formed by Na-, K-, Ca-sulphates or carbonates. The necessary sulphate may originate from several sources: brick, mortar, soil, air or rain. In bricks, sulphates are formed during the firing process and may remain present depending on the maximum temperature of firing. In mortar, sulphate originates normally from the Ca-sulphate added to control setting. Surfactant phases like air entraining agents and other mortar additives my increase the mobility of Na, K, Mg, Ca and sulphates in bricks. Efflorescence and wash out of lime usually occurs on masonry made of bricks or blocks with low water absorption. Water causing excessive wetting of mortar joints facilitates dissolution of lime in the pore water of the mortar joints and prevents carbonation of lime, as CO_2 from the air cannot penetrate into the saturated mortar structure (Brocken& Nijland, 2004). In masonry, there can be several types of efflorescence identified:

- late efflorescence of gypsum on clay brick masonry
- early masonry of sulphates on clay brick masonry
- efflorescence/wash out of lime on masonry
- efflorescence of sulphates on concrete blocks
- efflorescence of lime on concrete.

Corrosion

Corrosion is a process that occurs due to the presence of water in a liquid state on metal surfaces, natural stone or concrete. For example iron begins to corrode if the air humidity exceeds 65%, i.e. the absorbed water film on the metal surface is thick enough. The degradation products of organic materials such as wood or bitumen as well as the presence of ions of chlorides, sulphates and nitrates are of acidic nature and can accelerate the process of corrosion. It affects almost all metals relevant as building materials such as iron, zinc, aluminium or copper.

Concrete corrosion occurs due to cement hydratation. It can be caused by: acids, bases mostly Ca(OH)2, organic contaminants (oils and fats and phenols), sugar, salts, soft water (if 15-20% of Ca(OH)2 is washed out from the cement, the hardness is decreasing for 40-50 and the white stains are noticeable on the concrete surface).

Others

Additionally, water is responsible for hydration pressure (in minerals) and frost-melt-effects destroying the surface of building elements.

Processes and requirements related to indoor climate

Indoor climate is related to how the dwellers feel living or working in a building. It is related to optimal temperature, air humidity, movement of the air and temperature of the building construction and is defined by standard values (e.g. DIN 4108 in Germany).
A wet room is defined as an "interior space that contains that amount of water that in order to remove it is necessary to apply drainage of the floor" (DIN 18195).
The practical moisture content is the water content of a construction material, in which water contents found in investigations of a sufficient number of dried buildings that serve for living or working purposes are not exceeded in 90% of cases. For evaluation of the practical moisture content, generally the equilibrium moisture in case of 80% air humidity is used.
The critical moisture content is the lowest value for possible capillary rise of a material. For example for cellular concrete it reaches values of 18-25 Vol.%, brickwork 2,5-5,0 Vol.% and in the case of limestone the value of 14 Vol.% moisture.

Although it is difficult to define the optimal indoor climate for all persons, as it is strongly related to personal taste, it has been defined by standards (e.g. DIN EN ISO 7730). According to this standard the "acceptable indoor climate" is defined as the one that is deemed acceptable in terms of temperature by at least 80 % of the persons. This is dependent on a multitude of impact parameters such as room temperature, relative air humidity, air movement etc. (Frank et al., 1975). For its quantification different pairs of factors have been identified (e.g. indoor temperature vs. air humidity) and their interactions analysed. For an assessment of the alternation of the quality of indoor climate, the dependence between room temperature and air humidity can be analysed. It is defined for different types of activities (sitting, or active movement) and air velocity in the room (as depicted in Figure 7)
Requirements on air humidity are primarily related to hygienic and health aspects. It should not exceed the critical value so that condensation and moulding of building fabric does not occur. As a criteria for avoidance of moulding the temperature factor f_{Rsi} is defined as

$f_{Rsi} = \frac{\theta_{si} - \theta_e}{\theta_i - \theta_e}$ with θ_{si} indoor temperature on the surface of a building fabric [°C], θ_i room temperature [°C], θ_e - air temperature outside [°C].

Assessing changes in indoor climate is not straightforward as it is related to personal preference. Still, the defined criteria given above can serve as a bases for an assessment of how and in which way the flood factors can contribute to a reduction of the living quality in a building.

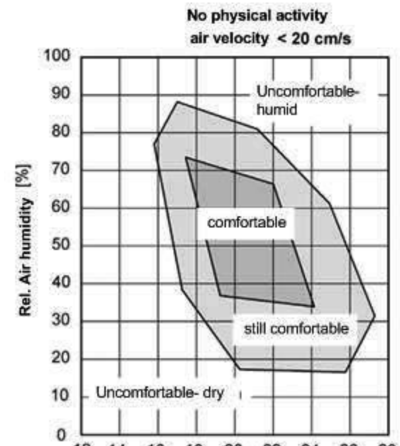

Figure 9-7 Indoor climate (Leusden et al., 1951)

Appendix 3.3b- Description of the damage potential for the relevant flood factors per building elements

Building as a whole

Depending on the static conditions in each particular case, either gaps and cracks are formed or the construction starts to arch. The principle of the buoyant and lateral forces acting on a building with an example of such an action are given in Figure 9-8.

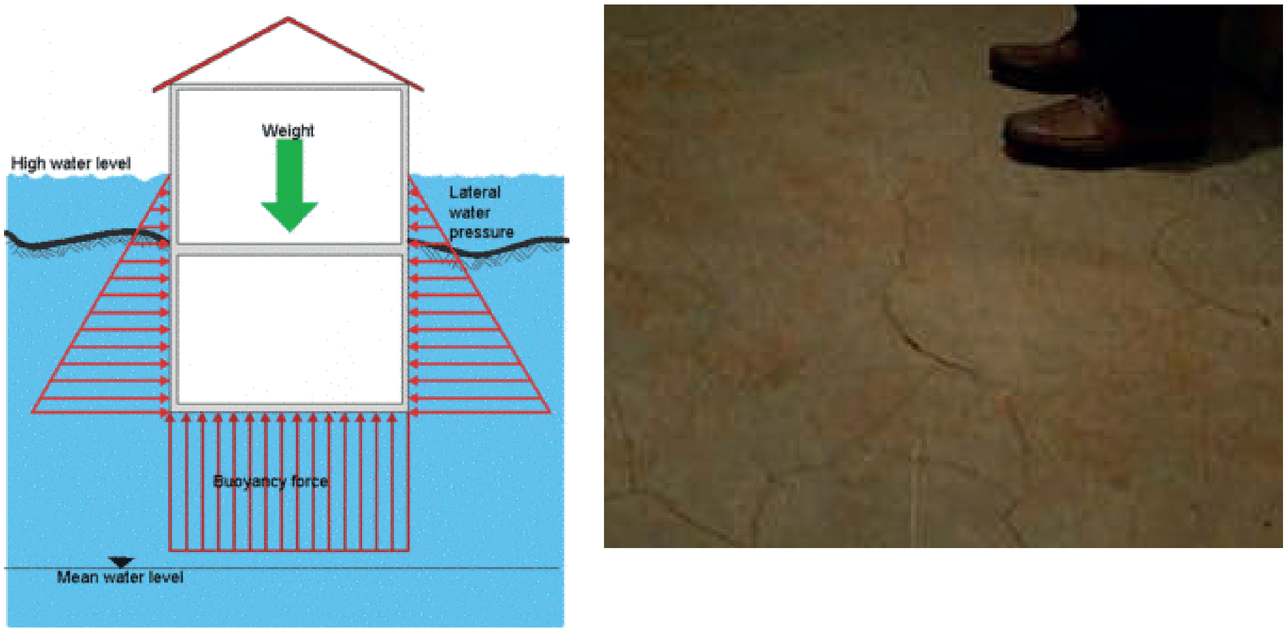

Figure 9-8 a) Buoyancy forces and lateral pressure asserted on a building b) consequences of the buoyancy during the flood event in Lauenburg, 2006 (own photo)

Because hydrostatic pressure increases with the depth of the water, the pressure on basement walls is greater than the pressure on the walls of the upper floor. Once the pressure exceeds the strength of the walls (including basement walls), it can push them in, cause extensive structural damage, and in consequence it can cause the house to collapse. If water is allowed to enter, the hydrostatic pressures on both sides of the walls and floor become the same, or "equalized", and the walls are much less likely to fail (EA, 2002). This danger is smaller in the case of massive multi-storey buildings due to the counter weight of the building pressing against the buoyant forces. In order to assess the stability of a specific building, a thorough static analysis should be performed. Such analysis has been beyond the scope of this work. The assumptions made in order to assess the susceptibility of a building to buoyancy has been made based on the building type, presence of the basement and are given in
In buildings with construction susceptible to flood damages, the most characteristic are cracks of elements such as walls and lintels. The width of crack reaches often few centimetres.
Buildings without rigid construction in the area of foundation are much more susceptible to flood damage caused by unequal settling down of the ground than those with rigid construction, such as reinforced concrete footing or foundation slabs (e.g. Nowak et al., 1998).[191].

[191] After the flood event in Wroclaw (Poland) in July 1997 only old buildings, built at the end of 19th century and the beginning of 20th century were damaged so seriously that they had to be excluded from further exploitation.

The aspect of moulding is being considered, but on the general level as much as it influence the indoor climate and odour. Moulding as a process will be discussed in the case of single building elements.

The main assumptions have been taken in order to define the damaging functions of the buildings based on their characteristics are summarised as following:

- ➔ detached and semi-detached buildings with basement and strip foundation, when exposed to 0.5 m of flood water are subjected to cracks in the flooring system
- ➔ detached and semi-detached buildings with basement and strip foundation, when exposed to 1 m of flood water (above ground) are subjected to severe structural damage
- ➔ if flood duration is greater than 15 days, moulding of all buildings has been assumed due to the increased humidity and the damage can be attributed to the activities of the removal of moulds (decontamination)
- ➔ in the case of the organic contamination, the decontamination has to be performed
- ➔ the more massive the building the better stability (Schmidt-Döhl, 2013)

1. **Walls**

(1) Masonry[192]:

Masonry walling units can be produced either form the burnt-clay bricks (1), natural stones (2) or concrete elements (3). The burnt-clay bricks are produced from suitable clay or any other material that contains clay, with or without sand, with or without additives and are burnt to obtain a ceramic compound (Rongen& Hestermann, 2010). They can be produced in a form of solid, perforated or hollow weight brick.

One distinguishes between two main types of masonry walls:

I) Single leaf masonry; can be used for both interior and exterior walls. For the interior walls, the brickwork made of small and medium size stones is used. For the exterior walls, large stones are to be considered (Rongen and Hestermann, 2010). Single leaf masonry is given as:
   (1) Not rendered
   (2) Visible masonry
   (3) Rendered without thermal insulation
   (4) Rendered with thermal insulation
   (5) With external thermal insulation composite system (ETICS)
   (6) With internal insulation

II) Double leaf masonry; they are composed of an internal supporting brick layer and the external that takes the protective role against the atmospheric conditions. Double leaf masonry (after DIN 1053, Franke 2008):
   (1) Without rear layer (rarely used)
   (2) With air layer
   (3) With air layer and thermal insulation
   (4) With core insulation with or without air layer
   (5) Rendered/ not rendered
   (6) Rear ventilated façade with panels and thermal insulation

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Those buildings had mainly brick or stone foundations with weak lime mortar, wooden ceilings in which not all beams had been anchored to walls and walls were made of low quality bricks. (Hola et al., 1998).

192 In this work, the standard values for dimensions, materials or static conditions and requirements of the masonry walls as defined in DIN 1053 (http://ziegel.de/technik/DIN1053.htm#5.1%20Mauersteine) have been taken as a basis.

Additionally for the basement walls, the two leaf masonry with perimeter insulation (e.g. EPS) is considered.

For the brickwork made of natural stones, different stone types are considered the main ones being: magmatite (granite or basalt), sedimentite (e.g. sand-lime stones) or metamorphite (e.g. quartzite) are used. They can take different forms and are often used as a facade element (Rongen& Hestermann, 2010).

The main wall types made of the natural stone are given as boulder masonry, rubble masonry, regular or irregular layer brickwork, ashlar masonry.

The most important physical and mechanical properties of masonry units that are relevant to their application for the construction of walls are: colour, surface texture, absorption and pore structure, thermal conductivity, thermal and moisture movement, compressive strength and tensile strength (Brady et al., 2002). In case they are compromised by flood water, the damage of a wall element occurs.

The main assumptions related to the *physical actions* are given as follows:

➔ For the conditions of flood duration of > 3 days capillary rise in brick masonry reaches in average 50 cm above water level. In terms of the water absorption, lack of vertical and horizontal damp-proof insulations favours transport of water into walls (Hola et al., 1998). Capillary rise can even reach up to 2m[193] over the level of flood water, depending on capillary-porous structure of the wall and the exposure time.
➔ Masonry walls, even those made of porous materials, which can soak easily, can function after drying (Nowak et al., 1998). The damage occurred is related to the necessary repairs on walls, cleaning and drying
➔ Masonry is unlikely to have serious effects, but an impact on thermal performance when wet (Scottish Office, 2009). If thermal insulation (such as crylamine, mineral wool or organic fill) has been affected, it will be replaced for the whole wall element.
➔ Flood can cause gaps and cracks at any velocity on a masonry wall element.
➔ Masonry may take a long time to dry, which will affect what can be done in repair as well as the resources (time, effort, electric power) needed to repair it
➔ Partition walls are damaged at any flood conditions and are to be replaced after a flood event.
➔ Cleaning of walls is considered for every type flood event with any flood parameters
➔ If drying has been performed utilising special procedures (including heating up to 40ºC and intensive airing the duration is estimated to 3 months (e.g. Nowak et al., 1998). In terms of drying the brickwork shows decreasing mass humidity of brick masonry from about 20 – 25% to 3% without any special procedures can last about 33 months.
➔ In case of partition walls which are tiled on both sides, e.g. in sanitary rooms the tiles hinder evaporation of water from walls and process of drying lasts longer. In such cases capillary rise of water is higher and the actual drying occurs above tile facing. During drying of the wall there appear humid stains, efflorescence on plaster and mould (Nowak et al, 1998).
➔ non-plastered buildings dry out faster (Bodzak et al.,1998)
➔ In the case of double shell masonry of sand-lime bricks with heat insulation and air space, floodwater can enter the cavities and saturate the insulation, and soak into the inner masonry shell. Even if the flood water is drained through the cavities, it is difficult to dry out the insulation material. The mineral fiber insulation used in this wall construction absorbed a huge amount of water and became saturated and fragile to handle. It loses its strenght and stability and has to be replaced. (based on the experiments conducted in Golz, 2012)

[193] Experience made after the flood event in Wroclaw (Poland) in July 1997, which enabled investigation of condition of walls after the flood.

➔ The walls using hollow brick blocks are very susceptible to flooding and require long drying time (several weeks). If the wall assembly is not-rendered at its external face, as in this arrangement, it offers less resistance against water penetration and the water uptake by capillary action, caused by the porous material structure, is very high (based on the experiments conducted in Golz, 2012).

➔ If ETICS is not fully adhered to the wall, water was easily running behind the ETICS and penetrated into the masonry (based on the experiments conducted in Golz, 2012).and as such, can be considered as damaged

The main assumptions related to the *chemical actions* (efflorescence, acidic attack) are given as follows:

➔ In case of cavity walls, after repeated exposures to floodwater, the steel wall ties between the internal and external leaf of the wall may start corroding. Flooding with saltwater contributes to the increase in probability of corrosion

➔ Efflorescence and wash out of lime usually occurs on masonry made of bricks or blocks with low water absorption. For the damaging functions this process and the damage occurred has been considered as non functional but is included for semioticl functions. The damage is calculated based on the cleaning costs required to remove the products of efflorescence.

➔ The efflorescence of gypsum typically occurs on masonry with bricks containing a considerable volume of small pores with diameter from 0.2 to 2 mm. Possibly, small pores contribute to the amount of water sucked from the mortar joint into the brick increasing the amount of dissolved Ca and sulphate transported into the brick, where it is deposited on the surface as gypsum.

The main assumptions related to the *biological actions* are included in the assessment for the building as a whole.

Figure 9-9 Examples of physical, chemical and biological actions on walls after a flood event a) cracking b) efflorescence c) moulding, in canton Nidwalden, Switzerland, August 2005 (courtesy NSV)

(2) Loam

Despite of being the oldest type of brickwork, the loam masonry is nowadays sill in use. The main types of loam masonry are given as (Rongen& Hestermann, 2010):

- Loam bricks
- Beaten cobwork
- Pressed loam
- “Teranig”- frost and water resistant loam brickwork

They can be either rendered or not rendered.

The main assumptions related to the *physical actions* are given as follows:

➔ Loam is very sensitive to moisture and water. In case of the contact with the flood water, the loam wall element is considered as damaged and has to be replaced

(3) Concrete

Concrete is a building material produced as a three phase system (cement, water, aggregate) or as a five-phase system (cement, aggregate, water, concrete admixtures and additives) (Reinhardt, 2010, (Rongen& Hestermann, 2010).

Reinforced concrete is often used for the conditions of high static loads or the building parts beneath the surface which are exposed to high hydrostatic pressures (e.g. basement walls) or for the prefabricated walls.

Cellular concrete is a lightweight concrete foamlike material which is formed by adding air, foam, or aluminium powder to the concrete mix. An expanding agent in that it increases the volume of the mixture while giving additional qualities such as nailbility and lessened the dead weight.

The following types of walls can be found (Rongen& Hestermann, 2010).

Single leaf walls

- Reinforced concrete made of standard concrete with thermal insulation (wood wool slabs and foam or expanded plastic slab)
- Lightweight concrete
- Reinforced basement walls with insulation (e.g. foam glass)

Concrete brickwork can be produced out of the cellular or solid concrete and take different forms and dimensions (DIN EN 771-3).

The main assumptions related to the physical actions are given as follows:

➔ Capillary rise reach in a concrete wall is usually not higher that 50 cm and is set to 10 cm for all flood conditions.

➔ Drying of solid concrete walls is estimated to 20 days in average

➔ Drying of cellular concrete walls utilising airing (Problem of overhumidity of walls made of cellular concrete, gypsum or if they are multilayer with soakable thermal insulation materials, such as crylamine, mineral wool or organic fill. It adds to problems not only with drying of walls but also to partial loss of strength, load-carrying capacity and thermal insulation properties (Hola et al, 1998).

➔ In general case, non-plastered buildings dry out faster (Bodzak J et al., 1998).

The main assumptions related to the chemical actions are given as follows:

➔ This process can take up to 10 years and for the scope of the work and definition of concrete damaging functions will not be considered.

The main assumptions related to the biological actions are given as follows:

➔ Products of metabolism of microorganisms have usually acidic pH. Those products in contact with components of cellular concrete, such as silicates and carbonates are neutralised and mineralised. It leads to the conclusion that despite its porosity, cellular concrete does not constitute a good basis for growth of bacteria and fungi (Bodzak et al, 1999). In case that wall elements exceed the critical moisture content, the materials that are biodegradable should be avoided such as ingrain wallpapers.

(4) Timber:

Timber as a construction material is widely in use and can take different forms the main ones being (Rongen& Hestermann, 2010):

- Timber framed structures (including the lime silicate boards insulation and loam infill masonry)
- Timber modules
  - Massive timber walls
  - Wooden boards
  - Wooden block boards
  - Wooden frames

The main assumptions related to the physical actions are given as follows:

➔ Flooded wooden partition walls, are considered to be deformed and have to be replaced. Long lasting overhumidity of wood, timber-like and other organic materials favours growth of fungi, mould and bacteria (Nowak et al., 1998).

➔ Timber will be damaged due to presence of moulds and (if their moisture content is higher that 20% for longer period of time (Garvin et al., 2003).

The main assumptions related to the biological actions are given as follows:

➔ Decay of timber wall components can start if their moisture content is higher that 20% for longer period of time (Garvin et al., 2003). Similar conditions are also favourable for fungi growth: mass humidity 20-25%, temperature 18 – 35°C and presence of air (Matkowski et al., 1998). Wood as organic material can be utilized by fungi as source of nutrients. In many cases the extent of damage of timber finishes depends on the method of fixing them. Finishes made of fibreboard can be deformed significantly due to overhumidity. The timber frame within the wall is unlikely to be negatively affected by floodwater if it dries out during few weeks. The longer the timber remains wet, the great the risk of decay.

(5) Prefabricated elements

Prefabricated wall modular elements are assembled in a factory and transported as a complete assembly to the construction site where they are placed in. The main types are given as: (Rongen& Hestermann, 2010).

- Prefabricated boards
  - Cellular and lightweight concrete boards (non and load bearing walls)
  - Reinforced concrete elements (load bearing walls)
  - Reinforced concrete facade elements
  - Metal walls with thermal insulation (non load bearing walls)
- Walls as a part of the skeleton frame
- Timber modules (presented in section (4) Timber)

In terms of their performance in relation to the potential damage, it is discussed within the (1)-(4) wall types based on the materials characteristics of the given types.

Additionally it is to mention that non load bearing walls or partition walls can be built out of different materials the main ones being:

- Brickwork
- Lime sand stone
- Concrete
- Gypsum boards
- Glass elements

In terms of their characteristics when exposed to flood water, the main assumptions have been presented in (1)-(4). Additionally it is assumed that the gypsum boards will be damaged and have to be replaced.

Insulation

Insulation is a part of the wall base with the role to prevent heat transfer between the building interior and the environment. Insulation used as a building element is made of mineral wool, Styrofoam, polyethylene or insulation composite system (ETICS). It can be either in loose form or as boards. Mineral wool is usually used in the form of thermal insulation boards. Insulation has lower rate of heat conductivity if exposed to floods than for example cellular concrete (Figure 9-5) Although insulation is a part of the wallbase, here it is analysed separately emphasising some of its main characteristics decisive for the damage assessment of a wall element.

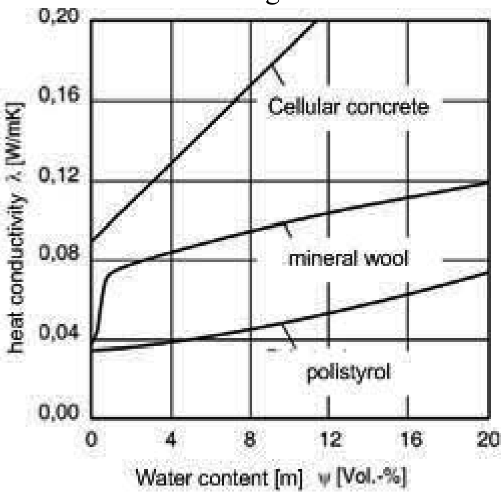


Figure 9-10 left: heat conductivity of wall materials as a function of the moisture content (source: unknown)

The main assumptions related to the physical actions are given as follows:

➔ Loose fill insulation and wools is considered to be effected by water. They may slump in wall cavities after becoming wet. Even small amount of water may affect the insulation properties.

➔ Closed cells plastics types of insulation are unlike to be affected by a flood event (Garvin et al., 2003). Damage of insulation materials in walls depends on the type of the material. Polyurethane foam of Styrofoam can be used further after drying out. Mineral wool after being flooded changes its structure and physical properties and needs to be replaced (Nowak et al., 1998). High water pressure causes materials with high absorbability, such as mineral wool, fibreboard, gypsum or cellular concrete to soak quickly.

➔ The thermal performance of some materials used for insulation may be reduced after being saturated with floodwater, especially lightweight blown-in materials .

➔ Hydrophobised insulation elements are not subjected to any structural damage (such as Garvin et al., 2013)

As is all cases (but from encapsulated, hydrophobised insulation element which are not damaged by water) in case they are exposed to flood water, the insulation is to be replaced, the chemical and biological actions will not be discussed.

Wall face:

As wall face different materials can be used, which characteristics mainly depend on the their location (outside or inside).

For the outside walls facing, the following materials are used:

- Rendered without rear ventilation (nowadays not often used, (Rongen& Hestermann, 2010))
- Rendered with rear ventilation facade including the following materials and elements:
  - Plaster (gypsum plaster, mineral plaster i.e. lime and cement, hydraulic lime)
  - Boards (gypsum boards, gypsum plasterboards)
  - Mortar

Mortar

The mortar is a paste used to bind construction blocks and the gaps between them It consists of the binding material [cement or lime], aggregate [grain size max. 4 mm], water, chemical admixtures) and the mortar mix formula (e.g. w/c-ratio)˙. It is used to fix the wall coverings (such as tiles). Depending on the mortar mixture the bed joints between brick blocks can temporarily act as a horizontal barrier layer.

➔ In a wall element the cracks can be generated by plastic shrinkage of the used mortar mix in an early stage, which allows flood water penetration. Cracking generated by plastic shrinkage of the mortar is caused by an increasing capillary tension whilst drying. The result is a decrease in volume as an irreversible shrinkage deformation. (Golz, 2012).

➔ Mortar is more permeable than a brick and the flood water can quickly saturate a mortar joint and through the pressure of a flood form a moisture pathway. Bricks will also absorb water and under the pressure of flood water may saturate and allow water to pass through them. But this will normally take longer than through mortar (Garvin et al., 2005).

Plasters

➔ Internal plasters, which are usually lime or cement-lime, get muddy and contaminated with bacteria. In some spots efflorescence occurs.

➔ Deformed elements should be exchanged; the rest, after drying, treated with fungicides and disinfectants.

➔ External plasters crack in a characteristic way if they are put on cellular concrete walls. It is caused by the difference of contraction deformation of cellular concrete blocks and cement-lime plaster, which occur during drying out process (Nowak et al., 1998).

Gypsum plaster

➔ Gypsum plaster may be damaged after relatively short flood event. It has to be removed from the wall face after the flood event to allow the underlying masonry to dry out (Garvin et al., 2003). This is usually carried out disregarding the plaster’s condition in order to allow the masonry beneath to dry out.

➔ Gypsum plasters, in form of gypsum plasterboard, soak very much and are contaminated with bacteria and fungi significantly.

Lime based plaster

➔ Lime based plasters have good water resistance properties and if they are applied over a water resistant render, such as sand/cement or proprietary sealant, they should provide effective resistance to flooding, especially in comparison with gypsum plasters.

➔ The water-resistant render beneath the plaster reduces water penetration into the underlying masonry. Therefore the wall can dry out more quickly and there is no need to remove the plaster finishes (Garvin et al., 2003).

Hydraulic lime

➔ Hydraulic lime finishes with water resisting additives can provide flood resistance for masonry walls. They can be used both internally and externally. They also allow walls to dry out without the need for replacement after flooding. (Garvin et al., 2003).

Plasterboard

Plasterboards are often used for solid masonry walls and cavity walls. It can be also used for timber-framed walls.

➔ They have very low flood resistance and usually have to be replaced after a flood event. They can be replaced with more water resisting liners, such as lime based plaster, ceramic tiles or hydraulic lime coating.
➔ If used for timber walls, after a flood event it needs to be removed to enhance the timber frame to dry out.
➔ Except this, plasterboard sheets usually become damaged after being exposed to floodwater. However, replacing plasterboard with water resistant timber sheeting will not be of much benefit, because it still will need to be removed after a flood event.
➔ Fixings with which plasterboard is attached to a wall if made of galvanised or stainless steel in order to avoid rust and staining of wall surfaces (Garvin et al., 2003).

Others

➔ Cement or lime based renders may detach, especially after exposure to frost or rapid drying out soon after the flood (Garvin et al., 2003).
➔ A concrete screed should be minimum 65 mm thick to provide a more flood resistant surface. If it is properly installed, there should be no need to replace it after a flood event.

Paint coating

➔ Painted walls will need to be redecorated after a flood event.
➔ In case low permeability lime based paints are used, the walls will dry out faster after flooding than in the case of oil based paints or emulsions will allow
➔ Paint coatings on walls and ceilings, which were in contact with water can muddy, contaminated with bacteria and washed out. It concerns especially lime paints and distempers.
➔ Coatings of oil colours and synthetic paints on wet wall plasters can disjoint and crack as a result of drying out of plasters.
➔ Water resistant paintings prevent floodwater soaking into the external wall, what in consequence shortens time required for the wall to dry out.
➔ Coatings applied on the external linings should prevent water penetration into underlying layers. On the other hand, they should not hinder water transport from the inside of the wall so that there is no formation on condensing zones in the wall (Cerni et al., 1996).

Coating-lining systems

➔ Water-repellent coatings have good hydrophobic properties and keep a relatively high permeability for water vapour, what is desirable for the external surfaces of the building. One of the reasons of application of water-proof coatings on lining materials is to increase their durability, as long-term presence of water in majority of building materials can damage their structure and influence adversely their thermophysical properties.
➔ The resistance of the plaster material to mechanical influences is better than that of water repellents (Cerni et al., 1996).

Wallpapers

➔ After being flooded, wall papers are damaged to different extents. Usually the damage is partial, but because of getting muddy or contaminated with bacteria they should be changed completely.

<u>Ceramic tiles</u>

➔ They can provide a water-resistant surface and can reduce the amount of floodwater penetrating through masonry.

➔ Although ceramic tiles have high resistance to floodwater, they form hindrance to water evaporation from walls. Therefore, if they are on both sides of the wall, capillary raise goes higher and drying out occurs above tiles (Nowak et al., 1998). That leads to significantly slower drying out (what increases the risk of mould and fungi development in case of present wooden elements) and also to anaesthetic.

➔ If applied on a suspended floors as they have to be removed after flooding to let access the sub-floor voids.

<u>Wood</u>

➔ In case a wall is covered by wood panels, they are to be removed due to their high susceptibility to flood water.

<u>Bituminous coating:</u>

It is a brownish-black solid or semisolid mixture of bitumen obtained from native deposits or as a petroleum by-product.

➔ They give an almost impervious surface coating, so they should be used only on walls where there is no risk of indirect penetration of moisture through parapets, sill, etc (Garvin et al., 2003). Polymerbitumen appears to have better resistance to thermal distortion, aging characteristics and better flexibility than bitumen

2. Floors

The flooring material is the main criteria for assessing the vulnerability and impact (damage). It is given as following:

Floor base (including insulation):

➔ In case of timber suspended floors, the floor cover can get damaged as well as its structure, including rot and warping. Also the timber boarding and decking can be damaged. Additional problem with suspended floors is that water can collect in the sub-floor voids and in order to remove it, the floor cover has to be taken off (Garvin et al., 2003).

➔ In the case of timber suspended floors, all elements being floor covering, pavement and base are replaced.

➔ Solid concrete floor is considered to provide better seal against water rising up through the floor than suspended floor construction. If they have damp proof membranes, they can be regarded as the most flood resistant floor type as they can reduce the rate of seepage into the building. As the ingress of water is likely to occur at the floor/wall joint, there should be connection between the damp proof membrane and the damp proof course in the wall. Floors with the damp proof membrane between the surface screed and the concrete slab dry out faster than floors with the damp proof membrane below the concrete slab.

➔ Solid concrete floor base does not have to be replaced in case of a flood event. It is returned to the initial state by drying and cleaning. Drying time is estimated to 2-3 weeks depending on the duration of flood (Zimmerman, 2006).

➔ Suspended concrete floors are especially vulnerable to damages to sand or cement screed as well as to damage of insulation. This problem is particularly relevant in case of floating floors (Garvin, 2004).

➔ In case that suspended concrete floors are exposed to flood, they are replaced together with the covering and pavement.

➔ Wooden floors have low resistance to floodwater because they swell up easily. They usually get disjointed from the base and deformed (Nowak et al., 1998).

- ➔ In case that suspended concrete floors are exposed to flood, they are replaced together with the covering and pavement.
- ➔ Floors made of loam are considered to be susceptible to flood water irrespectively of the water depth and duration
- ➔ All floors and ceilings made of masonry behave similar to walls and hat to be dried after a flood event
- ➔ Concrete beams within suspended concrete floor contain reinforcement which can corrode in case of high content of chloride in floodwater.
- ➔ Timber floor are consider to shrink or swell after being exposed to a flood event and wood is not stable after is has been exposed to flooding (Golz, 2012)
- ➔ In concrete floors, cement screed has an effect on the system behaviour, because water can reach between the construction layers via the wall/floor junction and consequently destroy the mineral fibre insulation The 14 cm thick concrete floor slab absorbs a considerable amount of water (with the degree of saturation of approximately 80% (Golz, 2012), which indicated the drying times of several weeks.

Floor pavement and covering:
For the main floor covering are listed in , the following assumptions are made:

- ➔ Carpets will be considered as completely damaged and need to be replaced after the flood as they usually get muddy and contaminated with bacteria (Garvin et al., 2003, Nowak, 1998).
- ➔ Linoleum is a floor covering made from solidified linseed oil (linoxyn) in combination with wood flour or cork dust over a burlap or canvas backing.
- ➔ The granulated thermal (and sound) insulation is considered as highly susceptible to flood water and becomes saturated after a flood event (Golz, 2012).

3. Staircases

The following assumptions have been made for definition of damaging functions:

- ➔ Material
- ➔ If one step is damaged, the whole staircase element will be refurbished/ replaced for the aesthetic functions
- ➔ Staircases of the same composition as the flooring element

4. Openings

The following assumptions have been taken when defining the damaging functions based on the physical processes as previously described and on the previous experiences and literature.

In general, the vulnerability of the opening elements depends on the susceptibility to the main flood factors of the base material but also on the connections between the opening item and adjacent building elements.

Wood:

- ➔ Massive wood doors and windows are likely to be only slightly affected by flooding, but some distortion often occurs and refitting is usually necessary. It can be minimized by ensuring that all faces of the timber including the bottom face, are effectively sealed using either and oil-based or waterproof stain or paint (Garvin et al., 2005).
- ➔ After drying wooden windows affected by flood waters are deformed and leaky. Paint coatings usually are spalling off. Chipboard doors, e.g. to basement are also deformed after drying and if earlier they were exposed to humidity and fungi, the process of fungi development becomes intensified. In case of steel windows and doors, paint coating is spalling off as well and in those places surface corrosion occurs (Nowak et al., 1998).

➔ Generally massive doors and frames are more flood resistant than hollow types which can be filled up with flood water, which can be later difficult to remove. Hollow timber doors will often delaminate after the exposure to flood water.

Synthetic material:
➔ If exposed to a flood event v<2m/s the plastic openings are not functionally damaged. The damage assessed is related to drying and cleaning of the affecting elements
➔ In case the openings are exposed to a flood event v>2m/s, the elements are considered to be deformed and need to be replaced.

Glazing:
➔ Glass breakage can happen if water pressure increases significantly on the window. Especially at risk would be single glazed windows with annealed glass. Double-glazing units with toughed glass should be more resistant to breakage (Garvin et al., 2003).

➔ In case of organic contamination, all elements are to be replaced.

5. Building services

The main assumptions have been made as follows:
➔ Pipes are not likely to be impaired (Penning Rowsell, 2004)
➔ Flood to the depth of 1,2m will not affect the sanitary fittings.
➔ Boilers that are reached by floodwater, they are considered to be destroyed.
➔ Damage to the electrical wiring is considered to be total if the water reaches the lowest socket/fuse. In the case of the level base cut-out, the renewal of the electricity network and fittings applies only to the building levels affected by flooding.
➔ If not properly anchored, the oil tanks detach from the building elements if the flood water exceeds the height of the tank. It is more likely to happen with the plastic tank. In the real case, this process is a buoyancy process as described in the section dealing with the physical processes. It means that the forces acting on the tank have to be related to its weight.
➔ Storage heaters and gas furnaces are considered to be destroyed after being exposed to the flood water.
➔ If the lowest point of the telecommunication network has been reached by the floodwater, it has to be renewed. Here it is to mention that those renewals works usually imply the works at the building fabric (repainting, plaster works), but they are not explicitly considered when assessing this damage. As the walls and floors are in that case also affected by the floodwater, this damage has already been included in the assessment of the walls and floors.

6. Inventory

The main assumptions have been made as follows:

Type (1):
➔ If the hkrit is applicable to a piece of inventory, such as in the case of the electrical appliances (e.g. washing and drying machine, stove), damage reaches its full extent (100% or the purchasing price of the element) when this water depth is reached, independently of the other flood factors (e.g. Penning Rowsell, 2004). For the heights less than hkrit, damage curve has a low slope (depending on the element) i.e. increases gradually, which includes damage for cleaning and drying.
➔ The furniture items such as sofa or bed are made of wood or wood and canvas develop a damage behaviour that indicates a h_{krit} at the level of the lying surface.
➔ The furniture items such as built in closets, or wardrobe have evenly distributed damage up to the level where the clothes is stored. Then the damage is increasing to the 50% of the value as the assumption is made that not all the items are destroyed. In the case of the semiotic functions, this damage increases to the full amount of the replacement costs.

Type (2):

➔ If hkrit is not relevant damage starts at the elevation level of the inventory item and gradually increases.

➔ If h_{krit} is applicable such as in the case of electrical appliances that are stored at a certain distance from the floor, full damage occurs at that level. In general a height of 1m has been taken as an assumption as an average height of the kitchen floor elements.

Type (3):

➔ If the hkrit is given (such as tables, chairs) damage slowly increases to the level of hkrit where it reaches its full extent.

For all inventory elements a price range has been defined (low, medium, high) giving the possibility to distinguish qualities of the items available and better differentiate the damage.

Appendix 3.4- A list of the measures and the associated costs (the summary of the main items) (source: survey conducted within the FP7 project SMARTEST, personal communication with the manufacturers, online survey)

List of measures (summary)	Unit cost range		Unit
(costs are based on the market values collectected in Oct 2008, revised January 2010 and 2013)	[EUR]		
Application of polymer bituminous seal (Schwarze Wanne)	300	500	m'
Application of water proof concrete (Weiße Wanne)	500	1000	m2
Vertical sealing of walls	150	300	m2
Horizontal sealing of walls (depending on the method)	250	600	m2
Protection of openings with demountable elements*)	700	2000	item
Protection from back water (non return valves)	500	1000	item
Shielding of the building*)	500	1000	m'
Wetproofing of walls (exterior- inside, outside face, interior, partition)	100	200	m2
Wetproofing of floors	35	100	m2
Wetproofing of ceiling	35	100	m2
Wetproofing of staircases	35	100	m2
Encapsulation of wiring	100	300	m'
Anchoring of oil tank	500	1000	item
Removal of inventory	-	-	-
Elevating the sockets/fuse box above expected flood level	1000	3000	all
Pump and a sump	500	2000	item
give up the object after flooding	-	-	-
give up the object after flooding after stability proof	-	-	-
do nothing- no necessity for changes	0	0	

*) Protection of the openings with the demountable elements (examples), full list is available at

http://floreto.wb.tu-harburg.de/loginlogout (password protected)

Doors			
1500 mm x 1200 mm *(RS Stapenek OHG)*	1200	1500	Item
1100 mm x 1200 mm *(RS Stapenek OHG)*	1300	1500	Item
800 mm x 600 mm *(IBS)*	1000	1200	Item
Windows			
800 mm x 600 mm *(RS Stapenek OHG)*	700	1000	Item
Floodproof windows (pressure resistant)			
800 mm x 600 mm *or 800mm x 400mm (FEHRMANN)*	300	1000	Item

TUBES- AIR FILLED			
NOAQ-TW (Tubewall)			
Dimensions	Model	Costs	
100 m X 1 m	10-NOAQ Tubewall TW50 x 10m	24,700 ₤	
	10-NOAQ Tubewall TW75 x 10m	26,200 ₤	
	10-NOAQ Tubewall TW100 x 10m	31,800 ₤	
TUBES- WATER FILLED			
		Costs	
Aquadam		None given	
Dimensions: 100 m x 1 m			
		Costs	
Tiger Dams		29,202 ₤	
Dimensions: 100 m x 1 m			
CONTAINERS- PERMEABLE			
Hesco Bastian Container		Costs	Unit
Dimensions: 100 m x 1 m		3,896 ₤	for units only
Harbeck Big Bag		Costs	
Dimensions: 100 m x 1 m	Up to .75 m	4.380,00 €	
	Up to 1.5 m	12.900,00 €	
	Up to 2.25 m	25.800,00 €	
Sandbags	Type	Costs	Unit
Dimensions: 100 m x 1 m	1m height Hessian bags	21,000 ₤	22,400 bags, for 100 m length and 1 m height
	1m height Hessian sandless bags	115,600 ₤	22,400 bags, for 100 m length and 1 m height
	Aqua-Sac	112,000 ₤	22,400 bags, for 100 m length and 1 m height
	FloodSax	145,600 ₤	22,400 bags, for 100 m length and 1 m height
CONTAINERS- IMPERMEABLE			
		Costs	Dimensions
Aqua-Levee		33,4200 ₤	30.4 m length and 1.2 m height
		100,260 ₤	91.2 m length and 1.2 m height
Floodstop (Modular Flood Barrier)		Costs	Dimensions
		15,000 ₤	100 m length and .5 m height
		35,000 ₤	100 m length and .9 m height
MRP Modular Shielding		Costs	Dimensions
		40,000 ₤	100 m length and .75 m height
FREESTANDING BARRIERS- FLEXIBLE			
Alteau Barrier		Costs	Dimensions

	18,700 £ + VAT and delivery	100 m length and .5 m height
	20,000 £ + VAT and delivery	100 m length and .7 m height
	35,000 £ + VAT and delivery	100 m length and .1.2 m height
Rapidam	Costs	Dimensions
	35,000 £ - 60,000 £	100 m long x 1 m high excluding resources
Watergate	Costs	Dimensions
	18,750 £	100 m long x 1 m high excluding resources
FREESTANDING BARRIERS- RIGID		
	Costs	Dimensions
Aquafence	475 £ pro meter	100 m long x 1 m high excluding resources
Aquabarrier	Costs	Unit
	1,000,000 £	All surface equipment for 1.5 m high system
FRAME BARRIERS- FLEXIBLE		
	Costs	
Portadam	Quoted on a job-to-job basis	
Geodesign Barrier	Costs	Dimensions
	29,800 - 52,300 £	100 m x 1.25 m
FRAME BARRIERS- RIGID		
IBS K system	Costs	
	Varies	
Mobile Flood Protection System	Costs	Dimensions
	12,000 £	100 m x .8m
	20,000 £	100 m x 1.2 m
Caro Waterwall & Waterdoor Flood Protection Products	Costs	Dimensions
	40,000 £	100 m x 1 m
Coplastix Stop Logs	Costs	
	Site specific	
DPS 2000 Hochwasserschutz	Costs	Dimensions
	60.000 €	100 m long x 1 m high excluding resources
Flood Ark	Costs	Dimensions
	120,000 £	100 m long x 1 m
IBS Mobile Wall Flood Protection System	Costs	Dimensions
	90,175 £	100 m long x 1.05 m
L Series Modular Demountable Flood Barrier System	Costs	Dimensions
	55,000 - 70,000 £	100 m long x 1 m
SECTIONAL BARRIERS- MANUAL		
Dutchdam	Costs	Dimensions
	602 £	1 m section
	60,200 £	100 m long x 1 m
Tilt Dam / Spring Dam	Costs	Flood Height
	£150.000	.6 m
	£170.000	.8 m
	£190.000	1 m
	£270.000	1.8 m

		£290.000	2 m
SECTIONAL BARRIER- AUTOMATIC			
Self Closing Flood Barrier (SCFB)		Costs	Dimensions
		2150 £ per meter	.5 m high
		2580 £ per meter	1 m high
		5160 £ per meter	2.5 m high
FLOOD GATES- MANUAL			
Lift Hinge Flood Gates		Costs	Dimensions
		£21.000	100 m long x 1 m high
FLOOD GATES- AUTOMATIC OR MANUAL			
Hydraulic Fill Up Barrier		Costs	Dimensions
		£50.000	100 m long x 1 m high
Pivot Barrier	Type	Costs	Dimensions
	Automatic	£17.000	5 m long x .6 m high
	Manual	£5.500	5 m long x .6 m high

Appendix 4.1 Development of FLORETO applying the V model

The V model has been applied to implement the decision support tool for the resilient built environment as given in Figure 4-1 in chapter 4.
Here, the individual steps of the design process are explained in more detail.

1. Requirements:

The requirements on software are defined in terms of the application domain, targeted users, their tasks and the environment within which the system will be used (Stone et al., 2005). For the development of FLORETO they are given as follows:

1) Application domain

The application domain of the tool is flood resilient planning of the single properties as described in section 3.3.

2) Targeted user group(s)

This tool primarily targets dwellers and should be tailored to their interests and their role in UFM (primary users). However, as introduced in section 3.3.3.3, the experts should give their feedback on the resilient plans within the feedback loops and as such should be considered as users. Also, the expert coordinators and general public are considered as secondary users. A summary is given in Figure 9-11.

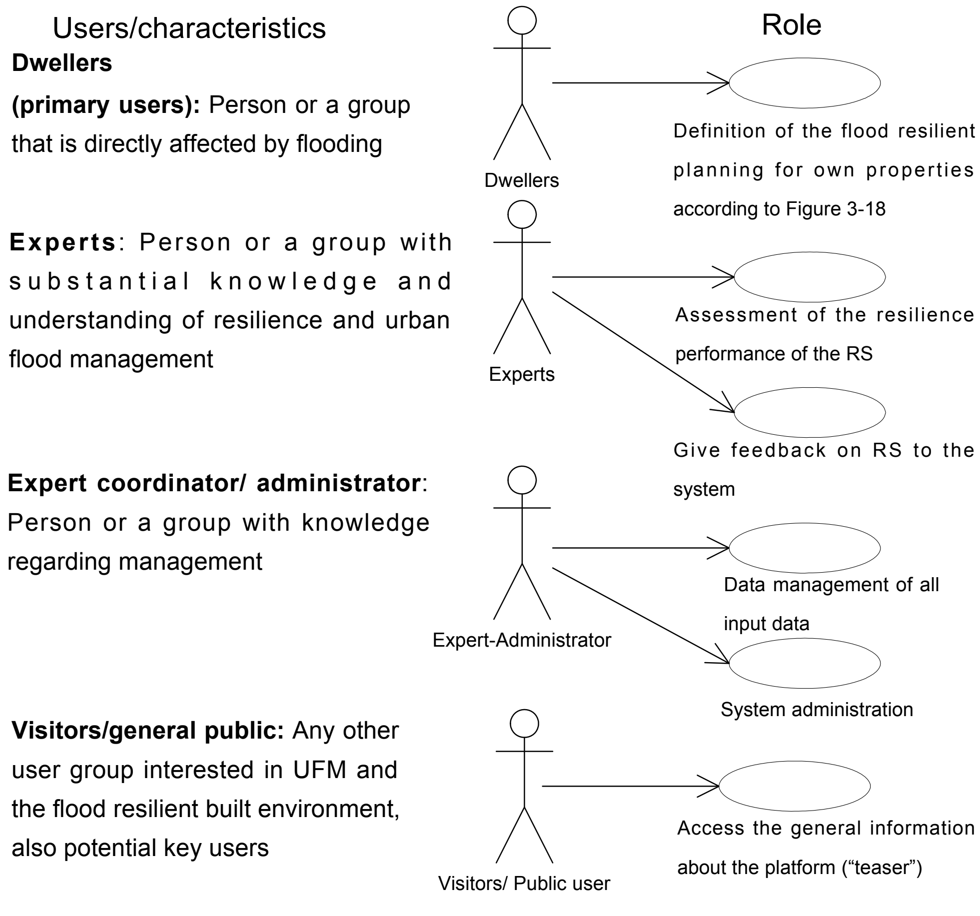


Figure 9-11 A UML Diagram depicting the user groups and their roles

3) Task analysis

Within this step it has been analysed what functionality the computer system must provide for supporting users in their tasks (Stone et al., 2005). In that context, user requirements are defined as [high-level abstract requirements describing the services the system should provide and constraints under which it must operate. System requirements set out the system's function, services and operational constraints in detail] (Sommerville, 2007).

The tool primarily supports dwellers to perform resilient planning at the property scale and it should follow the decision making chart as given in Figure 3-18. The single steps and the corresponding workflows are explained in section of Analysis.

The other targeted users as given in Figure 9-11 have an auxiliary/secondary role so that their role does not influence the content, but will have an impact on the design aspects. Apart from delivering the basis for the decision making, the tool should have a logical link to capacity building as introduced in the theoretical model and given in Table 3-47.

The assessment of the expectations of the key users and their requirements on such a tool has been performed interactively through discussions and feedback rounds with the users performing the acceptance test (Figure 4-1 of chapter 4). For the test dwellers from the catchments in Hamburg have been considered. This assessment was a part of the interactive learning program (ILP) in the Kollau catchment, Hamburg as given in section 5.1.3. Additionally, separate dialogues with the selected experts and students have been conducted to capture their main requirements (in total 10). The main outcomes of these assessments indicated the following expectations of such a tool:

Dwellers:

- The tool should be intuitive and easy for handling, if possible visualising the elements.
- The walkthrough should be straight forward with clear and precise instructions, i.e. the user should be guided through the workflow
- Clear and crisp definition of the key terms with the additional possibility to access this information without losing focus
- The tool should deliver a quick and reliable response
- Time is important. The whole procedure should not take longer than 30 minutes
- The tool should be easily accessible and free of charge
- The platform should be available in the native language of the users

Experts:

- The system should include an interactive option that enables feedback, which can be fed directly in the system

2. Analysis

Within the analysis phase, the workflow of the decision making process and the typical use cases have been identified.

The overall workflow of the resilient planning for the built environment is presented in Figure 3-15. The single tasks to be performed can be summarised in the three main groups being pre-processing, processing and post processing.

Pre-processing encompasses all activities related to the data collection: flood parameters and the system/ property (I-1, I-2, see Figure 3-15). Whereby the property data are to be entered by the user, the flood parameters are either entered by a user or imported from the flood probability assessment procedures and models as introduced in section 3.3.1.1. In case they are imported, it is to be checked whether they are available for the selected area. In case they are entered by a user, the plausibility of the results can be questioned, which is to be considered for further processing. A detailed workflow is given in Appendix 6a.

Processing includes the activities of the risk assessment phase (I-2, I-3, I-4) and resilient planning for the built environment, being II-1, II-2, II-3, II-4 and referring to the workflow depicted in Figure 3-15. In detail, the processing looks as depicted in Appendix 4.2

Post-processing includes the activities related to the assessment of the resilient performance and the collection of the users' feedback following the inner and the outer feedback loop as given in Figure 3-15 and described in section 3.3.3.3. This phase terminates with the storage and final management of data and results. The workflow is enclosed in Appendix 4.2

3. Design

The requirements for the software assessed in step 1 have to be implemented into the design of the tool. As the tool has to support the decision making process and at the same time enable the integration of the capacity building activities related to the e learning as given in section 3.4.3, the optimal integration can be achieved by having a joint platform for both activities. It gives a corporate identity and better overview of all required knowledge and activities required as well as enabling their better integration and interaction as well as a systematic application of learning modules for corresponding tasks in the decision making workflow. The web based platform - *Flood Resilience Portal* (http://floreto.wb.tu-harburg.de) as shown in Figure 4-2 in Chapter 4 has been designed encompassing both main aspects:

- decision support through the FLORETO Tool
- capacity building by integrating the self-learning module (FLORETO-*Inform*) and participants portal of the ILP[194]

The platform, as well as its modules are designed to be multilingual. For the scope of the case studies within this work the users are enabled to choose between the English and German languages.

The flood resilience portal is mainly based on the open source content management system (CMS) TYPO3[195], which has been adapted for the purposes of the logical structure and required functionalities. Apart from being open source, TYPO3, as a content management system, has considerable advantages qualifying it for application in the Flood Resilience Portal, the main ones being:

- The systems created by TYPO3 are easily accessible (URL, via Internet), which is especially important for private stakeholders
- It enables easy integration of different modules required for decision making and capacity building of stakeholders. Single modules can be easily exchanged without changing the whole system.
- The system is easy to administrate via a so called backend user interface which can also be accessed via internet.

As such a TYPO3 based platform is considered to be a good basis for integrative and modular application of both the FLORETO and ILP tools.

4. Coding

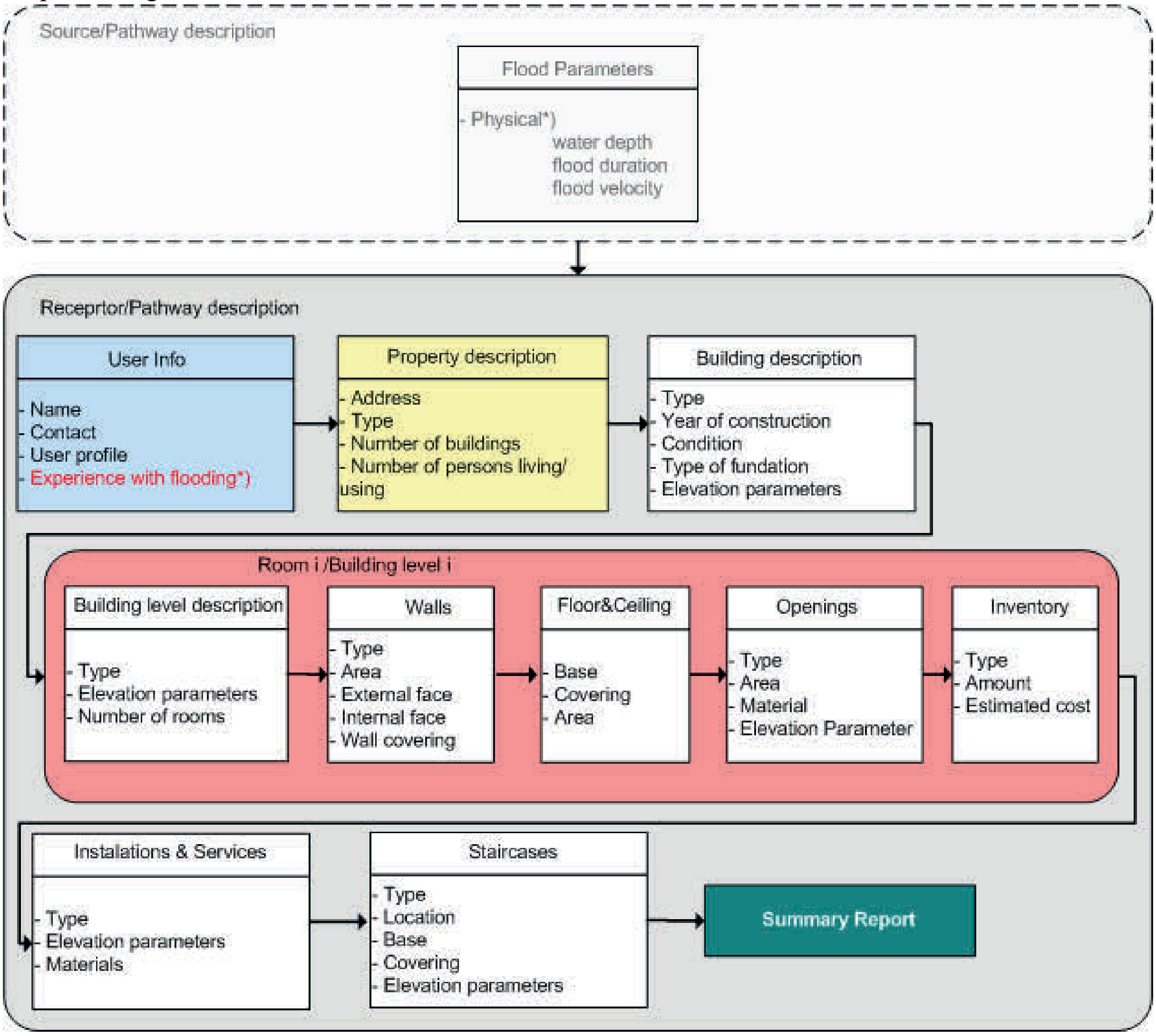
Coding (programming) part of the implementation has been beyond the scope of the work. This activity has been performed at the Institute of River& Coastal Engineering, TUHH in a close cooperation with the author of this Thesis within the projects: RIMAX-UFM (http://ufm-hamburg.wb.tu-harburg.de/), SMARTeST (http://www.floodresilience.eu/), FLOWS (http://www.northsearegion.eu/iiib/), and KLIMZUG-Nord (http://klimzug-nord.de/). A summary of the main technological features is given in the Appendix 4.3.

[194] The implementation of those tools is explained in section 4.3

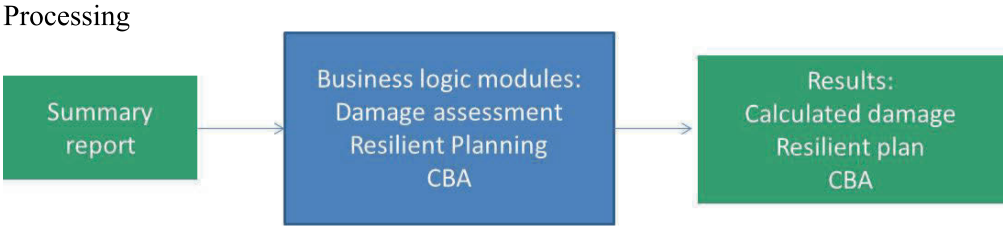
[195] http://typo3.org

Appendix 4.2 – FLORETO Workflow

Preprocessing:



Processing



Postprocessing

Appendix 4.3 – A summary of the main technological features of the FLORETO tiers

GUI

The user interface should enable users to accomplish all assigned activities of the workflow presented in Appendix 4-2.

The requirements for the tool given in section are considered for the development of the UI. For the design of the UI, the main design principles196 (Stone et al., 2005) have been considered as a guideline as given in Table 9-5.

Table 9-5 General design principles for UI (Stone et al., 2005) and Nielsen& Molich* (1990)

Nr	Principle	Description
1	Visibility	First step to goal should be clear
2	Affordance	Control suggests how to use it
3	Feedback	Should be clear what happened or is happening
4	Simplicity	As simple as possible and task-focused
5	Structure	Content organized sensibly
6	Consistency	Similarity for predictability
7	Tolerance	Prevent errors, help recovery
8	Matching *)	Match between system and real world*)

The focus of this work has been the implementation of the specific functional requirements (e.g. data collection of building elements). Those aspects will be given when discussing the different UI required by FLORETO. As FLORETO UI deals with a large amount of data which can easily be graphically visualised, a graphical user interface (GUI) has been considered for the design. It also coincides with the requirement and expectations of the primary users. Referring to the requirements on data management given in section s.s.4, the following activities should be enabled by a UI:

1) Data collection

The data collection module implements the workflow given in Appendix 6a. In the workflow, the data to be collected are grouped into units that correspond to the description of different building elements. Analysing the type of data given in Appendix 6a and following the *structure* principle (Table 1), it can be noticed that some of the parameters are to be defined in a plan view (e.g. number of rooms, type of flooring and ceiling), but some of the parameters have an elevation aspect and the vertical cross sections are more convenient for their collection (e.g. lowest sewerage point or room height). The property description (number and type of buildings) is not related to any building cross-section and as such needs a different layout. Also, the user description should be collected which implies collection of the textual data. Consequently, the four main scene layouts for collecting required data have been defined as given in Table 9-6.

Table 9-6 Scene layouts considered for the FLORETO GUI for data collection

Nr	Scene layout	Description
1	Scene layout 1	The view for the property description. Here the building type and the adjoining elements are to be selected.
2	Scene layout 2	The view for description of the building levels (basement and above ground

[196] There is a significant body of literature addressing user interface and web design (e.g. Stone et al., 2005, Shneiderman and Plaisant ,2009, Apple Computer, 2009; Microsoft Corporation, 2009). Still, design principles related to the complex browser based applications, which should fulfil both application and website requirements (such as FLORETO) with high interaction with the users and considering the available technology are rather scarce.

		floors as given in **Figure 4-5**. Here, a plan view of a building element is used to collect the required data, being walls, floors, ceilings and openings, and the data are defined.
3	Scene layout 3	The view for description of the services, staircases and installations (shown in Figure 4-7b). Here a vertical building cross section is used to collect the required data
4	Scene layout 4	The view for collecting the user description (textual) data (name, age, etc) as shown in Figure 4-6a.

The main issue to be solved by a graphical user interface for data collection is how to describe the building elements with a sufficient level of detail but without overlapping as required by the models of the business logic (damage assessment, data mining, cost-benefit), which at the same time can be easily performed by non-experts. Can a non-expert describe a property with the required level of detail and what would be the right graphical representation of the required building elements supporting this data collection? The design process of GUI has been performed in a iterative[197] manner with the two main steps being:

- o ***Demo model*** that was used for gaining experience and preliminary feedback from the key users during the acceptance testing of the demo version. The procedure and results are given in Chapter 5.
- o ***Final model,*** improved version of the demo model, which is then fully implemented into the FLORETO application and embedded into the Flood Resilience Portal

Within this chapter, only the final model has been presented. A description of the demo version is available at http://floreto.wb.tu-harburg.de (password protected).

Final model

The main design aspects of the final tool that were mainly subjected to the acceptance test are summarised in Figure 4-1 of Chapter 4.

Table 9-7 Testing aspects and the corresponding design principles

Nr	Design aspects	Design Principle considered
(a)	Clarity of the workflow	*consistency, visibility* and *simplicity* principle
(b)	Configuration of a building level i.e. rooms distribution	*structure* and *consistency, matching* principle
(c)	Definition of different layers and sub elements of the building parts and additional data	*structure* and *simplicity, matching* principles
(d)	Users' actions such as *drag&drop*, *type the value* or *select from a popup menu*	*tolerance, simplicity, feedback* principles

(a) Clarity of the workflow:

The overall model has been designed as a sequenced thread following the workflow depicted in Appendix 6a, whereby each step in the workflow represents one step in the user interface. The final model implements all four main scene layouts for the data collection and fully implements the workflow as given in Appendix 4.2. Through the *Navigation bar* the user can go back and forth throughout the workflow as shown in Figure 1. The *Info& help bar* has been extended to a crisp and concise online help regarding the actions to be taken in the *drawing panel* or *active view.* The main implementation features are given as:

- starting the workflow with the user's login and creating individual profiles as shown in with the users' data

[197] Making design process iterative is a way of ensuring that users can get involved in design and that different kinds of knowledge and expertise can be brought into play as needed (Stone et al., 2005)

- enabling import of the flood parameters from the external files or the web coverage server
- enabling the input of the spatial data (address and consequently the coordinates of the object) utilising the GoogleMaps API[198].
- including online help, describing the single steps and the key terms

(b) Configuration of a building level, i.e. rooms distribution

The final model fully implements the topology of the building elements, enabling entering of the "real" rooms. This aspect follows the *matching* design principle as given in Table 1. The procedure can be appreciated in Figure 1, which depicts the implementation of the scene layout (2). The user can configure the building level by *drawing* the configuration in the *Drawing panel*. The building and its elements are drawn on the screen similar to the drawing board using a "pencil". The actual dimensions of the elements can be entered, utilising the *Scale* option. The defined configuration for one building level (distribution and size of the walls, rooms) can be copied to the other building layers by selecting the corresponding button in the *Toolbox.* In the general case, those configurations are independent and can be defined separately.

As the final model is implemented in the FLORETO application, the problem of storage of the common elements shared by two rooms (e.g. doors and walls) has to be solved to avoid double entries in the database. In FLORETO, the walls and openings are entered only once, which is given in the section explaining the database tier. Also, it must be noticed that when collecting data by drawing the rooms, some of the parameters are entered implicitly. For example, by drawing the walls and defining the rooms, their size is automatically being entered, speeding up the collection process.

(c) Definition of different layers and sub elements of the building parts and additional data

The definition of the building layers and additional data (e.g. height or width of the openings) occurs in the *Active view*. In order to keep the overview of the entered data, the *Info panel* displays the features of the selected element - room, wall or opening.

(d) Users' actions such as *drag&drop*, type the value or *select from a popup menu*

The definition of building layers occurs in the *Active view*. For example, the floor elements can be defined by selecting different layers of a floor element and choosing the desired option from the popup list as shown in Figure 1. The popup menus are used wherever possible, controlling the input of the users following the tolerance principle (see Table 2). For all building elements a predefined list is offered, controlling the input of the users. In case any option is missing, the users should contact the expert-coordinator.

Building type is defined using the *drag&drop* function as shown in Figure 4-7. The elements to be *dragged&dropped* and placed in a certain location (e.g. openings or main fuse boxes) are given in the *Toolbox* as shown in the Figure 9-12- Figure 9-14:

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[198] http://code.google.com/apis/maps/index.html

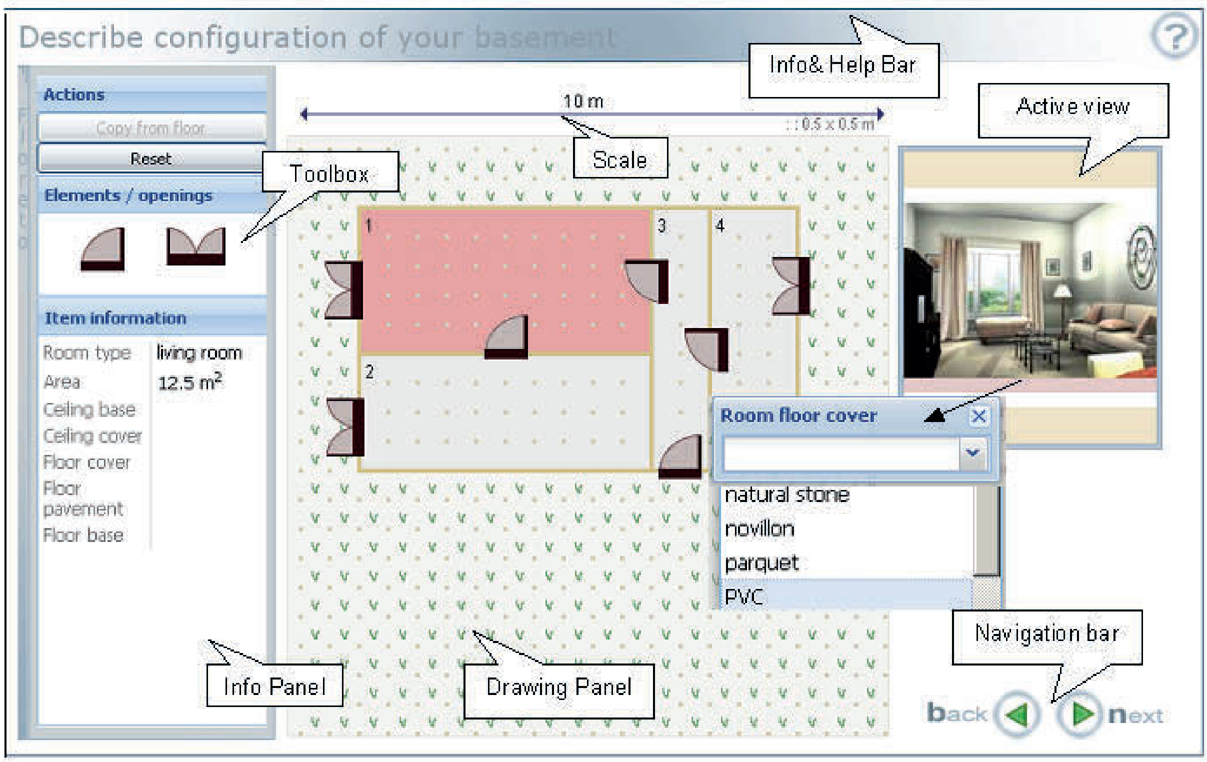


Figure 9-12: Example of the GUI for public user within FLORETO platform (scene layout type (2))

The users can freely enter only the general information about themselves as shown in Figure 4-6a.

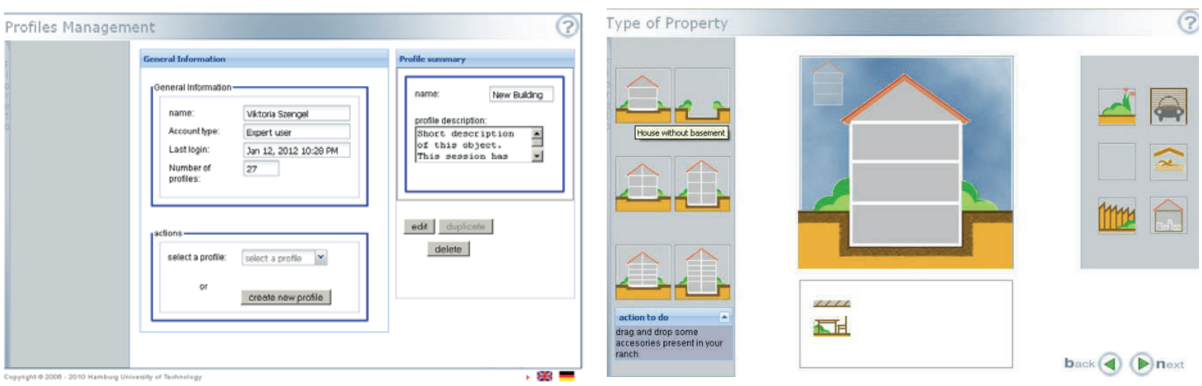


Figure 9-13: Examples of the FLORETO GUI interface a) entering the general information (4) b) layout type (1) enabling definition of the building type[199]

[199] The user has an option to define the adjoining elements such as garden or swimming pool, but the corresponding damaging functions have not been implemented yet.

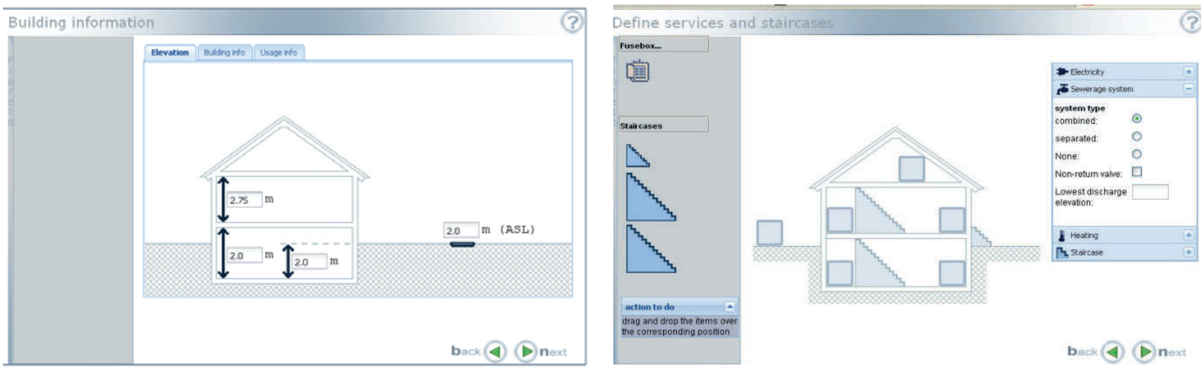


Figure 9-14: Examples of the FLORETO GUI interface a) layout type (3) enabling definition of the relevant elevation elements b) layout type (3)definition of the services and staircases

The introduction of topological functionality and free drawing options opens a number of issues to be solved in order to define elements in a consistent way. FLORETO GUI handles the problem by introducing a set of user friendly actions. For example, the deletion of unwanted elements is enabled using the **del** keyboard button.
Also, adding a new wall splits the existing wall and room into two parts, which can separately be defined. It is especially important for the case of internal walls, as partitions, supporting and non supporting walls can differ in their structure. Those functions enable better handling of the mistakes, following the *tolerance* principle.

Although the final model implements the topology, the model has its limits. It is at the moment supporting only the definition of horizontal and vertical walls, i.e. definition of non orthogonal or round building shapes is not possible. Also, 3d presentation of the plan views has not been considered for implementation. Also, FLORETO enables definition of one floor/ceiling material per room, which is in reality not always the case. Those issues open room for further improvement of the *matching* principle.

2) Input of the flood parameters

Flood parameters are to be defined or imported utilising GUI. The final model enables the full input of the flood parameters that result from the hydrodynamic modelling. The input can be performed either by importing of the parameters or by entering them by manually.

3) Visualisation of the steps of the decision making process and visualisation of results

The UIs for performing the steps of the data mining workflow and visualisation of results are given in the following section, which is devoted to describing the business logic.

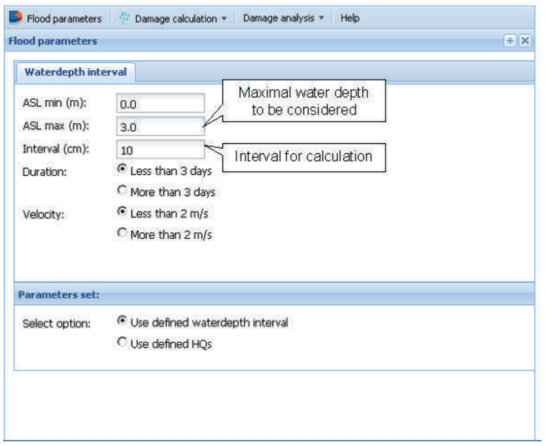
4) UI for the business logic modules

<u>Damage assessment</u>

The user interface has been designed following the workflow given in Appendix 6b and considering the design principles of Stone et al., 2005. Although the workflow as given in Figure 3-15 has been taken as a basis for the implementation, the workflow implemented in FLORETO enables display of the resilient systems to the user prior to the delivery of the damage assessment. This has been enabled due to the *time* factor that emerged as an important issue during the acceptance tests. In this way, the user is enabled to get the recommended resilient systems faster.
The steps of the damage assessment are grouped in menu items in the menu bar as shown in 8 to Figure 4-10. The walkthrough is straightforward, following the *simplicity, structure and consistency*

principles. After logging in the platform, the user can access the damage assessment interface either directly by selecting the option in the navigation bar as shown in Figure 1 or being automatically directed to this module after completing the data collection procedure. As illustrated in Figure 3-16 and specified in Appendix 4.2, risk assessment starts with loading/entering flood parameters, i.e. results of the flood probability assessment obtained from simulation models as given in section 3.3.1.1. For the scope of this work, flood depth, duration, velocity and the presence of heating oil have been considered[200]. Data management (database tier) of the data relevant for the damage assessment will be explained in more details within the next section. Flood parameters can be either imported or manually entered. Two possibilities for entering the flood parameters are enabled:

1. for a single flood event, where the water depth can be entered and the depth intervals (e.g. 10 cm) for which the damage is to be assessed are to be defined. The corresponding user interface is shown in Figure 9-15a.
2. Flood parameters are given for different annual recurrence intervals (e.g. 1,2,20 year floods) in case this information is available as shown in Figure 9-15b. The damage obtained for those statistical flood events are input data for the assessment of the annual damage as given in section 3.3.2.3.



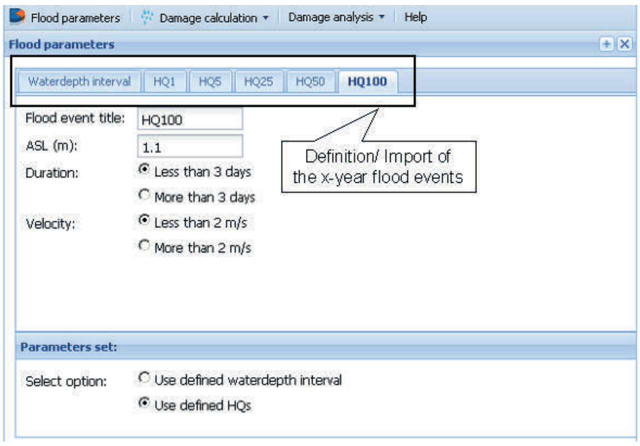


Figure 9-15 Flood parameters for damage assessment (a) for a given event (b) for x-year floods

The data describing the property are displayed on the right side of the GUI as shown in Figure 16b and Figure 4-10. The building elements are displayed within a hierarchical tree where the highest node represents the area (given with the aerial code) which contains buildings that the user entered. These buildings are then broken down to building levels and rooms. As the lowest leaf, the building element (e.g. door, wall) are given. It enables a separate damage calculation for each of those defined levels following the steps as given in the menu bar in Figure 6a. In the following step, the exposure analysis (here called weak point analysis) is performed. It has been introduced as an intermediate step towards the damage assessment, as it visualises the items that are affected by a flood (for the selected flood parameters).

[200] The data management within FLORETO as well as the user interface are flexible for introducing further parameters as soon as the theoretical background and concrete case studies are available

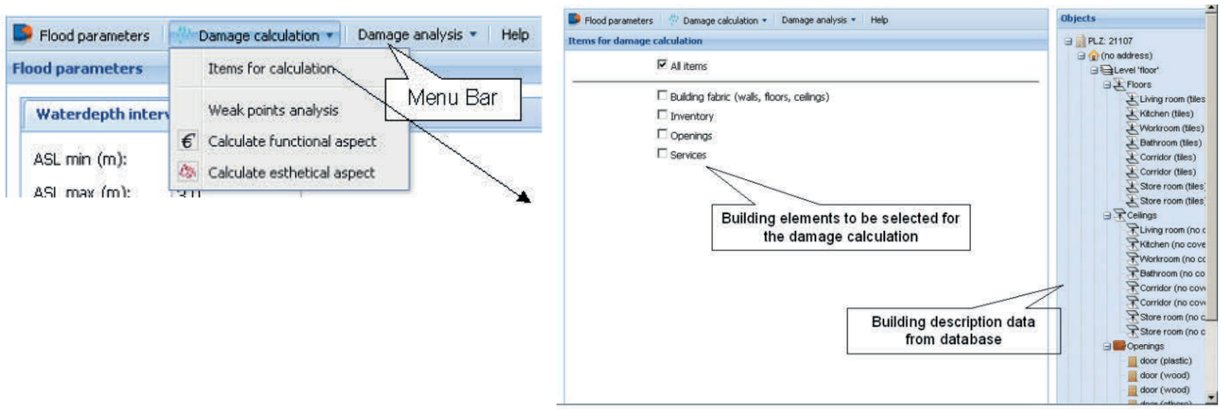


Figure 9-16 a) Menu bar highlighting the damage calculation item b) Selection of the option items for damage calculation as a step of the damage assessment

In the final step, the extent of damage can be calculated by selecting the option *calculate functional or (aesthetic) aspect* from the menu bar as shown in Figure 9-17.

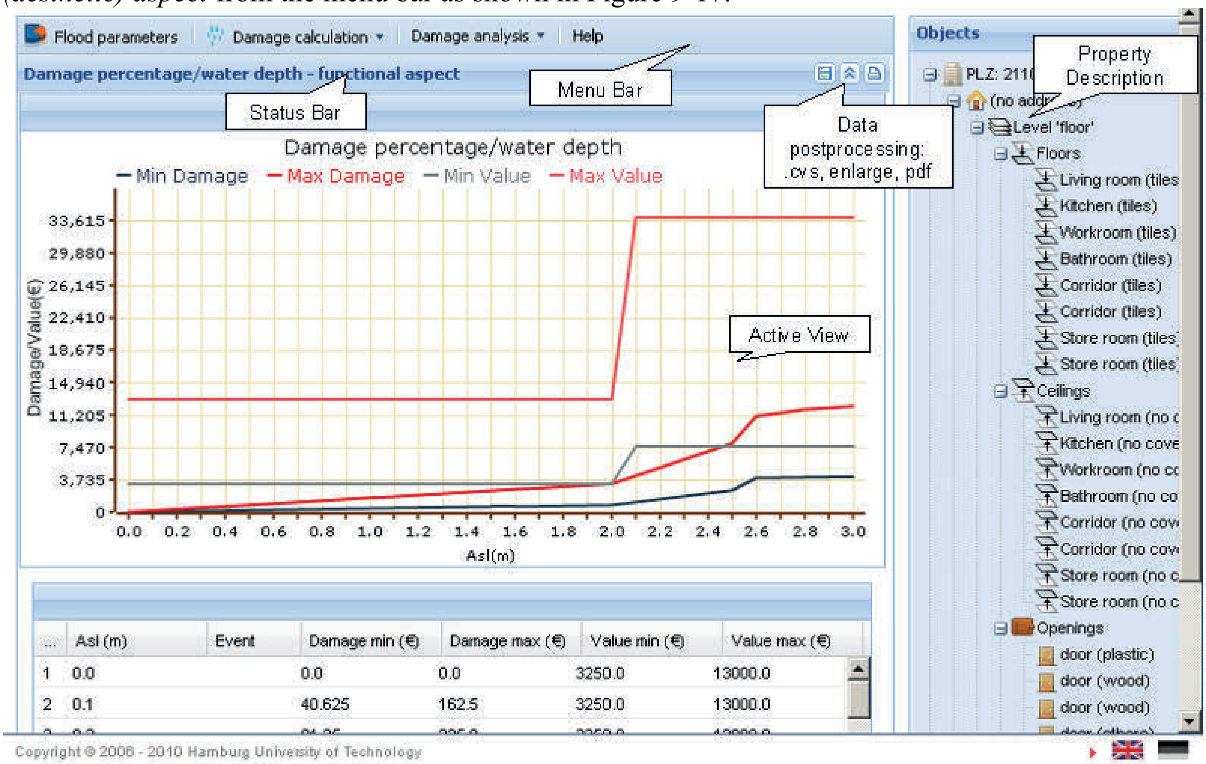


Figure 9-17 The main view of the damage assessment module within FLORETO

Both types of damaging functions, *functional and aesthetical* are stored in the database and assigned to the corresponding building element or combination of elements. The main aspects of the data management are given in the section devoted to the database description. By choosing the scale of assessment from the building element up to the group of buildings, the user can get a damage assessment for a defined step (e.g. in the 10cm interval, see Figure 9-15a) and given flood parameters in the form of a table and graphic as shown in Figure 9-17. The user can display the minimal and maximal estimated damage based on the range of costs considered for refurbishment. As a reference, the maximal and minimal value of the affected building elements is given. Alternatively, depending on the input flood parameters, the user can calculate the annual damage potential for the selected buildings. This result of damage assessment is the first input for scenario analysis, i.e. cost benefit analysis (CBA). In the post processing phase (Appendix 4.2), the user can print the report as a pdf or export the table (as a csv file) by selecting the corresponding option in the *Status bar*. The actual calculations of damage and risk are performed by the business rules that are stored and executed on the server (business logic) as shown in Figure 4-3, according to the theory described in 3.3.1.2.

Data mining module

For the design the principles of *simplicity, structure* and *consistency* have been considered. The flood parameters, in this case the flood depth, that are loaded form the Web Coverage Server[154] are displayed. They can be edited as described in section 3 dealing with the input parameters. After selecting the option to get a flood resilient plan, the suggestions regarding resilient systems are delivered to the user as shown in Figure 7a.

They are delivered in a very short and concise form as shown in **Figure 4-11**a. The more elaborated explanation of those systems is then delivered within the Tutorial or Knowledgebase of the FLORETO-Inform module or an external site of the SMARTeST[201] project devoted to explain FRe Technology and systems. The user gets a link to those pages as shown in Figure 9-18 and 9-19.

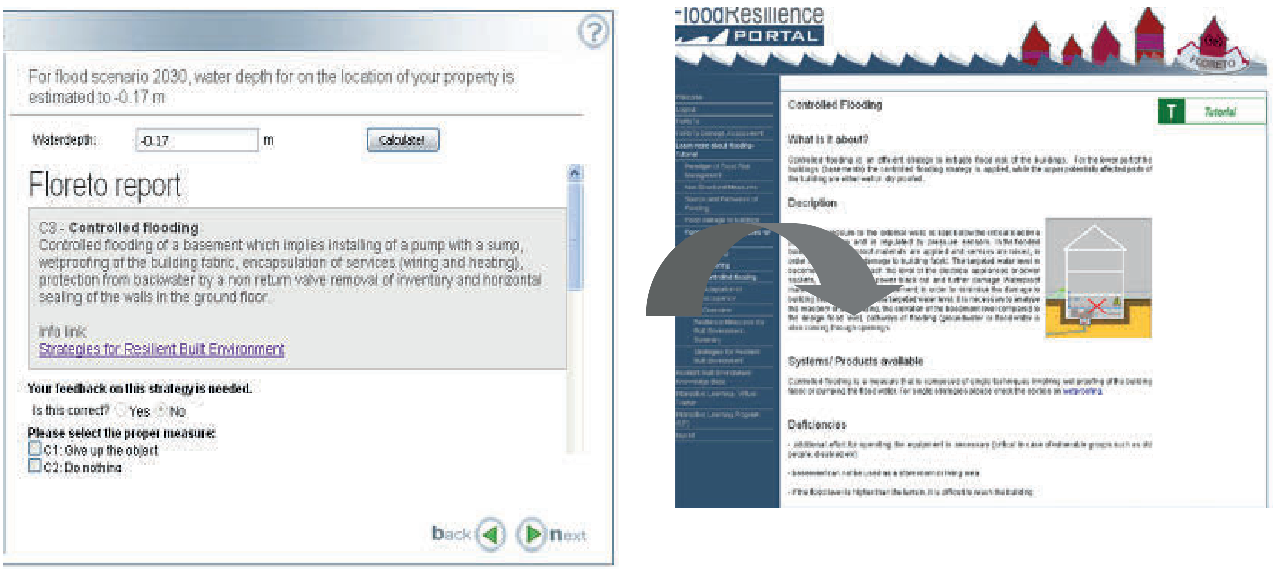


Figure 9-18 a) an example of the UI for technical selection process with a feedback option b) description of the delivered resilient system in the *FLORETO-Inform* module

201 http://tech.floodresilience.eu/flood-resilience-measures

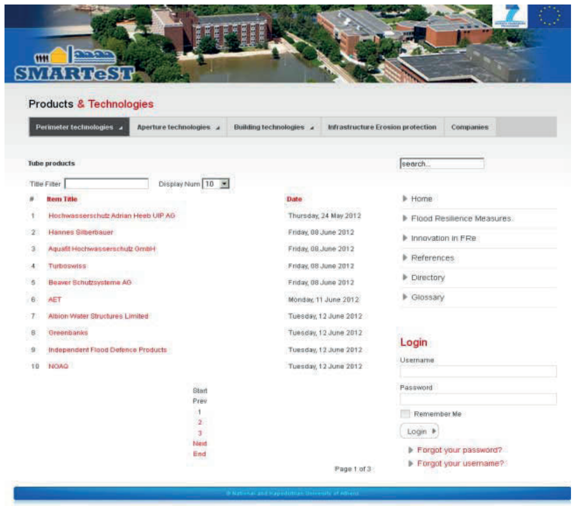


Figure 9-19 a) explanation of the delivered resilient system utilising E- lectures b) further explanation of the delivered resilient system and possible resilient technology to be used (http://tech.floodresilience.eu/flood-resilience-measures)

Appendix 4.4- Questionnaires- FAC&ILP

Appendix 4.4a List of questions for the test persons and observers after performing a flood simulation utilising the Flood Animation Studio

1. Do you feel at risk due to storm surges? Explain why?
2. In your opinion, how probable is the dike overtopping or breaching in in your area?
3. Do you know up to which level are you protected?
4. Are you familiar with the flood management and strategies to be performed by the authorities
5. What kind of impressions/ associations did the training evoke? Did you find it scary or rather unrealistic?
6. How would have you reacted?
7. Do you know now how should you behave?/ Would you be ready to invest in flood protection of your property?

Appendix 4.4b Assessment of efficiency of ILP- The content of the questionnaires before and after the ILP (as a part of the summative evaluation)

0) General Information (assessed only before the ILP)

Question	What is assessed
General information; affiliation educational level, *(hidden questions*)	Relation of social profile and the attitude towards flood risk

Ownership/ rent *(motivational and hidden question)*	Motivation for implementation of flood resilient measures
Number of tenants in the household (children/ adults/ vulnerable persons) *(motivational and hidden question)*	Relation of the attitude and behaviour to vulnerability of the people in the household
Experience with flooding *(control question)*	Relation between the experience, attitudes and initial knowledge of participants

I) Criteria 1: Questionnaires for assessment of efficiency of raising risk awareness

Question	**What is assessed**
Feelings about the flooding (anxious, relaxed) *(motivational and hidden question)*	Acceptance of flooding as phenomenon
What kind of impressions/ associations did the FAC evoke? Did you find it scary or rather unrealistic?	
How would have you reacted?	
What kind of impressions/ associations did the training evoke? Did you find it scary or rather unrealistic?	
Which sources for flood related information do you know and how do you get informed about flooding? *(opinion, motivation questions)*	

II) Criteria 2: Acceptance of own role through improved understanding of the relevant issues

Question	**What is assessed**
Origin of floods *(control question)*	Interest and actual knowledge on the topic
Factors relevant for flood situation in the study area? *(hidden, opinion, control question)*	The way the participants are dealing with the topic, understanding the complexity, relation to acceptance of responsibility
Influence of urbanisation to flood problems in the area (*hidden, opinion, control question)*	Indirectly understanding of the complexity
Problems in low lands (such as Hamburg) *(hidden, opinion, control question)*	Understanding of the complexity, level of abstraction
Flood management is exclusively responsibility of the authorities? Each citizen is responsible for own property?	Acceptance of own responsibility

Natural phenomena such as heavy rainfalls can cause flooding	
Human interference in natural catchments can increase risk to flooding	
Climate change can cause increase in flood risk in Europe and my area	
100 year flood event	Is it clear enough to what is meant by these often used terms?
Risk	
Flood risk management	

III) Criteria 3: Improved knowledge on flood resilient built environment

Question	**What is assessed**
What kind of resilience measures for built environment are you familiar with?	
Choose the right answer- The resilience measures on properties are: “easy to implement” “Serve nothing, I cannot have any influence on floods” “Flooding has low priority, no impact on my daily life” *(motivational, opinion and reference questions)*	Attitude towards resilience measures on properties
How do you react in case of flooding?	
What is the main obstacle for you to apply flood resilience measures on your own property?	
What kind of measures are you ready to apply to you own property?	
What is your attitude towards damage to your property? Direct damage Indirect (supplying problems, time effort) Intangible damage (psychological consequences)	

IV) Criteria 4: Proactive behaviour (Interviews a year after the program)

Question	**What is assessed**
Have you implemented resilient plan for your property adopted during the testing phase?	
If yes: have you experiences flood event afterwards? How did the measure perform?	
If no: what was the main reason for not implementing it?	

Appendix 5.1 Data collected in the Nidwalden area (summary taken from the insurance folders and the onsite visits) (Elaborated in the project work Pajak, 2006, supervised by N. Manojlovic)

	Folder	file		address	Aufräumungsarbeiten	Baumeisterarbeiten	Bodenbeläge	p.	Unterlagsböden		Wandbeläge		Abdichtungen	Baureinigung	Malerarbeiten	Elektroanlagen	Heizung, Lüftungs-. Klimaanlagen		Spezialanlagen	Sanitäranalgen	Küchen	Bad	Türen	
1	2005-3139	2005-3139_20060210100015		Bahnhofstr 19, 6362 Stans (Stiftung Altersfürsorge)											4.700,00	500,00							7.600,00	
2	2005-3508	2005-3508_20060210155219		Hartsteinwerk AG, Seerosenstr. 20, Stans			3.379,10								5.469,00	1.088,00	198,95						6.055,00	
3	2005-0585	2005-585_20060210110704		Achereggstr. 6, 6362 Stans															6.345,00	3.513,60	Blitzschutz			
4	2005-2360	2005-2360_20060412095405		Georgina Frank-Parmelin, Fischmattstrasse 17, 6374 Buochs			1.803,05						461,45				1.704,85	H+L		3.839,60				
5	2005-4462	2005-4462_20060210113431		Doris Benz-Eichenberger, Seestr. 47, Buochs			2.400,00				5.000,00	holz			3.000,00		3.000,00	Heiz						
6	2005-0992	2005-992_2006041235310		Margaritha Mattmann Hofstetter, Restaurant Krone	3.750,00	18.000,00	23.219,45				4.127,00		2.028,35		12.437,00	37.898,85	12.035,80	Heiz. + Lüft	47.146,80	10.534,80	99.941,80			
7	2005-1496	2005-1496_20060210144914		Krüger-Schellenberg, Seerosenstr 39, 6362	500,00				1.090,20						4.500,00	2.500,00	10.635,00	Heiz					4.542,10	
8	2005-1813	2005-1813_20060210142457		Bahnhofstr 15, 6362 Stans (Police Gebäude)													27.012,20	Heiz+Klima (?)						
9	2005-2031	2005-2031_20060210094357	photos	Dorfplatz 12, Stans		20.000,00	57.004,70	(29)	11.900,00		24.238,70	Trennwand	3.272,70		10.691,60		17.458,00	H/L+L+Klima+ Tank					9.342,70	
10	2005-2039		photos	Fischmattstrasse 20, 6374 Buochs	125,00										800,00								100,00	
11	2005-2309	2005.2309		Schmid Rolf, Achereggtr.4, 6362 Stans											15.800,00									
12	2005-2426	2426_20060412110559		H. A. Cueni-Graziano, Rotzbergstrasse 4, 6362 Stansstad	5.281,25		136.023,56			Zementunterlagsboden	7.498,40		2.456,20		12.206,31		8.613,80	Klima+Heiz		13.390,40			15.740,00	
13	2005-3147	Schadenjournal1		Zumbühl Katharina, Achereggstrasse 10, 6362 Stans			147,40								1.291,20	4.000,00								
14	2005-3208	2005-3208_20060213154855		Marie Wyrsch-Keiser, Quai 7, 6374 Buochs	450,00						2.431,00				3.495,00	450,00							12.476,00	
15	2005-3594	2005-3594_200602100093443		Robert Ackermann, Stationsstr.7, 6373 Ennetbürgen											12.000,00		25.000,00	Heizkessel/Boiler						
16	2005-4052	2005-4052_20060210143651		STWEG Marina Park, Kehrsitenstr. 23, 6362 Stans											2.000,00	3.389,85	53.116,30	Heiz Demontage+Lüftungsanlagen		2.000,00				
17	2005-4885	4885_20060412094301		Steinmann Albe, Schützenmattstr. 11, 6374 Buochs			1.829,00				2.120,00	plaster			4.590,00		7.548,00	boiler		5.620,00			5.536,00	
18	2005-5016	2005-5016_20060210095413		Achereggstr. 1, 6362 Stans											4.735,20								242,10	

	Folder	file	Fenster	Austattung, Innenausbau	Gipserarbeiten	Schreinerarbeiten		Entfeuchter	Waschmachine	Reinigung		Pumpen	Demontagen	Stromverbrauch	Lift	others		Heizungsanierung	Elektroinstallationen	Regiearbeiten	Dämmschichten	Sum	Sum without lift	Kostenzusammenstellung	type of a building	more info about the building	description of damage
1	2005-3139	2005-3139_20060210100015				7.962,00			32.500,00	1.000,00					3.500,00	4.000,00	metallbau					61.762,00	58.262,00	54.300,00	Stahlbau	(?) 32 Woh. PTT-und Ladenlokalen	Tiefgarage, Keller überflutet; Lift
2	2005-3508	2005-3508_20060210155219			13.215,95			3.447,05	6.098,90				5.815,20						1.170,00		4.470,70	50.407,85	50.407,85	32.800,00	Stahlbau	2 Wohn. Garage als Zwischenbau und Gartenhaus	-
3	2005-0585	2005-585_20060210110704																				9.858,60	9.858,60	67.600,00	Massivebau	7+7 Wohn.	ganze Hafenpark, Lift unter Wasser
4	2005-2360	2005-2360_20060412095405						806,00	1.065,08				975,50			404,40	Wände grundieren und abreiben			3.182,95		14.242,88	14.242,88	14.545,60	Massivebau	brick ?	Heizung, kontrolle, Vorbehalt Elektroantrieb, Tumbler, WM Motor und Steuergerät, Zimmer Boden neu erstellen, Wände Verputz reparieren; Wände, Türe, Garagetor und Sockel neu streichen
5	2005-4462	2005-4462_20060210113431											1.946,00			600,00	Radiatoren					15.946,00	15.946,00	19.405,35	Massivebau	single-family	Wasser in der Fisherstube (UG), Boden beschädigt und evtl. Wasser unter dem Boden
6	2005-0992	2005-992_2006041235310		50.469,00	25.000,00	105.427,45		1.468,00		5.000,00	Baureinigung											458.484,30	458.484,30	471.803,30	Massivbau	brick, single-family ?	-
7	2005-1496	2005-1496_20060210144914			8.419,30			5.000,00	3.049,00										1.884,00			42.119,60	42.119,60	43.180,00	Massivbau	single-family	Erdgeschoss im Wasser, Geschoss ist in der Umbauphase,
8	2005-1813	2005-1813_20060210142457						1.245,00							41.748,00							70.005,20	28.257,20	70.005,20	Massivbau	5 Wohnungen und Büro, Liftanlage	wasserschaden in den Kellerräumen, Nachmeldung Ölschaden, Lift (41478)
9	2005-2031	2005-2031_20060210094357			6.036,35	11.614,00		4.403,00	9.600,00	956,30		5.670,00	2.677,60	436,85	2.475,50	23.000,00	Tableau		20.214,00			240.992,00	238.516,50	175.000,00	Massivbau	Tariff 1,179; Geschäftshaus mit Kaffee und 5 Wohn., Garagenanbau	Wasser im Keller, Heizung, Waschküche ~ 35 cm unter Wasser; Erdgeschoss (Cafe, Bäckere) ~15 cm unter Wasser
10	2005-2039			1.200,00				650,00	2.967,00			800,00				1.250,00						7.892,00	7.892,00	7.922,00	Massivbau	?	
11	2005-2309	2005.2309						1.000,00		11.540,00					18.200,00	3.460,00	others					50.000,00	31.800,00	50.000,00	Massivbau	?	
12	2005-2426	2426_20060412110559		43.552,00	17.460,70	1.760,00		114,00								7.758,55	Bad in UG, Wandkonstruktion		2.314,75			274.169,92	274.169,92	300.000,00	Massivbau	concrete blocks ?	-
13	2005-3147	Schadenjournal1						315,00				1.069,25			2.500,00	9.593,55	Eigenleistung+others+Mulde+Sandsäcke+Metallbau					18.916,40	16.416,40	21.416,40	Massivbau	concrete blocks ?	Fenster und Garagen wurden zugemauert, um Schaden zu verhindern
14	2005-3208	2005-3208_20060213154855			2.513,75			105,00		312,00		25,00			5.888,40	15.610,05	sauna+Garagentore+Beleuchtung(2)					43.756,20	37.867,80	39.093,35	Massivbau	3 Wohn.	sauna im UG, Tapeten Leisten und Türen, Bauernschrank
15	2005-3594	2005-3594_200602100093443				1.500,00			7.954,05	2.000,00						1.871,95	Radiatoren					50.326,00	50.326,00	52.326,00	Massivbau	6 Wohn., Garageanbau	Hochwasser, mit Aufräumarbeiten wird begonnen
16	2005-4052	2005-4052_20060210143651						3.916,20		6.216,60		11.942,95			12.000,00							94.581,90	82.581,90	97.210,10	Massivbau	24 Wohn., Büro und Schwimmbad, 2 Liftanlagen, Auoeinstellhalle	Tiefgarage, Einstellhalle überflutet, Kellerzugänge sowie Keller/Heizungsraum/ Disponibel Hauswartsraum/ Technikraum (Schwimmbad) und Hauseingang
17	2005-4885	4885_20060412094301						2.592,00		75,00						8.364,00	4 new walls, insulation		3.220,15			41.494,15	41.494,15	44.100,00	Massivbau	concrete blocks ?	-
18	2005-5016	2005-5016_20060210095413																				4.977,30	4.977,30	4.977,30	Massivbau	Gemeinde-Verwaltungsgebäude mit 2 Wohn.	
19	2005-2117	2005-2117_20060210141846		5.000,00						700,00	Kanalnetz		1.700,00		43.000,00				5.050,00		5.394,00	171.994,00	128.994,00	155.000,00	Holz-Bruchstein	Wohn- und Geschäftshaus (6 Wohn.)	Heizung unter Wasser - 2m Wasser, Keller 1m unter Wasser, Parterre auch beschädigt

	Folder	file		address	Aufräumungsarbeiten	Baumeisterarbeiten	Bodenbeläge	p.	Unterlagsböden		Wandbeläge		Abdichtungen	Baureinigung	Malerarbeiten	Elektroanlagen	Heizung, Lüftungs-. Klimaanlagen		Spezialanlagen	Sanitäranlagen	Küchen	Bad	Türen	
20	**2005-2636**	2005-2636_2006021510384 0		Bruno Tomasi, Achereggstr 8, 6362 Stans	6.000,00		9.112,00								25.000,00	40.000,00	39.578,00	Heiz+Tanksanierung+Wärmeerzeugung					12.000,00	
21	**2005-3798**	2005-3798_2006021010071 8		Marcel Gubler, Seestr. 9, Ennetbürgen											5.750,00		500,00	Heiz					1.750,00	
22	**2005-1989**	2005-1989_2006021315522 2		Seeplatz 12, Buochs			5.901,30				4.635,00	putz			6.210,20		18.275,40	Heizkessel+Heizöltankanlage+Heizungsinstallation		880,70			12.064,00	
23	**2005-1573**	2005-1573_2006021011270 3		Karl Frank, Seestr. 25, 6373 Ennetbürgen	49.000,00		78.000,00	Holz, Textilien, Kunstoff	36.500,00	some of them - suspended			1.864,50		12.900,00		27.200,00	Heiz		241,00			28.049,60	Garagentore+Aussent.+T. innen+Ch
24	**2005-2697**	2005-2697_2006021014330 1		Erwin Elsener-Wettstein, Dorfplatz 8, 6362 Stans			3.580,50				2.060,00	verputzte Aussenwärmedämmung			2.332,00								5.252,55	
25	**2005-2743**	2005-2743_2006021011154 6		Blättler-Bättig Walter, Kehrsitenstr.7, Stans			534,25																175,80	
26	**2005-1049**	1049_2006041211315 2		Pierre-Jose Brodard-Michel, Dorfplatz 7, 6362 Stans	7.000,00	19.966,25	25.487,00								32.979,00	11.165,90	31.044,20			20.078,00	46.627,45			
27	**2005-1129**	Schadenjornal1		Käslin-Mathis, Ledergasse 26, 6375 Beckenried																		753,20	1.800,00	
28	**2005-1133**	2005.1133		Wullschleger-Husistein Urs, Riedstr. 3, 6362 Stans																		1.000,00	700,00	
29	**2005-1135**	1135_2006041213443 9		Martha Wirth-Stauffer, Kilchlied 1, 6362 Stans	2.585,60										7.367,05		24.023,00				3.939,25	480,50	1.799,00	
30	**2005-1528**	1528_2006041214042 6		Zgraggen ernst, Seestr. 22, 6052 Herguiswill			5.781,10		5.817,50						4.082,70								2.225,65	
31	**2005-1894**	1894_2006041208401 0	photos	Bruno Jann, Alpenstrasse 21, 6373 Ennetbürgen			5.700,65		8.339,90	durch Heizschlangen (3393)					2.471,25		2.832,00	Heiz			10.783,30		2.745,00	
32	**2005-2146**			no address given													1.704,85	Bodenheizung + Zentralstaubsaugersystem			1.800,00			
33	**2005-2416**	2416_2006041211252 0		Hugo Waser, Seerosenstr. 20, 6362 Stansstad			9.281,10		3.977,85						9.291,25								2.066,75	
34	**2005-3108**	2005-2108_2006041209271 8		Theo Gehrig, Kehrsitenstr.1, 6362 Stans			1.213,70								2.909,70									
35	**2005-3189**	Schadenjournal3189		Gander-Keiser Josef, Rigiweg 6, 6374 Buochs			271,40								400,00		4.000,00	Heiz						
36	**2005-3433**	2005-3433_2006021510320 1		Seehotel Pilatus AG, Seestr. 32, Hergiswil	3.485,50	2.383,90											7.309,60	Klima						

	Folder	file	Fenster	Austattung, Innenausbau	Gipserarbeiten	Schreinerarbeiten		Entfeuchter	Waschmachine	Reinigung		Pumpen	Demontagen	Stromverbrauch	Lift	others		Heizungsanierung	Elektroinstallationen	Regiearbeiten	Dämmschichten	**Sum**	**Sum without lift**	**Kostenzusammenstellung**	type of a building	more info about the building	description of damage
20	**2005-2636**	2005-2636_2006021510384 0				500,00	Holzwand	7.000,00	7.336,00	4.100,00	+entfeuchtung			1.310,15		22.972,00	?+Verteilanlage					174.908,15	174.908,15	126.000,00	Holz-Bruchstein	6 Wohn. und Ladenlokal, Mietertragausfall	Keller/Lager - betrifft das ganze Gebäude, Gesamtes UG bis UK Decke im Wasser, Wasserstand im EG ~30cm, Feuchtigkeitsschäden an Boden und Wänden. Dito. an sämtlichen Türblattern, Gesamte Elektroinstallation un Elektrotableau
21	**2005-3798**	2005-3798_2006021010071 8		1.700,00												1.750,00	Sauna					11.450,00	11.450,00	15.500,00	Holz-Bruchstein	brick (?), 2 Wohn. inkl. Sonnenkollektoren	Keller, Heizraum, Sauna unter Wasser
22	**2005-1989**	2005-1989_2006021315522 2	340,00		5.141,10			2.580,00	4.495,00							7.256,85	?+Kaminsanierung					67.779,55	67.779,55	37.727,00	Holz+Bruchstein	3+3 Wohn. Abstellraum, Garagen	Wassereinbruch im Parterre und Keller
23	**2005-1573**	2005-1573_2006021011270 3			20.000,00	7.900,00		5.154,15		13.400,00	Reinig. with Ensorgung and Schadenminderung					2.000,00	Aufzüge		13.734,10		2.213,25	298.156,60	298.156,60	70.320,00	Holz+Bruchstein	3 Wohnungen und Fischerei	Wasser im Keller, ~25 cm
24	**2005-2697**	2005-2697_2006021014330 1											1.127,75									14.352,80	14.352,80	14.352,80	? (Tariff 1.1)	1 Wohn.	Laden unter Wasser, ebenfalls Wursterei, sämtl. Maschinen in 20 cm tiel im Wasser
25	**2005-2743**	2005-2743_2006021011154 6						5.563,10	698,85			1.839,95				3.565,00	Bohrungen			7.174,75		19.551,70	19.551,70	22.140,75	? (Tariff 0.81)	7 Wohn. und Wintergarden	Wasser im Keller eingedrungen
26	**2005-1049**	1049_2006041211315 2				60.385,65				8.000,00	Baureinigung											262.733,45	262.733,45	368.105,20	?		-
27	**2005-1129**	Schadenjornal1										18.000,00										20.553,20	20.553,20	20.553,00	?		-
28	**2005-1133**	2005.1133				1.000,00		500,00								800,00						4.000,00	4.000,00	4.000,00	?		-
29	**2005-1135**	1135_2006041213443 9	315,00	2.887,00		8.592,00		1.735,25	2.921,05	3.930,70		60,00	1.334,00									61.969,40	61.969,40	53.500,00	?		Heizung, WM, Tumbler, Sockel, Abschottungen bei Aussentüren und Toren
30	**2005-1528**	1528_2006041214042 6	160,00	5.541,00				1.885,00					390,00	1.245,00		1.892,00	Dampfsperrarb			3.629,70		32.649,65	32.649,65	32.649,65	?		-
31	**2005-1894**	1894_2006041208401 0		2.680,00				737,00	1.916,80				2.225,80			1.726,75	Gefrierschrank + Heizungsreparaturen	6.212,00	2.235,70			50.606,15	50.606,15	60.488,60	?		-
32	**2005-2146**			35.910,00												12.290,00	electronic devices+others					51.704,85	51.704,85	50.000,00	?		-
33	**2005-2416**	2416_2006041211252 0		12.858,20	5.500,00			5.094,00		664,30			3.172,15			2.562,00	+ Beheben der Schäden beim Schacht in Garage		653,90			55.121,50	55.121,50	68.434,55	?		-
34	**2005-3108**	2005-2108_2006041209271 8	1.254,50			1.483,00		1.224,00											1.251,00			9.335,90	9.335,90	11.016,20	?		Lichtschacht; Keller: Fenster rep., Lampen ersetzen, Malerarbeiten; Wohnung: Heizbrenner und WM kontrollieren Teppich in Eingang ersetzen, Türe rep./ersetzen
35	**2005-3189**	Schadenjournal3189						1.528,35				60,00										6.259,75	6.259,75	6.259,75	?		Hochwasser im Kellerräumen, Waschküche und Garagen
36	**2005-3433**	2005-3433_2006021510320 1				572,00				547,70		10.176,55				23.173,50	Schlosserarbeiten(2)+Schadenbegrenzung		2.484,70	2.260,75		52.394,20	52.394,20	61.368,15	?		-
37	**2005-3496**	2005-3496_20060210134403			5.000,00	1.500,00		10.502,10								20.891,40	Aufzüge+Aufmauern+Deckenverkleidungen			3.411,50		80.601,70	80.601,70	20.000,00	?	multifamily	Überschwemmung im UG und an Techn Anlagen sowie Lift

The colours indicated in the table are related to the location of the buildings in the study area (N-W-E-S).

Appendix 5.2 The template for data collection used in the test area of Lauenburg and Hamburg which served as a basis for the FLORETO workflow

General Information

Building ID
Street /Nr.
Datum
Owner/Rent
☐ Dwelling Profile Number
☐ Business Profile Number

Experience with flooding ☐ Yes ☐ No
When?
Was it related to the examined property or you experienced flooding elsewhere?

Water depth?

Flood duration?

Direct damage occured in the above mentioned cases?
In case that HQmax (for the given conditions) occures, can you estimate the damage potential of your estate?

Indirect damage:
interruption of job ☐ Yes ☐ No how long?
Electricity black out? ☐ Yes ☐ No how long?
Other indirect damage?

alternative:
Do you think that you live in flood prone area?

Are there any existing measures to protect your property against flood?
If so, which one?

Would you spend any money in retrofitting measures ?
If so, how much money would you spend at most?

Regarding the area you live, what should be improved regarding flood protection?
What do you expect from:
the authorities?
experts on flood management related issues?

Information
How do you get informed about flood related issues?

Do you think that you are well informed about flood related issues?
Do you think that you are sufficiently advised by the experts?

Would you use internet as a source of information? ☐ Yes ☐ No

Kommentar

Building

Building ID
Street/Nr
Buildingtype
☐ main building ☐ adjoining building other:
Lowest building point: m
Base Area: [m2]
Main building type
☐ single house ☐ dupplex ☐ multi family residence other:
Parts of the main building
☐ Groundfloor ☐ Cellar Number of building floors: ☐ Souterrain
☐ Glass garden ☐ Garage Other:
Adjoining building
☐ Garage ☐ Other:
Year of construction:

Construction type:
☐ Carcass ☐ pre fabricated el. ☐ Timber Other.
☐ Masonry ☐ reinforced concr ☐ steel framed constructions
Cap:
☐ yes ☐ No Material: Height:

Heating
☐ District heating ☐ Gas-Central heating ☐ Oil-Central heating

Oil tank
☐ outside ☐ Steel tank Tank volume [l]:
☐ in the basement ☐ Plastic tank Tank weight [kg]
☐ on first/second floor Tank hight:[m]

Electricity
☐ level based cutout ☐ not level based cutout
Emergency cutout Location and level of the main fuse m

Drainage (sewerage system): type
note: consider ALL drainage points incl roof or balcony

possible pathways of flooding
☐ surface How?
☐ groundwater How?

Stairs (outside)
stair base: (material) Staircase covering:
Height:

Comment:

consider:
overall building condition
dampness
mould

Basement

Building ID
Street/Nr
Type of Basement:
☐ part cellar ☐ full cellar ☐ low built cellar
Anzahl Räume:

Basement height:
Basement elevation

Drainage: (description of the main pipes and their heights)

non return valve?

External walls:
Type (base, insulation)
Covering:

Did you have ever had problems with a high groundwaterlevel?

Condition of the walls: dampness on the walls ☐

Note: for detailed cellar description please, consider the form **Room.**

Room

Building ID
Strasse/Hausnr.
Room type:
Floor:
Width: Length: Height:

Windows Number Form ☐ square or rectangular ☐ other

Reveal ☐ inside ☐ outside Thickness cm

Panes ☐ Single glazing ☐ Double glazing Sealing

Size To be opend: inwards ☐ outwards ☐

Material: ☐ Plastic ☐ Metal ☐ Wood Other:

Hight above floor m

Doors
Outside doors:
Number Form ☐ square or rectangular ☐ other

Size m² Reveal ☐ inside ☐ outside Thickness cm

Material ☐ Glass ☐ Synthetics ☐ Metall ☐ Wood Others

Doors inside the building

☐ Glass ☐ Synthetics ☐ Metall ☐ Wood Others

Inventory
Movable assets:

Estimated value:

Fixtures:

Estimated value:

Comment:

Appendix 5.3- Initial data mining model built for testing of the FLORETO Business Logic for the Hamburg dataset

The stucture of the file containing the dataset is given as follows:

@attribute NAME OF THE ATTRIBUTE {ATTIBUTE VALUES}

The attributes marked with an underscore have been considered for the 46attribute set

62 attributes

@attribute base_elevation numeric
@attribute building_profile {PRIVATE,PUBLIC,BUSINESS_UNIT,COMBINATION}
@attribute building_usage
{HOUSE_WITH_BASEMENT,HOUSE_WITHOUT_BASEMENT,DUPLEX_WITH_BASEMENT,DUPLEX_WITHOUT_BASEMENT,MULTI_WITHOUT_BASEMENT,MULTI_WITH_BASEMENT}
@attribute additional_assets {yes,no}
@attribute building_condition {NEW,OLD,OLD_REFURBISHED,}
@attribute basement_present {yes,no}
@attribute building_foundation
{CONCRETE,REINFORCED_CONCRETE_SLAB,REINFORCED_CONCRETE_STRIP,BRICKWORK,PILES,OTHERS,UNKNOWN,NONE}
@attribute ground_lowestOpeningElevation numeric
@attribute ground_inventory_yes_no {yes,no}
@attribute basement_inventory_yes_no {yes,no}
@attribute basement_usage_intensity {medium,high_medium,medium_low,others}
@attribute ground_usage_intensity {high_medium,medium_low,high,medium}
@attribute ground_ExternalWallFace
{plaster,cladding,cladding_slab,others,cement_asbestos,gypsum_boards,gypsum_plaster,tiles,none}
@attribute ground_ExternalWallBase
{masonry,stoneware,timber_carcass,reinforced_concrete,concrete,none,others,masonry_one_shell_full_brick_wo_insulation,masonry_one_shell_full_brick_w_insulation,masonry_one
shell_full_brick_w_insulation_bonde,masonry_vertically_perforated_brick,masonry_vertically_perforated_brick_w_insulation,masonry_clinker,masonry_double_shell_full_brick_with_air_layer,masonry_double_shell_full_brick_with_air_layer_a,masonry_double_shell_full_brick_wo_air_layer,rear_ventilated_facade_with_insulation,waterproof_concrete}
@attribute ground_ExternalWallCovering
{mineral_paint,water_emulsion_paint,others,tiles,wood,oil_and_synthetic_paint,none,wallpaper,ingrain_wallpaper}
@attribute ground_ExternalWallOrientation {lateral,direct,others}
@attribute ground_ExternalCapMaterial {tiles,masonry,concrete,wood,others}
@attribute ground_ExternalCapHeight numeric
@attribute ground_InternalWallBase {reinforced_concrete,masonry,stoneware,timber_carcass,concrete,none,others}
@attribute ground_InternalWallFace
{plaster,cladding,cladding_slab,others,cement_asbestos,gypsum_boards,gypsum_plaster,tiles,none}
@attribute ground_InternalWallCovering
{mineral_paint,water_emulsion_paint,others,tiles,wood,oil_and_synthetic_paint,none,wallpaper,ingrain_wallpaper}
@attribute ground_Floorbase
{concrete,stone,waterproof_concrete,solid_concrete,wood,vaulted_slab,loam,masonry,suspended,reinforced_concrete,others,none,pumice_stone,wooden_beams}
@attribute ground_FloorCovering
{screed,coating,carpet,tiles,PVC,wood,mineral_paint,others,laminate,terrazzo,novillon,epoxy,parquet,natural_stone,linoleum,render,none}
@attribute ground_Windowsmaterial {wood,aluminium,stainless_steel,others,plastic,chipboard,massive_wood,none}
@attribute ground_Doorsmaterial {wood,aluminium,stainless_steel,others,plastic,chipboard,massive_wood,none}
@attribute ground_ExternalStairBase {concrete,masonry,others,natural_stone,metal,none,wood}
@attribute ground_ExternalStairCovering {tiles,others,pvc,carpet,wood,none}
@attribute ground_InternalStairBase {concrete,masonry,others,natural_stone,metal,none,wood}
@attribute ground_InternalStairCovering {tiles,others,pvc,carpet,wood,none}
@attribute basement_ExternalWallBase
{reinforced_concrete,masonry,stoneware,timber_carcass,concrete,none,others,masonry_one_shell_full_brick_wo_insulation,masonry_one_shell_full_brick_w_insulation,masonry_one
shell_full_brick_w_insulation_bonde,masonry_vertically_perforated_brick,masonry_vertically_perforated_brick_w_insulatio

n,masonry_clinker,masonry_double_shell_full_brick_with_air_layer,masonry_double_shell_full_brick_with_air_layer_a,masonry_double_shell_full_brick_wo_air_layer,rear_ventilated_facade_with_insulation,waterproof_concrete}
@attribute basement_ExternalWallFace {plaster,cladding,cladding_slab,others,cement_asbestos,gypsum_boards,gypsum_plaster,tiles,none,screed}
@attribute basement_ExternalWallCovering {mineral_paint,water_emulsion_paint,others,tiles,wood,oil_and_synthetic_paint,none,wallpaper,ingrain_wallpaper}
@attribute basement_ExternalWallOrientation {lateral,direct,others}
@attribute basement_external_cap_material {tiles,brickworks,concrete,wood,others}
@attribute basement_external_cap_height numeric
@attribute basement_InternalWallBase {reinforced_concrete,masonry,stoneware,timber_carcass,concrete,none,others,waterproof_concrete}
@attribute basement_InternalWallFace {plaster,cladding,cladding_slab,others,cement_asbestos,gypsum_boards,gypsum_plaster,tiles,none}
@attribute basement_InternalWallCovering {mineral_paint,water_emulsion_paint,others,tiles,wood,oil_and_synthetic_paint,none,wallpaper,ingrain_wallpaper}
@attribute basement_Floorbase {concrete,stone,waterproof_concrete,solid_concrete,wood,vaulted_slab,loam,masonry,suspended,reinforced_concrete,others,none,pumice_stone,wooden_beams}
@attribute basement_FloorCovering {screed,coating,carpet,tiles,PVC,wood,mineral_paint,others,laminate,terrazzo,novillon,epoxy,parquet,natural_stone,linoleum,render,none}
@attribute basement_CeilingBase {concrete,stone,waterproof_concrete,solid_concrete,wood,vaulted_slab,loam,masonry,suspended,reinforced_concrete,others,none,pumice_stone,wooden_beams}
@attribute basement_CeilingCovering {coating,carpet,tiles,PVC,wood,mineral_paint,others,laminate,terrazzo,novillon,epoxy,parquet,natural_stone,linoleum,render,none}
@attribute basementWindows {wood,aluminium,stainless_steel,others,plastic,chipboard,massive_wood,none}
@attribute basementDoors {wood,aluminium,stainless_steel,others,plastic,chipboard,massive_wood,none}
@attribute basementExternalStairBase {concrete,masonry,others,natural_stone,metal,none,wood}
@attribute basementExternalStairCovering {tiles,others,pvc,carpet,wood,none}
@attribute basementInternalStairBase {concrete,masonry,others,natural_stone,metal,none,wood}
@attribute basementInternalStairCovering {tiles,others,pvc,carpet,wood,none}
@attribute TypeInventoryMovableAssets {yes,no}
@attribute InventoryFixtures {yes,no}
@attribute waterproof_wiring numeric
@attribute sewerage_system {separate,others,combined}
@attribute non_return_valve {yes,no}
@attribute heating_system {OIL,ELECTRICITY,NO_HEATING,DISTRICT,GAS}
@attribute oilTankLocation {FLOOR_LEFT,others}
@attribute OilTankMaterial {Aluminium,Steel,others}
@attribute pathway_above {door,others,below}
@attribute pathway_below {door,others,below}
@attribute WaterDepthBasement numeric
@attribute WaterDepthGroundFloor numeric
@attribute sourceOfFlooding {water_course,rainfall,sea_lake,torrent,groundwater}
@attribute class {C1,C18,C16,C19,C2,C7,C5,C3,C4,C17,C8,C10,C11,C20,C12,C13,C14,C9,C6}

"@data"
0,PRIVATE,HOUSE_WITH_BASEMENT,yes,NEW,yes,CONCRETE,0,yes,yes,medium,high_medium,cladding,masonry_double_shell_full_brick_with_air_layer_a,mineral_paint,lateral,others,0,stoneware,plaster,mineral_paint,stone,tiles,aluminium,wood,concrete,tiles,wood,carpet,masonry,others,mineral_paint,lateral,others,0,stoneware,plaster,mineral_paint,stone,others,stone,mineral_paint,aluminium,wood,others,others,concrete,tiles,yes,yes,1,separate,yes,DISTRICT,others,others,door,door,200,200,water_course,C1
0,PRIVATE,MULTI_WITH_BASEMENT,yes,NEW,yes,CONCRETE,0,yes,yes,medium_low,high_medium,plaster,reinforced_concrete,mineral_paint,lateral,others,0,reinforced_concrete,plaster,wallpaper,concrete,PVC,plastic,wood,concrete,others,concrete,tiles,reinforced_concrete,others,mineral_paint,lateral,others,0,reinforced_concrete,plaster,mineral_paint,stone,tiles,stone,others,aluminium,wood,concrete,others,concrete,tiles,yes,yes,1,separate,yes,DISTRICT,others,others,door,door,200,100,water_course,C7
0,PRIVATE,HOUSE_WITHOUT_BASEMENT,yes,OLD,no,CONCRETE,0,yes,no,others,high_medium,cladding,masonry,others,direct,others,0,masonry,plaster,wallpaper,wood,laminate,plastic,plastic,others,others,others,others,others,others,others,

others,others,0,others,others,others,others,others,others,others,others,others,others,others,others,others,no,no,1,separate,no,DISTRICT,others,others,others,others,200,150,water_course,C18

0,PRIVATE,MULTI_WITH_BASEMENT,yes,OLD,yes,CONCRETE,0,yes,yes,medium_low,high_medium,plaster,masonry,mineral_paint,lateral,others,0,stoneware,plaster,mineral_paint,concrete,carpet,plastic,wood,concrete,others,natural_stone,others,waterproof_concrete,plaster,mineral_paint,lateral,others,0,stoneware,plaster,mineral_paint,waterproof_concrete,others,concrete,others,stainless_steel,stainless_steel,concrete,others,concrete,tiles,yes,yes,1,separate,yes,DISTRICT,others,others,door,door,200,50,water_course,C16

2,PRIVATE,HOUSE_WITH_BASEMENT,yes,NEW,yes,CONCRETE,0,yes,yes,medium,high_medium,plaster,masonry,mineral_paint,others,others,0,stoneware,plaster,mineral_paint,concrete,laminate,wood,wood,concrete,tiles,concrete,carpet,masonry,gypsum_plaster,others,others,others,0,stoneware,plaster,wood,stone,tiles,wood,mineral_paint,stainless_steel,wood,others,others,others,others,no,no,0,combined,yes,DISTRICT,others,others,door,door,200,150,water_course,C1

21 attributes

@attribute building_profile {PRIVATE,PUBLIC,BUSINESS_UNIT,COMBINATION}

@attribute building_usage {HOUSE_WITH_BASEMENT,HOUSE_WITHOUT_BASEMENT,DUPLEX_WITH_BASEMENT,DUPLEX_WITHOUT_BASEMENT,MULTI_WITHOUT_BASEMENT,MULTI_WITH_BASEMENT}

@attribute additional_assets {yes,no}

@attribute building_condition {NEW,OLD,OLD_REFURBISHED,}

@attribute basement_present {yes,no}

@attribute building_foundation {CONCRETE,REINFORCED_CONCRETE_SLAB,REINFORCED_CONCRETE_STRIP,BRICKWORK,PILES,OTHERS,UNKNOWN,NONE}

@attribute basement_usage_intensity {medium,high_medium,medium_low,others}

@attribute ground_usage_intensity {high_medium,medium_low,high,medium}

@attribute ground_ExternalWallBase {masonry,stoneware,timber_carcass,reinforced_concrete,concrete,none,others,masonry_one_shell_full_brick_wo_insulation,masonry_one_shell_full_brick_w_insulation,masonry_one shell_full_brick_w_insulation_bonde,masonry_vertically_perforated_brick,masonry_vertically_perforated_brick_w_insulation,masonry_clinker,masonry_double_shell_full_brick_with_air_layer,masonry_double_shell_full_brick_with_air_layer_a,masonry_double_shell_full_brick_wo_air_layer,rear_ventilated_facade_with_insulation,waterproof_concrete}

@attribute ground_Floorbase {concrete,stone,waterproof_concrete,solid_concrete,wood,vaulted_slab,loam,masonry,suspended,reinforced_concrete,others,none,pumice_stone,wooden_beams}

@attribute ground_FloorCovering {screed,coating,carpet,tiles,PVC,wood,mineral_paint,others,laminate,terrazzo,novillon,epoxy,parquet,natural_stone,linoleum,render,none}

@attribute ground_Windowsmaterial {wood,aluminium,stainless_steel,others,plastic,chipboard,massive_wood,none}

@attribute ground_Doorsmaterial {wood,aluminium,stainless_steel,others,plastic,chipboard,massive_wood,none}

@attribute basement_ExternalWallBase {reinforced_concrete,masonry,stoneware,timber_carcass,concrete,none,others,masonry_one_shell_full_brick_wo_insulation,masonry_one_shell_full_brick_w_insulation,masonry_one shell_full_brick_w_insulation_bonde,masonry_vertically_perforated_brick,masonry_vertically_perforated_brick_w_insulation,masonry_clinker,masonry_double_shell_full_brick_with_air_layer,masonry_double_shell_full_brick_with_air_layer_a,masonry_double_shell_full_brick_wo_air_layer,rear_ventilated_facade_with_insulation,waterproof_concrete}

@attribute basement_Floorbase {concrete,stone,waterproof_concrete,solid_concrete,wood,vaulted_slab,loam,masonry,suspended,reinforced_concrete,others,none,pumice_stone,wooden_beams}

@attribute basement_FloorCovering {screed,coating,carpet,tiles,PVC,wood,mineral_paint,others,laminate,terrazzo,novillon,epoxy,parquet,natural_stone,linoleum,render,none}

@attribute basement_CeilingBase {concrete,stone,waterproof_concrete,solid_concrete,wood,vaulted_slab,loam,masonry,suspended,reinforced_concrete,others,none,pumice_stone,wooden_beams}

@attribute basementWindows {wood,aluminium,stainless_steel,others,plastic,chipboard,massive_wood,none}

@attribute basementDoors {wood,aluminium,stainless_steel,others,plastic,chipboard,massive_wood,none}

@attribute WaterDepthBasement numeric

@attribute WaterDepthGroundFloor numeric @attribute class {C1,C18,C16,C19,C2,C7,C5,C3,C4,C17,C8,C10,C11,C20,C12,C13,C14,C9,C6} ……………………… (the list of the objects is not final as it exceeds 300 lines)

Appendix 5.4- FLORETO- testing of the technical performance and acceptance

Appendix 5.4a- Testing protocol

A Userlogin enter username und password → „Login“

B Floreto –english

1. Welcome to Floreto → “Next”
2. *General Information* (name, account type, last login, number of profiles) inscribed

Actions “Select profile” or “Create new profile”

Profile summary name, description →”edit”
→”duplicate”
→”delete”

I. (→”edit”)

(1)User information

Information (first name, last name, age, phone number, e-mail, user profile (→Options))
Address (search, address postal code, county, city, province, country (→Options))
Experience →”+”→ year (→Options), event location (→Options), comment
→”x”
Comment

→”next”
→”back” → confirm delete “yes/no”

(2) Type of property

Drag and drop each house and object into the graphic and remove it again
(→Changing house type “yes/no”)

→”next”
→”back”

(3) Building information

Elevation (enter 2 (without basement) or 4 (with basement) elevations)
Building info (pick every option)
Usage info (pick every option and enter numbers)

→”next”
→”back”

(4) Basement configuration

Error messages:
• → “next”
→Error!(Please draw at least one wall. Use the mouse on the grid to proceed !) “ok”
• draw up to 3 walls → “next”

→ Error!(Please draw at least one room. You may need 4 walls to proceed !) "ok"

• draw at least 4 walls → "next"

→ Error!(You seem to have forgotten Openings (door and/or windows!). drag and drop one over the room(wall) !) "ok"

• add window → "next"

→ Error!(please chose the material for at least one wall, click on the wall and then on the right panel to proceed !) "ok

• select wallbase → "next"

→ Error!(please identify the rooms you have created. Choose the room type (kitchen for instance).) "ok"

• select room type → "next"

→ Error!(please select the floor base material) "ok"

• select floor base → "next"

→ Error!(please choose the opening material) "ok"

• select opening material

→ "Copy from floor" (if floor is already created)→ copy level structure? "yes/no"
draw walls and create 2 rooms, add a window and a door
→ "reset" → reset level structure?"yes/no"

select:

room (each one): ceiling base (→Options),
ceiling cover (→Options),
room type (→Options),
floor cover (→Options),
floors pavement (→Options),
floor base (→Options)

wall (at least one): inner covering (→Options),
inner face (→Options),
wallbase (→Options),
wallface material (→Options),
cap (pick "has cap"→Options, height)

door: door material(→Options)
width
height

window: door material(→Options)
width
height
elevation

item information (all given information)

→"next"
→"back"

(5) <u>Basement inventory</u>

room 1:

pick inventory from the list (folder: furniture, electrical appliances, personal belongings and utensils)
check "delete one item", "delete selected", "clear all"

room 2: same

nothing picked → Error!(Please add at least on inventory) "ok"

→"next"
→"back"

(6) Floor configuration

Error messages:
• → "next"
→Error!(Please draw at least one wall. Use the mouse on the grid to proceed !) "ok"
• draw up to 3 walls → "next"
→ Error!(Please draw at least one room. You may need 4 walls to proceed !) "ok"
• draw at least 4 walls → "next"
→ Error!(You seem to have forgotten Openings (door and/or windows!). drag and drop one over the room(wall) !) "ok"
• add window → "next"
→ Error!(please chose the material for at least one wall, click on the wall and then on the right panel to proceed !) "ok
• select wallbase → "next"
→ Error!(please identify the rooms you have created. Choose the room type (kitchen for instance).) "ok"
• select room type → "next"
→ Error!(please select the floor base material) "ok"
• select floor base → "next"
→ Error!(please choose the opening material) "ok"
• select opening material

→ "Copy from basement" (if basement is already created)→ copy level structure? "yes/no"
draw walls and create 2 rooms, add a window and a door
→ "reset" → reset level structure?"yes/no"

select:
room ceiling base (→Options),
(each one) ceiling cover (→Options),
room type (→Options),
floor cover (→Options),
floors pavement (→Options),
floor base (→Options)
wall inner covering (→Options),
(at least one) inner face (→Options),
wallbase (→Options),
wallface material (→Options),

cap (pick "has cap"→Options,height)
door door material(→Options)
width
height
window door material(→Options)
width
height
elevation

item information (all given information)

→"next"
→"back"

(7) Floor inventory

room 1:
pick inventory from the list (folder: furniture, electrical appliances, personal belongings and utensils)
check "delete one item", "delete selected", "clear all"

room2: same

nothing picked → Error!(Please add at least on inventory) "ok"

→"next"
→"back"

(8) Services and staircases

Fehlermeldungen:
→"next" → Error!Oiltank not positioned. "ok"
drag-and-drop Oiltank →"next" → Error!Fusebox not positioned. "ok"

drag-and-drop fusebox
drag-and-drop staircases
→"next" →Error!(Choose a base and a cover material for all your staircases) "ok"

electricity check every option, enter elevations
sewerage system check every option, enter elevations
heating check every option, enter volume, pick tank material
staircases pick base and cover material for each staircase (has to be selected)

→"next"
→"back"

(9) final report

→"next"
→"back"

II. (→"duplicate")
→This session will be duplicated "ok"
same as (→"edit"), but everything`s filled

III. (→"delete")
→confirm delete! Do you really want to delete this profile? This cannot be undone! "yes/no"
→Delete profile "ok"

Appendix 5.5- Questions used for the formative and summative assessment of the LAA (with the focus on dwellers)

Available at http://laa-wandse.wb.tu-harburg.de (password protected)

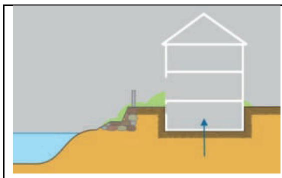
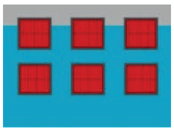
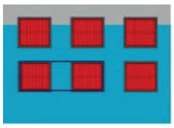
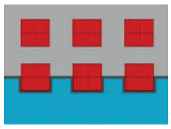
Appendix 5.6a- Summary of the CBA performed on the examined buildings in Lauenburg

Table 1: Overall CBA ratio for the affected study area considering the RS 3 and 4. The resilient systems RS 1 and 2 are dependent on the individual decisions of homeowners and as such are not considered for the overall analysis. Detailed list of the costs per buildings are given in Pasche& Manojlovic, 2008 also available at the link: http://www.lauenburg.de/download/stadt/gutachten-zum-hochowasserschutz.pdf

Criteria	N/D-RS	
	RS 3	RS 4

Cost effectiveness (gross)	Costs of investment [€]	1,740,00	2,400,000
	Maintenance costs [€]	17,000	21,000
	Annual overall costs [€]	77,000	98,000
	Benefit-cost ratio [€]	0,42	0,37
		- -	-

Appendix 5.6b- Resilience performance analysis of the selected building in Lauenburg

	No RS	D PRS-1 	D-RS-2 	D-RS3 	D-RS4 
Resilience Proxies (Table 3-4)	Value	P-RS1 Controlled flooding of basement	P-RS1 Controlled flooding of basement	P-RS4 Controlled flooding of basement+ shielding of the ground floor	P-RS4 Controlled flooding of basement+ shielding of the ground floor
Threshold capacity	medium-high	Individual for the building (depending on the acceptable risk)	Set by the community/authorities	Set by the neighbourhoods	Set by the community/authorities
I) Time to equilibrium	medium	individual	individual	individual	fast
II) Resources and effort needed	medium-high	Low-medium	Low-medim	low	low
III) Level of permanency and impact of	2	no damage	no damage	no damage	no damage
IV) Damage evolution	2-3	4	4	3	3-4
V) Flexibility of contingency measures	no	no	no	no	yes
VI) Continuous supply of services	no	no	no	no	yes
VII) Sensitivity to malfunctioning	high	Low Critical element-pump	Low Critical element-pump	Low Critical element-pump	Low Critical element-pump and the weakest building
VIII) Transformability	-	high	high	High-medium	High-medium

Appendix 5.7- The Results obtained at the test area Hamburg

Appendix 5.7a- The damage calculated utilising FLORETO in the Wandse study area for the selected buildings ID3 and ID7

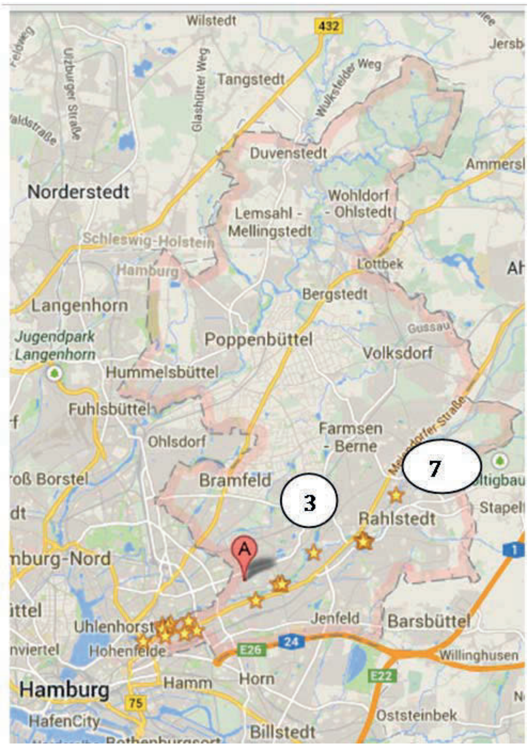


Figure 9-20 Location of the examined buidligns ID3 and ID7

Table 9-8. List of assessed properties and short description.

ID	Location	Type
3	StS190	Private, Detached, single-story home, no basement
7	BA 21	Detached, two-storey residential building, with basement

Legend

Low density residential

ID 3 StS 190

This building is a new single-storey detached house, without basement. This type of building is abundant in the upper parts of the catchment, where low density residential zoning exists. The photo of the building is shown in Figure 9-21. Some relevant information was retrieved, which gives FLORETO the capacity of making a more precise assessment. This information is summarised in Table 9-9.

Table 9-9: Description of the Building ID3

Building condition:	New
Type of foundation:	Concrete slab
First level height:	2,5 m
Number of rooms:	4
Number of openings	7
Number of walls:	21
Location of fuse:	First level
Fuse level-wise:	Yes
Waterproof wiring:	Yes
Main fuse elevation:	100 cm
Main socket elevation:	100 cm
Sewage system type:	Separated
Non-return valve:	No
Lowest discharge elevation:	unknown
Heating:	Electricity

Figure 9-21 Photo of StS 190.

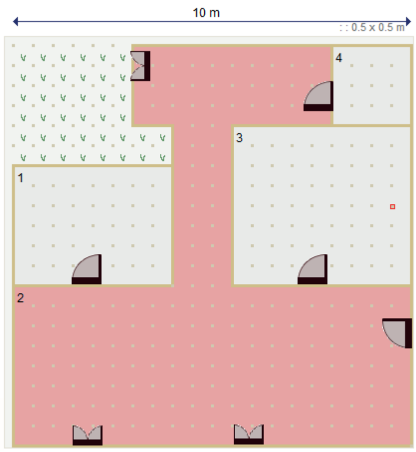


Figure 9-22 Floor plan layout for ID 4 as depicted in FLORETO.

The furniture and appliances considered for ID 3 are listed in Table 9-10.

Table 9-10 Considered inventory for ID 3

Room	Furniture	Quantity	Room	Furniture	Quantity
Kitchen	Built-in closet	1	Living room	Armchair	1
	Ceiling lamp	2		Ceiling lamp	2
	Chair	4		Curtain window	2
	Table	1		Sofa	2
	Dish washer	1		Tv table	1
	Kitchen appliances	1		Telephone	1
	Refrigerator	1		Books	1
	Kitchen utensils	1		Deco	1
Bedroom	Bed	1		Painting	1
	Built in closet	1		Computers	1
	Ceiling lamp	1		Stereo	1
	Chair	2		TV	1

	Clothes and shoes	1
	Deco	1
Bathroom	Washing machine	1
	Tumble dryer	1
	Sanitary equipment	1

Damage/Risk Assessment:

The estimated damage is given in Figure 9-23. For the water depth of 0,20 m corresponding to a 100 year event, the estimated damage amounts to 43.200 EUR (Dmin) and 93.600EUR (Dmax), depending on the quality of materials and inventory in the building.

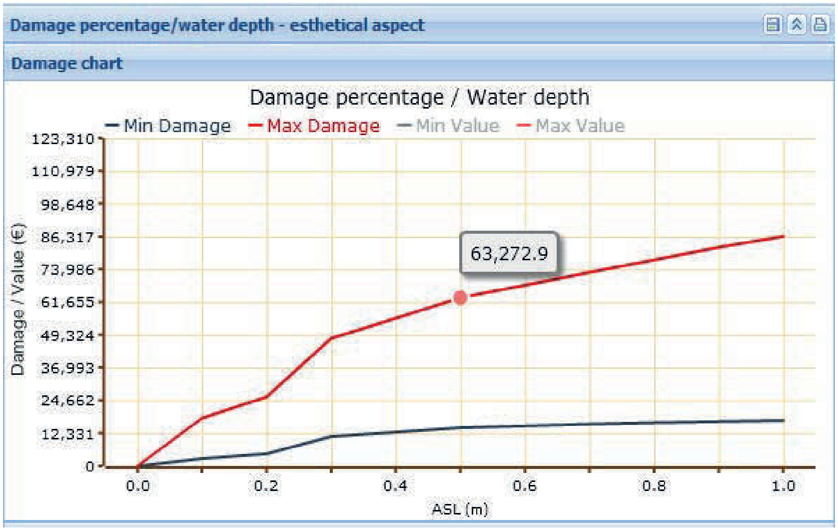


Figure 9-23 Damage costs vs. flood depth curve from FLORETO.

<u>ID 7 BA 21</u>

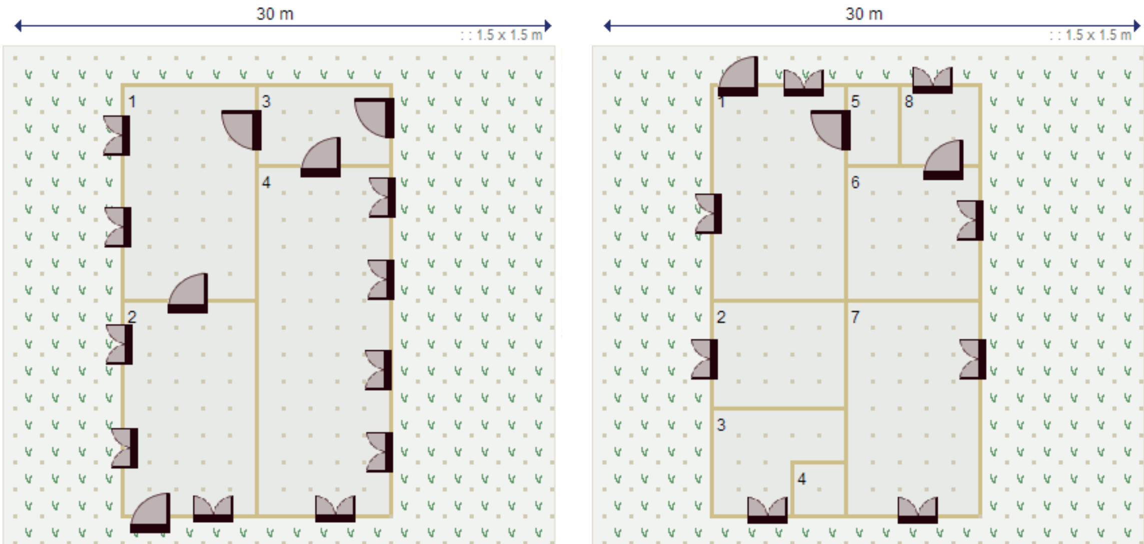
This property is a multi-storey residential building with basement and its photo is shown in Figure 9-24. This information is summarised as follows:

Table 9-11 Description of the Building ID7

Building condition:	**New**
Type of foundation:	Concrete
First level height:	3 m
Number of rooms:	12
Number of openings	26
Number of walls:	43
Location of fuse:	Basement
Fuse level-wise:	Yes
Waterproof wiring:	No
Main fuse elevation:	150 cm
Main socket elevation:	20 cm
Sewage system type:	Combined
Non-return valve:	No
Lowest discharge elevation:	50 cm
Heating:	Gas

Figure 9-24 View from Google maps (street view)

The abovementioned data was the input, along with the floor plan of the building, for the calculations of damage.



Floor plan layout of ID 7 basement (left) and first floor (right) as depicted in FLORETO.

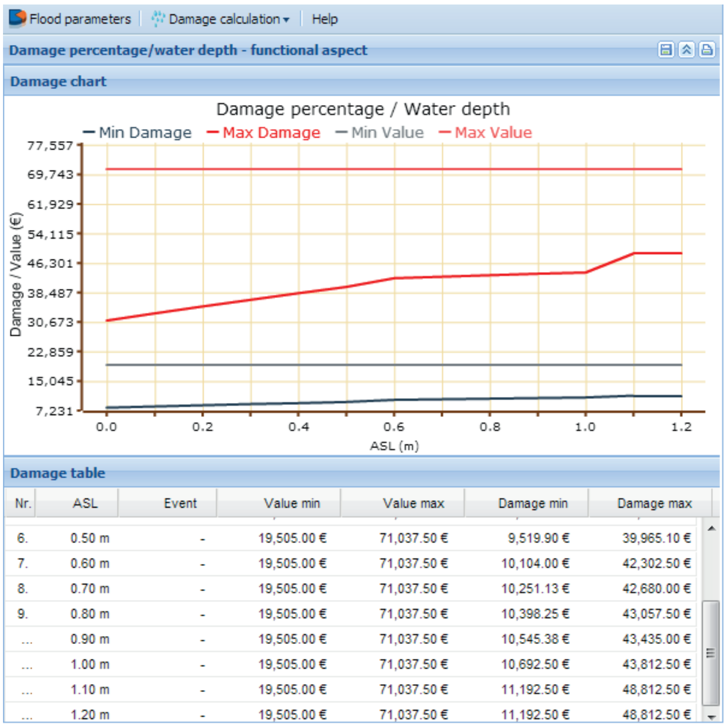
The furniture and appliances considered for ID 7 are given in Table 9-12.

Table 9-12 Generic inventory for ID 7

Room	Furniture	Quantity	Room	Furniture	Quantity
Basement	Oven	1	Basement	Armchair	2
Heating room & WC	Sanitary equipment	1	Workroom	Warderobe	1
	Shelves	1		Freezer	1
	Electrical appliances	1		Washing machine	1
Basement	Commode	1		Books	1
Store room	CDs	1		CDs	1
	Deco	1		Deco	1
	Stereo	1		Toys	2
	Sport machine	1		Bicycle (adult)	2
	Workbench	1		Bicycle (child)	1
Living room	Armchair	1	Kitchen	Dish washer	1
	Commode	1		Oven	1
	Curtains	1		Refrigerator	1
	Chair	1		Kitchen unit	1
	Curtains (small)	1		Wall cupboard	1
	Table	1		Other furniture	1
	TV table	1		Telephone	1
	Deco	1		Kitchen utensils	1
	Photos	1		Stocks	1
	TV	1		Stove	1
	Armchair	1	Workroom	Piano	1
	Ceiling lamp	1		Musical instrument	1
Toilet	Sanitary equipment	1		Warderobe	1
	Rug	1		Armchair	2
Living room	Telephone	1	Dining room	Stereo	1

	Clothes and shoes	1		Photos	1
	CDs	1		Sofa	1
	Deco	1		Table	1
	Computer	1		Floor lamp	1
	Copy machine	1		Commode	1
	Laptop	1		Chairs	6
	Monitor	1		Telephone	1
	Stereo	1	Store room	Commode	1
	Built-in closet	1		Stereo	1
Bathroom	Warderobe	1		Stocks	1
	Sanitary equipment (large)	1		Clothes and shoes	1
	Sanitary equipment (small)	1		Rug	1
				Shelves	1
				Warderobe	1

Damage/Risk Assessment:
The estimated damage is given Figure 9-25. For the water depth of 0,20 m corresponding to a 100 year event, the estimated damage amounts to 11.200 EUR (Dmin) and 48.800 (Dmax), depending on the quality of materials and inventory in the building. For this particular case, the Dmax has been considered.

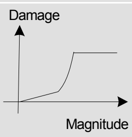
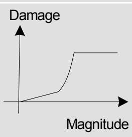
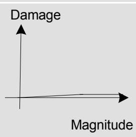


Nr.	ASL	Event	Value min	Value max	Damage min	Damage max
6.	0.50 m	-	19,505.00 €	71,037.50 €	9,519.90 €	39,965.10 €
7.	0.60 m	-	19,505.00 €	71,037.50 €	10,104.00 €	42,302.50 €
8.	0.70 m	-	19,505.00 €	71,037.50 €	10,251.13 €	42,680.00 €
9.	0.80 m	-	19,505.00 €	71,037.50 €	10,398.25 €	43,057.50 €
...	0.90 m	-	19,505.00 €	71,037.50 €	10,545.38 €	43,435.00 €
...	1.00 m	-	19,505.00 €	71,037.50 €	10,692.50 €	43,812.50 €
...	1.10 m	-	19,505.00 €	71,037.50 €	11,192.50 €	48,812.50 €
...	1.20 m	-	19,505.00 €	71,037.50 €	11,192.50 €	48,812.50 €

Figure 9-25 Damage assessment curves for the buildign BA 21

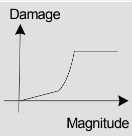
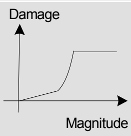
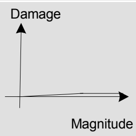
The other selected buildings are stored in the FLORETO database (password protected)

Appendix 5.7b- Resilience performance of the selected buildings ID3 and ID7 in the Wandse test area

Nr	Proxies	ID3; no measures	ID3; RS- shielding of the building	ID7; RS- wetproofing of the ground floor
		Resistance:		
I	Threshold value of the design flood*	Medium-low (affected from a 25y event)	High (extreme events) -can be designed in a way to resist the low freq. events as the corresponding flood depths are bearable (s. Chapter 5)	High
	Restorative resilience:			
Recovery Capacity:				
I	Time to equilibrium (return to the acceptable state)	2. Medium- months	1. fast: less than weeks/month(s)	1. fast: less than weeks/month(s)
II	Resources and effort needed for reaching the equilibrium		1. low- reduced to cleaning and drying of the building fabric	2. medium- drying, cleaning + minor (esthetical) repairs required
III	Level of permanency and impact of the (tangible) damage	3. high- repairs of building fabric needed	1. no damage up to the threshold value	2. minor damage that can be repaired without considerable costs.
IV	Damage evolution			
Coping capacity:				
V	Flexibility of the contingency measures)	2. no	3. not required/ applicable	Conditional 1. Yes (as upper floors available)
VI	Continuous supply of the services enabled	3. no	1. yes	1-2. yes with (considerable effort)

VII	Sensitivity to malfunctioning(criticality)	High	High- the system depends on one factor, which in case of failure, causes the failure of the overall system- flood barriers	Low- the risk is distributed over a range of elements
	Adaptive Resilience:			
VIII	Transformability of the system	Low	Low- the system has to be redesigned	Medium- High

ID7- BA21

Nr	Proxies	ID7; no measures	ID7; RS- Sealing of the basement and shielding of the building	ID7; RS- Controlled flooding of the basement; wetproofing of the ground floor
	Resistance:			
I	Threshold value of the design flood*	Medium-low (affected from a 50y event)	High (extreme events) -can be designed in a way to resist the low freq. events as the corresponding flood depths are bearable (s. Chapter 5)	High-
	Restorative resilience:			
Recovery Capacity:				
I	Time to equilibrium (return to the acceptable state)	2. Medium- months	1. fast: less than weeks/month(s)	1. fast: less than weeks/month(s)
II	Resources and effort needed for reaching the equilibrium		1. low- reduced to cleaning and drying of the building fabric	2. medium- drying, cleaning + minor (esthetical) repairs required
III	Level of permanency and impact of the (tangible) damage	3. high- repairs of building fabric needed	1. no damage	2. minor damage that can be repaired without considerable costs.
IV	Damage evolution			
Coping capacity:				
V	Flexibility of the contingency measures)	2. no	3. not required/ applicable	Conditional 1. yes

VI	Continuous supply of the services enabled	3. no	1. yes	1-2. yes with (considerable effort)
VII	Sensitivity to malfunctioning(criticality)	High	High- the system depends on one factor, which in case of failure, causes the failure of the overall system- flood barriers	Low- the risk is distributed over a range of elements
	Adaptive Resilience:			
VIII	Transformability of the system	Low	Low- the system has to be redesigned	Medium- High

Appendix 5.7c- The results from the test of the FAC application in Hamburg- V1

	Questions:			
Nr Per son	Do you feel at risk due to storm surges? Explain why?	In you opinion, how probable is the dike overtopping or breaching in HH-W?	Do you know up to which level are you protected?	Are you familiar with the flood management and strategies for HH-W performed by the authorities?
1	no, I live on the 1st floor	Not at all	no	no
2	no, I have trust in the authorities	maybe in 20 years	yes, dike top level	yes, from the annual reports and brochures
3	no, I live on the 1st floor	Not at all	6,0 m (?)	no
4	You, due to changes in river regime	Highly probable	7,50?	partly
5	Yes, due to dike breach	Highly probable	7,50?	no
6	Yes, I live in HH-W since 1973 and I am familiar with the problem	Highly probable	yes	yes
7	Yes, the whole HH-W is at risk	Yes, in 40-50 years	no	yes, annual brochures

Results of the questionnaires after the training (observers)

	Questions		
Nr Person	What kind of impressions/ associations did the training evoke? Did you find it scary or rather unrealistic?	How would have you reacted?	Do you know now how should you behave?/ Would you be ready to invest in flood protection of your property?
1	Helps to prepare better for the real event	Better preparation	no
2	Unrealistic	I do not know	If not too expensive
3	Remembrance to real flood event in 1962	Collection of the important documents	Yes, by using the flood protection products for openings
4	Unrealistic	Depending on the situation	Partly/ yes
5	Was good and realistic	The same as the test persons	I am not the homeowner and therefore not interested
6	Unrealistic, in real situation it is often not possible to escape though the window	Not leaving through the window	Yes, heating system should be elevated

Appendix 5.7d- The summary of the results from the FAC application in Hamburg- V2

TUHH Technische Universität Hamburg-Harburg — WASSERBAU River and Coastal Engineering

Name: ____________________ **Datum** __________

Kontakt:

1 Glauben Sie, dass ein Hochwasserrisiko für Sie existiert?
- Ja ich wohne im Erdgeschoss
- eher nicht
- nein
- ja
- eher nicht, 4. Stock
- Für die Stadt Hamburg ja, meine Wohnung nein (5. Stock)
- Mein Wohnhaus liegt 28mNN, immerhin 20km von der Innenstadt gen Norden entfernt.
- Aber das Grundwasser ist hoch und wird steigen. Bei extremen Regenfällen wird der Keller vollaufen
- Ja aber nur theoretisch. (Bachlauf am Haus)

2 Wissen Sie, was für Konsequenzen der Klimawandel hat?
- Zunahme Sturmfluten
- Zunahme konvektiver Niederschlagereignisse -> Hochwasser etc
- teilweise
- Ja
- steigender Meeresspiegel
- häufigere, heftigere Unwetter
- Ja, durch den steigenden Meeresspiegel
- mehr Extremwetterereignisse
- Ja, mehr Winde, Stürme, Hochwasserschmelze
- Nein
- Nein, nicht exakt
- mehr oder weniger

3 Aus der Erkenntnis, die Sie hier gewonnen haben, würden Sie sagen, dass Sie bei fortschreitendem Klimawandel nicht ausreichend gegenüber einem Hochwasserrisiko geschützt sind ?
- jaein, in der Stadt gibt es sicher große Probleme
- nein
- ja
- Im großen und ganzen nein
- elektronische Geräte ausschalten
- Nein, bei einem Hochwasser wäre ich wahrscheinlich nicht ausreichend geschützt
- Doch ich wohne im 2. Stock
- Die Erkentnis die ich davor hatte ist, Hamburg muss sich zukünftig ausreichend darauf vorbereiten,
- welche Folgen ein fortschreitender Klimawandel mit sich bringt
- Die nächsten 20 Jahre wird es wohl noch gut gehen
- geschützt wahrscheinlich schon, aber nicht vorbereitet -> Verhalten in einer solchen Situation

4	Wissen Sie jetzt was Sie tun können?
	Sind Sie bereit, bauliche Maßnahmen an Ihrem Haus zu verwirklichen,
	um einen möglichen Hochwasserschaden so gering wie möglich zu halten?
	Ja, man weiß auf was man achten muss bei der Rettung wichtiger Gegenstände
	Ja
	Ja, dazu wäre ich bereit
	Strom abschalten, wichtige Sachen stapeln
	nicht einfach mit ja zu beantworten
	Ich habe kein Haus
	Nein. Ich habe eine kleine Wohnung im 5. Stock
	schwierig umzusetzen
	bedingt(liegt im ermessen des Hausbesitzers)
	Nein
	kein Eigenheim
	Wenn es finanzierbar ist
	habe eine Mietwohnung
5	Reaktionsanalyse
	Was hat Ihnen Angst gemacht?
	alles
	keine Angst, alles ersetzbar
	die Schnelligkeit
	Ja
	Nein
	Das alles ümfällt
	Der Strom
	Sirene, wie schnell das Wasser kommt
	Wie tief das Wasser war
	Nichts
	Kombi aus Strom und Wasser
	Wie hätten Sie sich voraussichtlich in der Flutbox verhalten?
	panisch
	Versicherung angerufen
	ähnlich chaotisch
	nicht so cool
	andere Reihenfolge
	Papiere zuerst genommen und raus
	Genau so wie der Probant
	ähnlich
	ängstlich
	Operative Hektik
	Strom vergessen
	unbeholfen->hätte wohl einfach

Was hat das Flutungsmodell bei Ihnen bewirkt?

Das Wasser stieg schneller als ich erwartet habe

nasse Füße

wie schnell Dinge "hinüber" sind

Respekt

Panik, Verlust persönlicher Gegenstände, Hilflosigkeit

Erst die Dokumente retten und dann persönliche Sachen(Kleidung)

Wichtige Unterlagen sicher lagern

Interesse für das Thema

Gänsehaut

keine Ahung

Ich hätte alles auf das Regal getan

schnelle Auswirkung

Modelle helfen evtl. Gefahrensituationen besser zu beurteilen, daher natürliches Instrument um sich auf ein solches Szenario vorzubereiten

Ich habe dieses Event schon im Fernsehen gesehen. Ich wäre systematischer vorgegangen und hätte das Regal besser genutzt. Etwas mehr Dynamik wär's gewesen

Beklemmung

Das Wasserist sehr schnell eingedrungen, man hat kaum Zeit zum reagieren.

Ich werde an Strom denken

Hat es bei Ihnen Assoziationen hervorgerufen oder haben Sie es eher als unrealistisch empfunden?

weder noch

realistisch, aber steigt das Wasser so schnell?

realistisch wie Oder-Hochwasser

Es war realistisch

Ich frage mich gerade wo und wie schnell ich zur Hauptsicherung komme

Bilder von der Flut 1962

unrealistisch

halb und halb

Ja, da ich am Deich wohne

Ich denke, dass es unter entsprechenden Bedingungen realistisch sein könnte

Kam der Realität nah

Dass wenn man elektronische Geräte hat, man einen Stromschlag bekommt

gute Simulation

unrealistisch nein, aber schwer zu beschreiben

Hat mich an Katastrophen erinnert

6	Würden Sie Internet-basierte Wissenssysteme zur persönlichen Lösungsfindung für eine Anpassung
	an den Klimawandel und das zunehmende Hochwasserrisiko verwenden?
	ja
	Auf jeden Fall
	nein
	nicht wirklich
	Unter meinen momentzanen Lebensumständen eher nicht. Wenn ich ein eiegenes Haus direkt
	Ich habe keine Ahnung
	Habe ich schon gesehen, bin erstaunt, dass so wenig diese Methoden Anwendung finden
	Ja, wenn es realisierbare Vorschläge aufzeigt
	sicher, aber wohl nur, wenn ich direkt betroffen wäre bzw. die Gefahr vesteht
7	Würden Sie an den Veranstaltungen die von der TUHH zum Thema Hochwasserrisiko
	angeboten werden, teilnehmen?
	Wenn ich in Hamburg wohnen wurde ja!
	Nein, so lange ich über 80 mNN wohne
	Ja
	Ja, sehr spannend
	Eher nein
	Nein
	Kommt auf den Termin drauf an.
	Ja schon
	Gibt es weiteres, was Sie zum Hochwasseranimationsstudio anmerken wollen?
	offener Gestalten, da Besucher von geschlossenen Räumen abgeschreckt werden, alles super
	tolle eindrucksvolle Aktion
	Nein

Appendix 5.7e- The summary of the results from the ILP application in Hamburg, Kollau

Assessment of the participants' profiles

Criteria Participant	Affiliation/ educational level	Ownership/ rent, type of building	Nr of tenants in the household (children/ adults/ vuln. persons)	Experience with flooding
1	Blue collar	Rent/ terrace	1	no
2	University diploma	Owner since 20 years /detached house	2 adults	yes, once
3	University diploma (engineer)	Owner since 45 years/detached house	2 adults	yes, 6 times

4 5, 6	Family: Clerk and shop attendant, retired person	Owner since 35 years resp 8 years /detached house	6 (2 children, 2 adults, 1 old person)	yes, 6 times (old person) yes once (family)

Appendix 5.8- The damage calculated utilising FLORETO in the Heywood study area

ID 1. 29 CA

This property is a single-storey residential building without basement. The building is shown in Figure 1 Some relevant information was retrieved, which gives FLORETO the capacity of making a more precise assessment. This information is summarised as follows:

Building condition:	Old
Type of foundation:	Concrete
Height of first level:	2,7m
Number of rooms:	4
Number of openings	8
Number of walls:	14
Location of fuse:	Ground floor
Fuse levelwise:	No
Waterproof wiring:	No
Main fuse elevation:	120cm
Main socket elevation:	20cm
Sewage system type:	Combined
Non-return valve:	No
Heating:	Gas

Figure 9-26 29 CA (source: Google Maps)

- Construction materials of the first level (prone to be flooded):

Flooring: **Concrete with carpet or tiles**
Façade: Facing brickwork, no plaster
Rooms: 4 rooms (living room, kitchen, sleeping room, bathroom, corridor) with the typical inventory

Figure 9-27 represents the floor plan of ID 1.

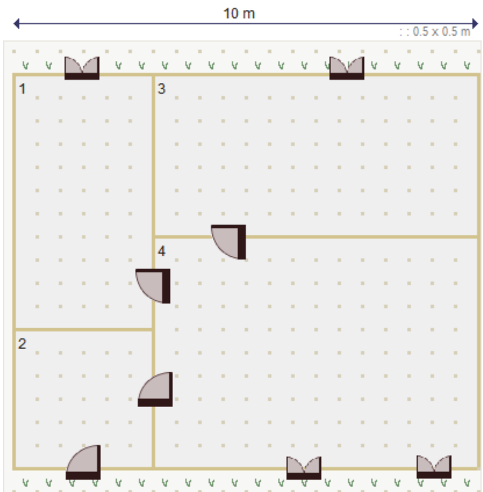


Figure 9-27 Plan view ID1

The furniture and appliances considered for ID 1 are listed in Tale 9-13.

Table 9-13 ID1 Inventory

Room	Furniture	Quantity	Room	Furniture	Quantity
Living room	Chair	1	Bathroom	Sanitary equipment	1
	Commode	1		Rug	1
	Table	1	Kitchen	Kitchen appliances	1
	TV table	1		Fitted kitchen	1
	Sofa	1	Corridor	Ceiling lamp	1
	Telephone	1		Rug	1
	CDs	1		Wall cupboard	1
	Deco	1			
	Paintings	1			
	Photos	1			
	Stationary	1			
	TV	1			
	Armchair	2			

Damage/Risk Assessment:

The estimated damage is given in the figure below. For the water depth of 0,60 m corresponding to the 2006 flood event, the estimated maximum damage amounts 29.000 EUR (Figure 9-28).

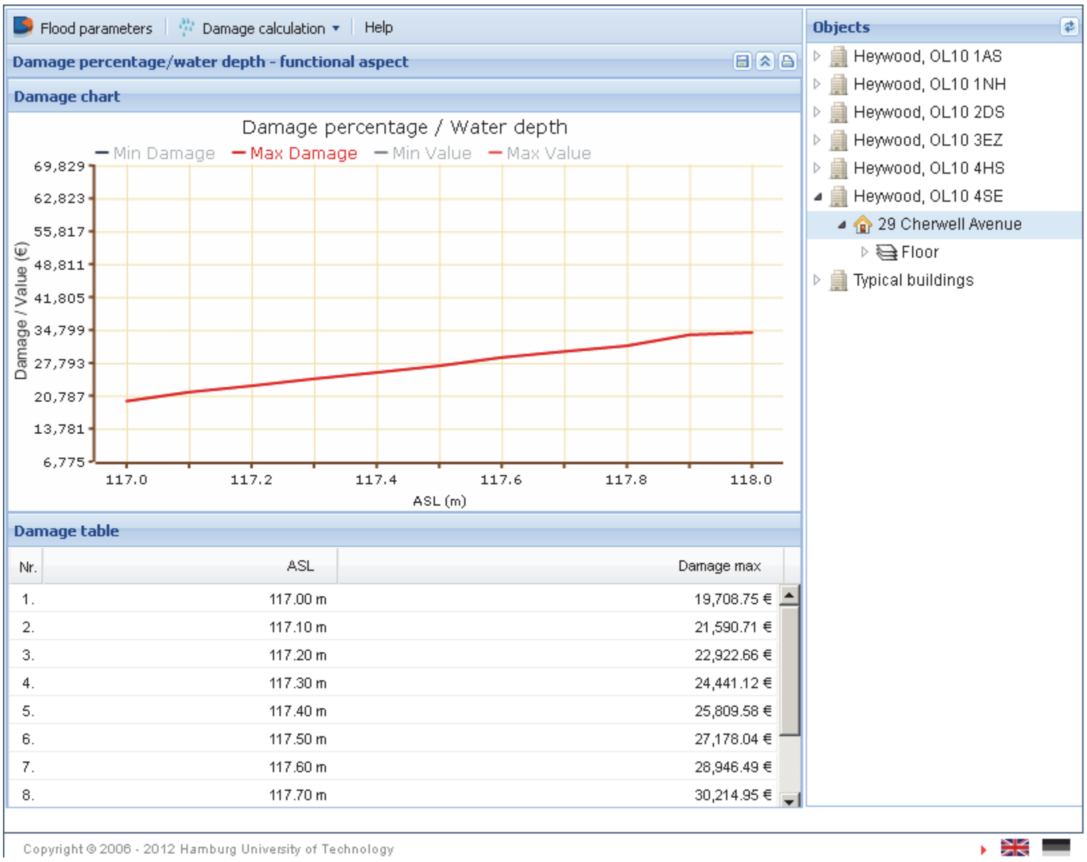


Figure 9-28 Damage assessment for ID1

ID 2. 1 MBC

This building is a single-storey detached house, without basement (Figure 9-29). The relevant information is summarised as follows:

Building condition:	**New**
Type of foundation:	Concrete
First level height:	2,7m
Number of rooms:	5
Number of openings	9
Number of walls:	16
Location of fuse:	Ground floor
Fuse level-wise:	No
Waterproof wiring:	No
Main fuse elevation:	120cm
Main socket elevation:	20cm
Sewage system type:	Combined
Non-return valve:	No
Lowest discharge elevation:	Unknown
Heating:	Gas

Figure 9-29 1 MBC

- Construction materials of the first level (prone to be flooded):

Flooring: **Concrete with carpet or tiles**
Façade: Traditional masonry, insulated cavity wall
Rooms: 5 rooms (living room, kitchen, sleeping room, bathroom, corridor) with the typical inventory

Figure 9-30 represents the floor plan of ID 2.

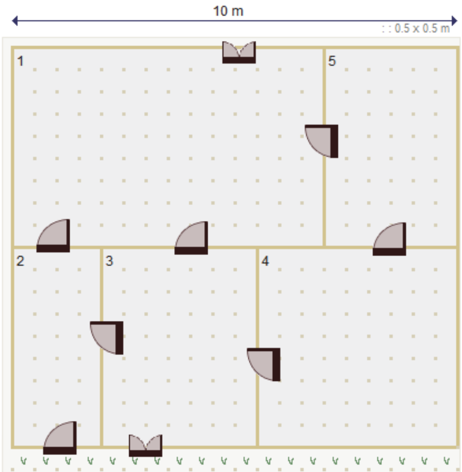


Figure 9-30 Plan view ID2

The furniture and appliances considered for ID 2 are listed in Table 9-14.

Table 9-14 ID2 Inventory

Room	Furniture	Quantity	Room	Furniture	Quantity
Living room	Armchair	1	Corridor	Commode	1
	Built-in closet	1		Floor lamp	1
	Ceiling lamp	1	Bathroom	Sanitary equipment	1
	Chair	1	Bedroom	Floor lamp	1
	Chair	3		Wall cupboard	1
	Commode	1		Warderobe	1
	Curtains	1	Kitchen	Kitchen unit	1
				Table	1

Damage/Risk Assessment:

The estimated damage is given in Figure 9-31. For the water depth of 0,80 m corresponding to the 2006 flood event, the estimated maximum damage amounts 29.000 EUR.

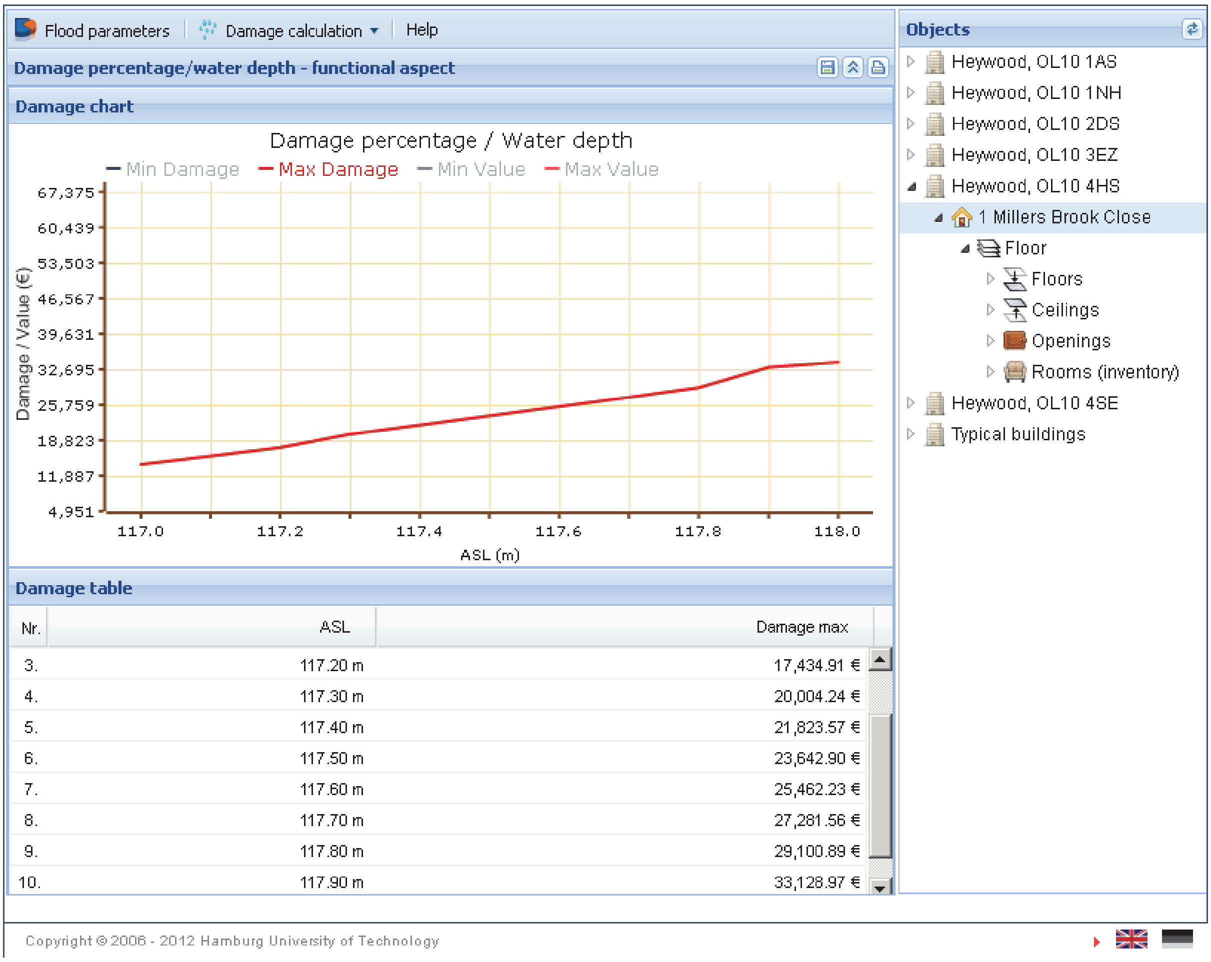


Figure 9-31 Damage assessment for ID2

ID 3. 22 MFC

This building is a two-storey semi-detached house, with basement (Figure 9-32). The relevant surveyed information is summarised as follows:

Building condition:	**Old**
Type of foundation:	Concrete
First level height:	2,7m
Number of rooms:	5
Number of openings	12
Number of walls:	16
Location of fuse:	Ground floor
Fuse level-wise:	Yes
Waterproof wiring:	No
Main fuse elevation:	90cm
Main socket elevation:	20cm
Sewage system type:	Combined
Non-return valve:	No
Lowest discharge elevation:	Unknown
Heating:	Gas

Figure 9-32 22 MFC

- Construction materials of the first level (prone to be flooded):

Flooring:	**Concrete with carpet or tiles**
Façade:	Facing brickwork, partly with plaster
Rooms:	5 rooms (living room, kitchen, sleeping room, bathroom, corridor) with the typical inventory

Figure 9-33 represents the floor plan of ID3.

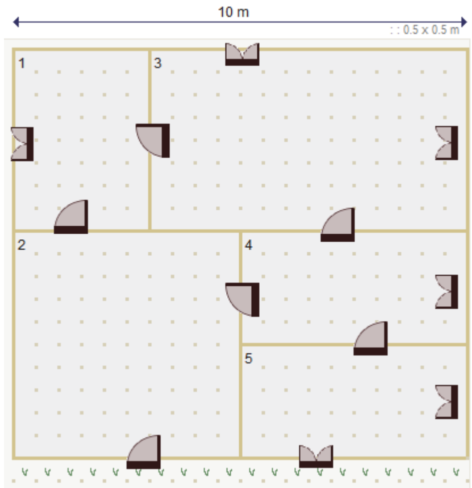


Figure 9-33 Plan view ID3

The furniture and appliances considered for ID 3 are listed in Tble 9-15.

Table 9-15 ID3 Inventory.

Room	**Furniture**	**Quantity**	**Room**	**Furniture**	**Quantity**
Living room	Floor lamp	1	Bedroom	Bed	2
	Commode	1		Built-in closet	2
	Chair	4		Chair	1
	Aimchair	1		Ceiling lamp	1
	Books	1	Corridor	Ceiling lamp	1
	CDs	1		Chair	1
	Clothes and shoes	1		rug	1
Bathroom	Sanitary equipment	1	Kitchen	Kitchen appliances	1
				Refrigerator	1
				Fitted kitchen	1

Damage/Risk Assessment:

The estimated damage is given in Figure 9-34. For the water depth of 1,00 m corresponding to the 2004 flood event, the estimated maximum damage amounts to 61.000 EUR.

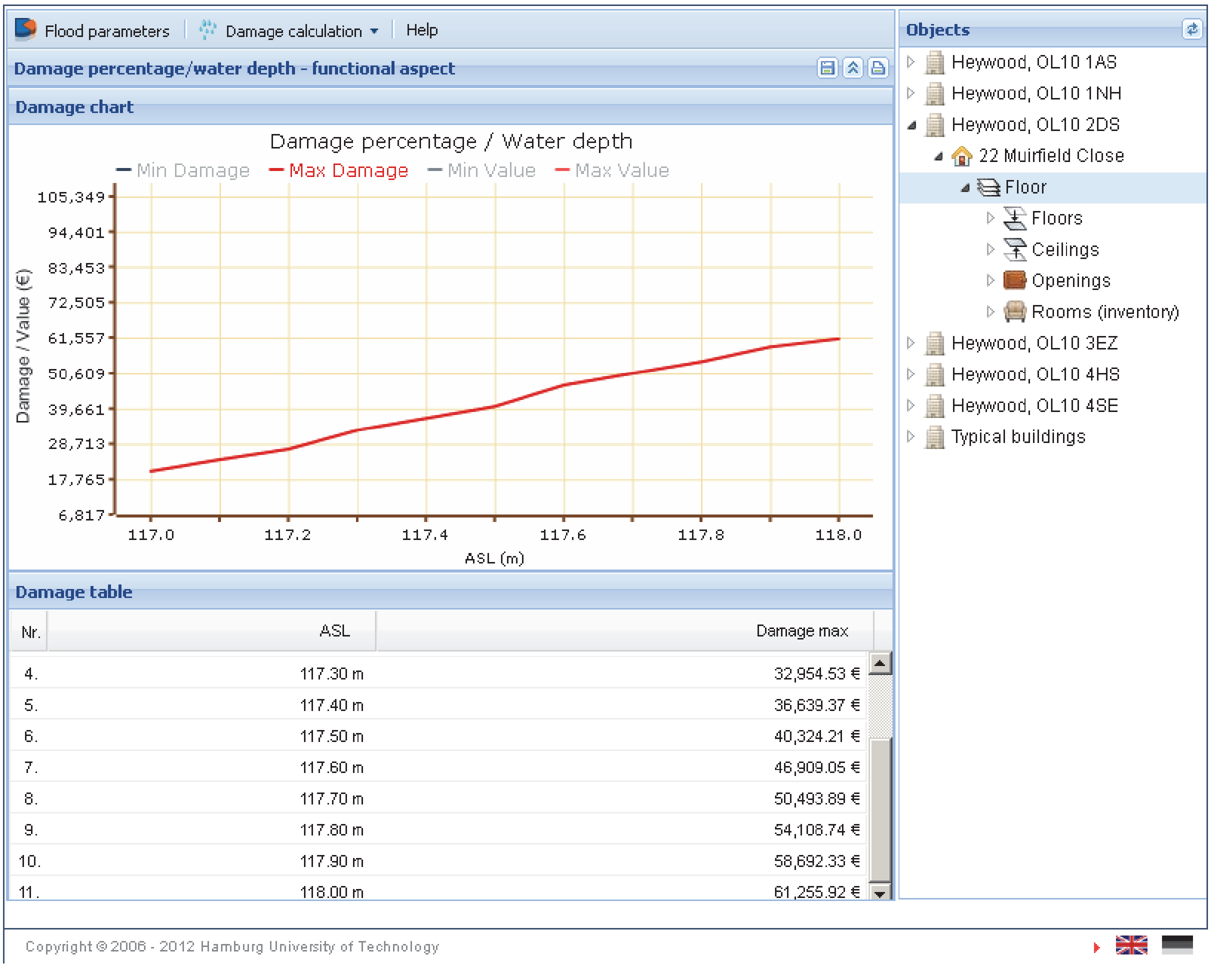


Figure 9-34 Damage assessment for ID3

ID 4. 32 PR

This building is a two-storey building row, with two-bedroom terraced homes, and no basement (Figure 9-35)

The relevant information is summarised as follows:

Building condition:
Type of foundation: Concrete
First level height: 2,7m
Number of rooms: 3
Number of openings 8
Number of walls: 10
Location of fuse: First floor
Fuse level-wise: Yes
Waterproof wiring: No
Main fuse elevation: 100cm
Main socket elevation: 30cm
Sewage system type: Combined
Non-return valve: No
Lowest discharge elevation: 20cm
Heating: District heating

Figure 9-35 32 PR

- Construction materials of the first level (prone to be flooded):

Flooring:	**Concrete with carpet or tiles**
Façade:	Brickwork (front), plaster/brickwork (back)
Rooms:	Two-bedroom home
Windows	Arched, wooden frame casement

Figure 9-36 represents the floor plan

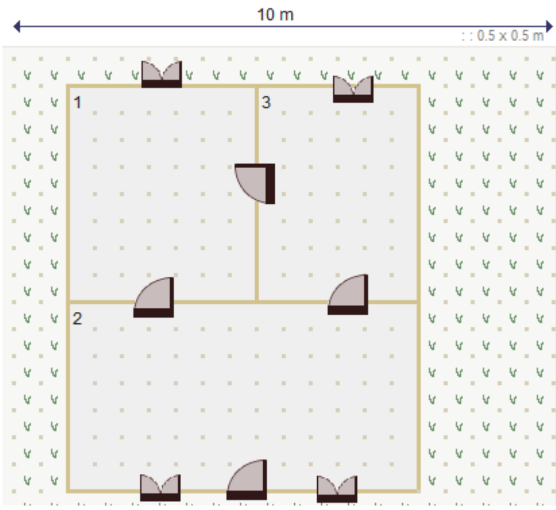


Figure 9-36 Plan view ID4

The furniture and appliances considered for ID 4 are listed in Table 9-16.

Table 9-16 ID4 Inventory

Room	Furniture	Quantity	Room	Furniture	Quantity
Kitchen	Fitted kitchen	1	Living room	Armchair	1
	Table	1		Ceiling lamp	1
	Dish washer	1		Chair	4
	Kitchen appliances	1		Commode	1
	Refrigerator	1		Curtains	2
	chair	6		Floor lamp	1
Bathroom	Sanitary equipment	1		Rug	1

Damage/Risk Assessment:

The estimated damage is given in Figure 9-37. For the water depth of 0,60 m corresponding to the 2006 flood event, the estimated maximum damage amounts 24.000 EUR.

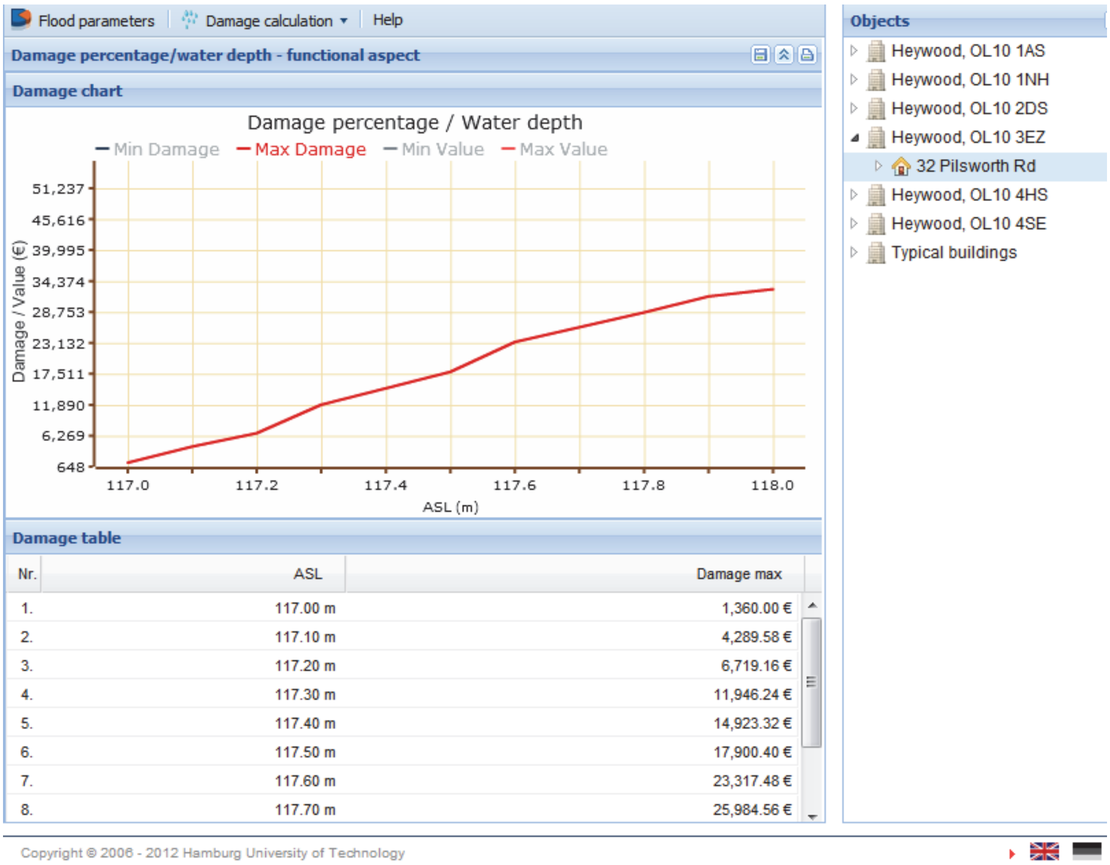


Figure 9-37 Damage assessment for ID4

ID 5. 127 RS

This property is a two-storey, terraced building with no basement comprising several housing units (Figure 9-38). The relevant information has been summarised as follows:

Building condition:	
Type of foundation:	Concrete
First level height:	2,6m
Number of rooms:	4
Number of openings	9
Number of walls:	13
Location of fuse:	First floor
Fuse level-wise:	Yes
Waterproof wiring:	No
Main fuse elevation:	260cm
Main socket elevation:	30cm
Sewage system type:	Combined
Non-return valve:	No
Lowest discharge elevation:	Unknown
Heating:	District heating

Figure 9-38 127 RS

- Construction materials of the first level (prone to be flooded):

Flooring:	**Timber suspended floor with carpet or tiles**
Façade:	Each unit has different
Rooms:	4 rooms (living room, kitchen, sleeping room, bathroom, corridor) with the typical inventory

The floor plan for FLORETO can be seen in Figure 9-39.

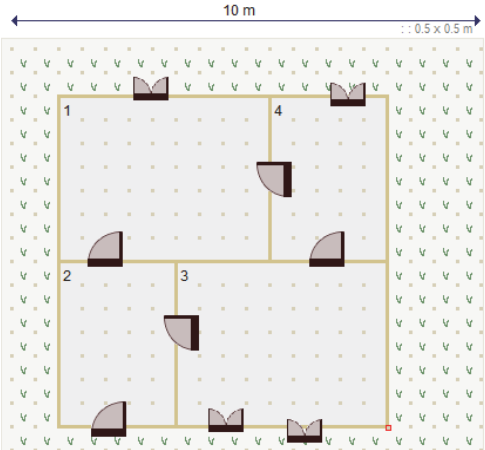


Figure 9-39 Plan view ID5

The furniture and appliances considered for ID 5 are given in Table 9-17.

Table 9-17 ID 5 Inventory

Room	Furniture	Quantity	Room	Furniture	Quantity
Living room	Armchair	2	Kitchen	Fitted kitchen	2
	Ceiling lamp	1		Chair	4
	Chairs	6		Table	1
	Curtains	1	Corridor	Rug	1
	Rug	1		Chair	1
	Sofa	1	Bathroom	Sanitary equipment	2
	Table	1		Wall cupboard	1
	TV table	1			
	Paintings	1			
	Deco	2			
	Photos	1			
	Stationary	1			
	Toys	1			
	Computer	1			
	Printer	1			
	TV	1			

Damage/Risk Assessment:

The estimated damage is given in Figure 9-40. For the flood level is 0,4m corresponding to the 2006 flood event, the estimated maximum damage amounts to 10.000 EUR.

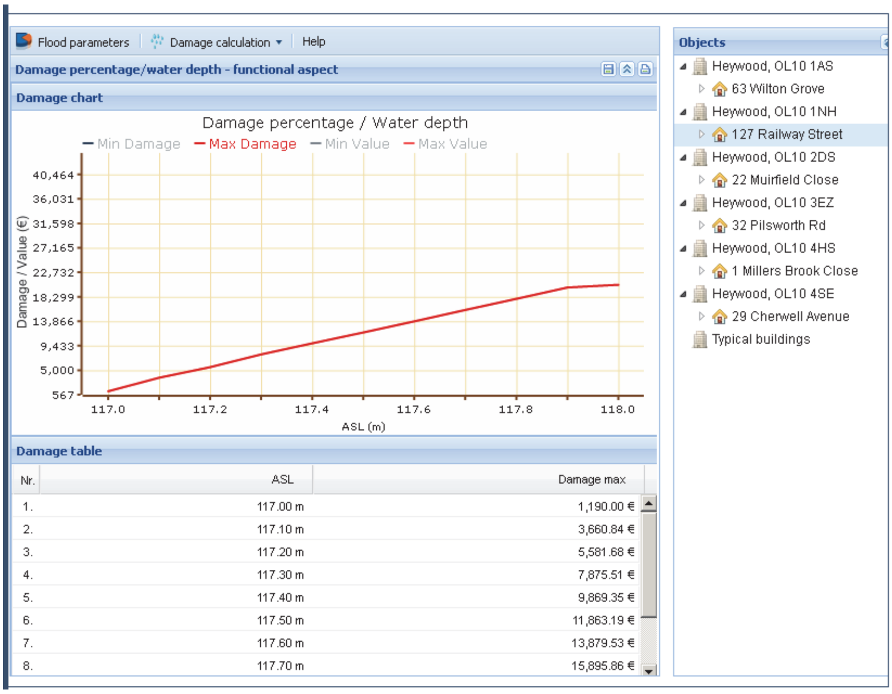


Figure 9-40 Damage assessment for ID5

ID 6. 63 WG

ID 6 is a two-storey semi-detached home without basement (Figure 9-41). The relevant information obtained during surveys is summarised as follows:

Building condition:	**Old**
Type of foundation:	Concrete
First level height:	2,7m
Number of rooms:	4
Number of openings	8
Number of walls:	13
Location of fuse:	First floor
Fuse level-wise:	yes
Waterproof wiring:	No
Main fuse elevation:	100cm
Main socket elevation:	30cm
Sewage system type:	Combined
Non-return valve:	No
Lowest discharge elevation:	Unknown
Heating:	District heating

Figure 9-41 63 WG

- Construction materials of the first level (prone to be flooded):

Flooring:	**Timber suspended floor with carpet or tiles**
Façade:	facing brickwork, plastered masonry in the 1st floor
Rooms:	Four-bedroom house
Windows:	Large bay windows in the ground floor (plastic)

Figure 9-42 represents the floor plan for the restaurant as depicted in the data collection module of the FLORETO software.

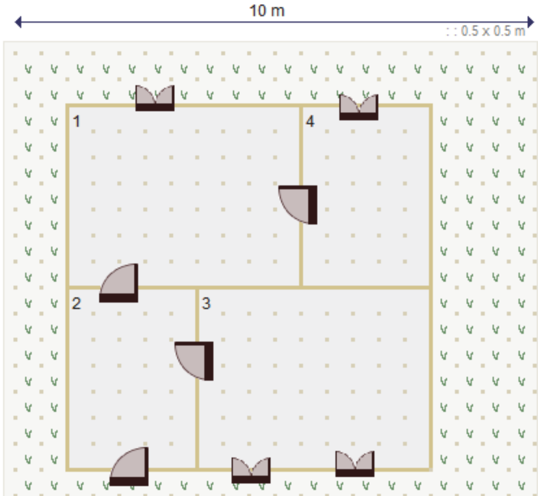


Figure 9-42 Plan view ID6

The furniture and appliances considered for ID 6 building are listed in Table 9-18.

Table 9-18 ID6 Inventory

Room	Furniture	Quantity	Room	Furniture	Quantity
Living room	Armchair	1	Kitchen	Fitted kitchen	3
	Built-in closet	1		Table	1
	Ceiling lamp	1		Chair	5
	Chair	5		Kitchen utensils	1
	Commode	1	Corridor	Rug	1
	Curtains	1		Ceiling lamp	1
	Sofa	1		Wall cupboard	1
	TV table	1	Bathroom	Sanitary equipment	1
	Telephone	1			
	CDs	1			
	Books	1			
	Paintings	1			
	Photos	1			
	Toys	1			
	Computer	1			
	Monitor	1			
	Stereo	1			

Damage/Risk Assessment:

The estimated damage is given in Figure 9-43. For the water depth of 0,25 m corresponding to the 2006 flood event, the estimated maximum damage amounts to 8.000 EUR.

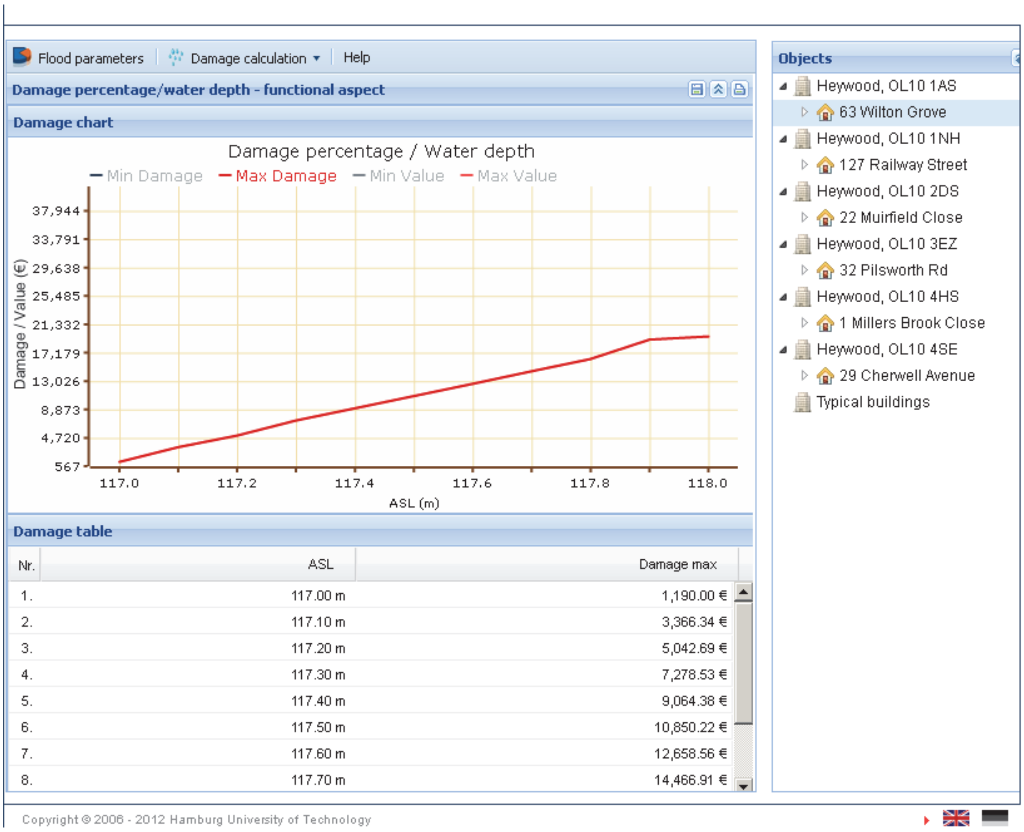


Figure 9-43 Damage assessment for ID6

Curriculum Vitae

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