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Considering Sustainability in the Development of Consumer Goods

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Für Alexandra, Ida und unseren baldigen Neuzugang

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List of Abbreviations

3E	Economics, Environment, Equity
3P	People, Planet, Profits
AMT	Amazon Mechanical Turk
ANCOVA	Analysis of Covariance
ANOVA	Analysis of Variance
B2B	Business to Business
B2C	Business to Consumer
BB	Bio-Based Plastics
bn	Billion
CED	Cumulated Energy Demand
CIRP	College International pour la Recherche en Productique
CPG	Consumer Packaged Goods
CSR	Corporate Social Responsibility
DACH	Germany, Austria, Switzerland
df	Degrees of Freedom
DfE	Design for the Environment
ECQFD	Environmentally Conscious Quality Function Deployment
EED	Energy Efficiency Directive
e.g.	Exempli gratia (for example)
et al.	Et alii (and others)
etc.	Et cetera (and so on)
EUR	Euro
f.	and the following page
FB	Fossil Fuel-Based Plastics
FMCG	Fast Moving Consumer Good
FSC	Forest Stewardship Council
G	“Green” Design
H	Hypothesis
HIT	Human Intelligence Task
i.e.	id est (that is)
ICED	International Conference on Engineering Design
LCA	Life-Cycle Analysis
LCC	Life-Cycle Costing
M	Mean
NGO	Nongovernmental Organization

NI	No Material Information
NPD	New Product Development
O	Original Design
p.	Page
pp.	Pages
PC	Post-Consumer Recycled Plastics
PLA	Polylactic Acid
PR	Public Relations
PSS	Product Service System
QFD	Quality Function Deployment
R&D	Research and Development
REACH	Registration, Evaluation, Authorization, and Restriction of Chemicals
SD	Standard Deviation
SMCG	Slow Moving Consumer Good
SME	Small and Medium-Sized Enterprise
TBL	Triple Bottom Line
TUHH	Hamburg University of Technology
UNCED	United Nations Conference on Environment and Development
U.S.	United States
USD	United States Dollar
WCED	World Commission on Environment and Development
W	Watt
WtP	Willingness to Pay

1 Introduction

Oceans clogged with plastics, toxic e-waste illegally disposed of in developing countries, or clothes sewed under inhumane working conditions – evidence that current consumption practices pose a serious threat to the economic, social, and environmental well-being of the planet is abundant (Schrader & Thøgersen 2011, p. 3; Rost 2015, p. 299 f.). In general, overconsumption along with the international division of labor is responsible for many aberrations in this respect. Consumer electronics are a prime example; particularly, cheap products produced in low-wage countries under poor working conditions, which are then shipped to western countries with a continuously decreasing lifespan use while often releasing harmful substances, and are finally exported back to developing countries for disposal. A snapshot of the recent coverage on the consequences of current consumption practices from leading newspapers is compiled in Figure 1.

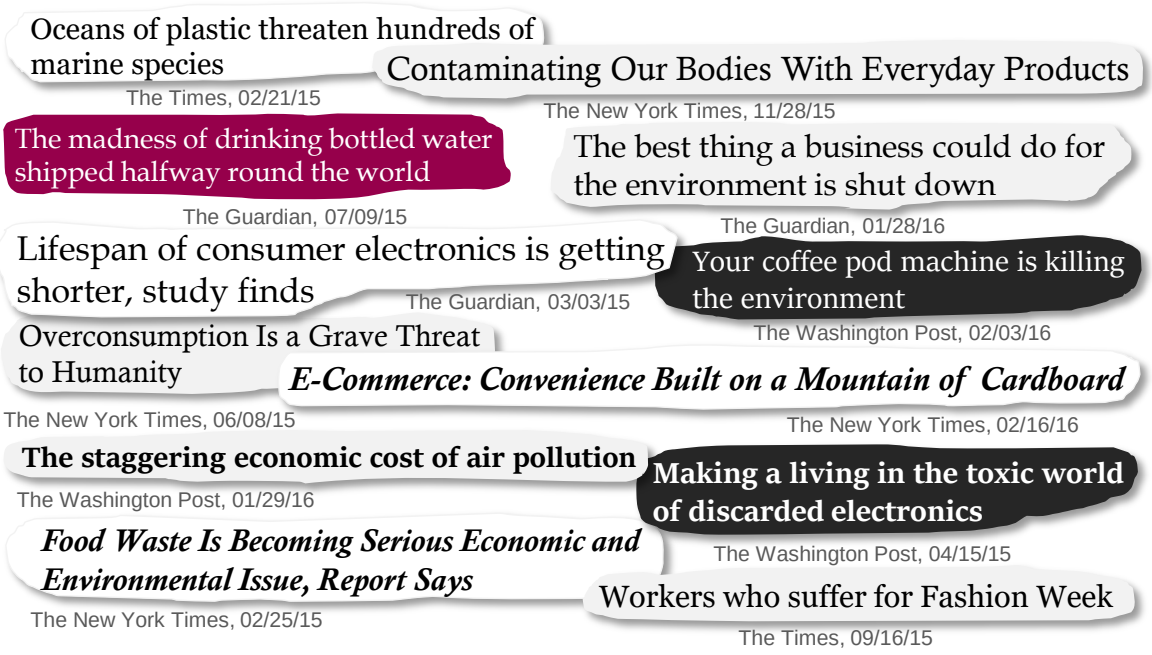

Figure 1: Headlines Covering the Consequences of Current Consumption Practices[1]

Subsumed under the goal of "improving sustainability", addressing such aberrations has been identified by academia, governments, and NGO[2] as one of the key challenges of the present and the future (Prothero et al. 2011, p. 32 f.; Pettersen 2015a, p. 252 f.). This challenge can be met through (1) a significant change in current consumer behavior (Pettersen & Boks 2008, p. 287; Strömberg et al. 2015, p. 163) and (2) products that are clearly more sustainable than most of today's products (Boks & McAloone 2009, p. 442 f.;

[1] Sources of newspaper headlines are provided in Appendix I.

[2] NGO = nongovernmental organization.

Dangelico et al. 2013, p. 643). Thus, the primary factors of the sustainable consumption equation are demand and supply – the population that buys everyday products and the companies that develop, produce, and sell them (Luchs & Miller 2015, p. 254).

On the demand side, consumer surveys report a willingness to change consumption behavior (i.e. buying less or at least buying more consciously). However, such studies potentially suffer from severe social desirability bias: participants provide answers they feel obligated to give on the survey because it comes at no extra cost – often different from the real-life purchasing decision. Thus, consumers' claims may not translate into actual behavioral changes (Luchs et al. 2010, p. 29). As a result, a plethora of studies finds that consumers value product sustainability more and more (Otto Group 2013, p. 38 f.; Nielsen 2015, pp. 8–10; Consumer Council 2016, p. 20 f.). In reality, this is only reflected in consumers' purchasing decisions to a minor extent (Esty & Simmons 2011, p. 269; Luchs et al. 2012, p. 903). Thus, more research is called for to understand and influence individuals about consuming in a more sustainable way (Phipps et al. 2013, p. 1232; Luchs & Miller 2015, p. 265).

On the supply side, many of the negative externalities of a product's manufacture and use (e.g. pollution or energy consumption) are already designed into the product itself (Hopkins 2010, p. 76). Hence, companies need to tackle sustainability in the product development stage, at which all substantial features and properties of a product are defined (Ponn & Lindemann 2011, p. 273). Thus, product development to a great extent predetermines a product's sustainability performance for its entire life-cycle (Woll et al. 2011, p. 851). However, while "unsustainable" products readily come to mind (e.g. leaf blowers or deck flooring from tropical woods), it is challenging to think of a product that – if industrially mass produced, used, and disposed – truly has no, or at least only marginal, negative impact on anything and anybody (Diegel et al. 2010, p. 69; Petersen 2015, p. 92). Generally speaking, it remains elusive what exactly constitutes a more sustainable product (Brockhaus et al. 2016a, p. 128 f.). Definitions available in the literature necessarily have to remain on a quite abstract level. One widely used definition understands more sustainable products as "all kinds of products that have or aim at an improved environmental and social quality (…). The ultimate aim is to satisfy customers and gain a competitive advantage in the market" (Seuring & Müller 2008, p. 1705). Since sustainability is generally understood as being a relative concept, numerous contradictory possibilities to incrementally improve product sustainability emerge. Today, developing more sustainable products is on the agenda of many companies even though a clear vision of their properties is missing.

1.1 Research Objective and Research Questions

Adding sustainability to a product's requirement list complicates an already complex process. Besides the paramount technical challenges, it also adds contextual factors to be considered (Alblas et al. 2014, p. 519): for example, managing stakeholders and supply chain relationships (Goffin 2012, p. 111). Research on product development traditionally focuses on developing solutions for such challenges in the form of methods and tools (Ponn 2016, p. 413). This also holds true for sustainable product development (Klöpffer 2003, p. 157). However, this approach may not meet the true needs of companies since research often has too little insight into the real challenges of the industry (Ponn 2016, p. 411). Specifically, while practitioners are concerned with the details of developing products in the light of severe project constraints, researchers are often focusing on generic frameworks and universally applicable methods. They concentrate on the bigger picture and pay little attention to the constraints of individual projects (Ponn 2016, p. 413). A gap between theory and practice emerges. As a result, most of the sustainability-related methods proposed in the literature do not make it into the product development process of any company (Baumann et al. 2002, p. 418 f.; Hallstedt 2008, p. 35 f.; May et al. 2012, p. 444).

Even though an extensive body of literature on sustainable product development exists (this will be substantiated in Chapter 3), little is known about the practical implications of the rather fuzzy notion of sustainability on established development processes (Woll et al. 2011, p. 850). To date, only limited empirically-grounded research analyzes the specific ways companies use for meeting the challenge of developing more sustainable products. Nevertheless, especially before the looming danger of sustainability being degraded to a hollow marketing phrase, moving beyond the hype is deemed promising (Diegel et al. 2010, p. 68). Product development appears to be a suitable starting point since sustainability requirements for products are often fuzzy (Alblas et al. 2014, p. 518) and must be translated into a heap of objective, measurable, and reproducible product properties. Thus, the research objective of the current dissertation is stated as follows:

Research Objective:	**Gaining a better understanding of how product sustainability is accounted for in product development and contributing to the further adoption of sustainability principles through identifying best practice examples.**

The research objective is directly derived from the phenomenon of growing sustainability awareness, as described previously. Thus, it is a both timely and relevant topic. Three research questions are put forward concerning the research objective; Figure 2 provides an overview.

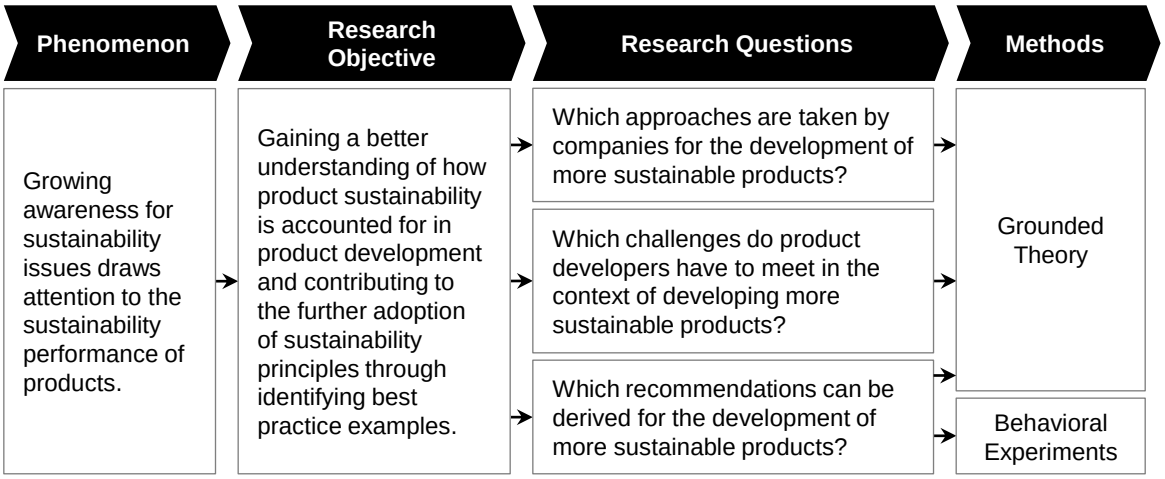

Figure 2: Phenomenon, Research Objective, Research Questions, and Methods

The first research question is concerned with identifying, comparing, and describing different strategies companies employ to include the notion of sustainability in their product development processes. It reads as follows:

Research Question 1:	**Which approaches are taken by companies for the development of more sustainable products?**

As has been established, considering sustainability in product development drives complexity and warrants additional academic attention. However, to conduct meaningful (especially conceptual) research, a sufficient knowledge of the actual challenges product developers face in their daily work is necessary. As extant research is frequently criticized for a lack thereof, the second research question is stated as follows:

Research Question 2:	**Which challenges do product developers have to meet in the context of developing more sustainable products?**

For addressing the first two research questions, an explorative, qualitative study utilizing a Grounded Theory approach is taken. Its goal is to generate meaningful insights into companies' approaches and challenges. Through comparing best practices across cases, it is also designed to help derive recommendations for practice. However, as it is typically not possible to generalize findings from qualitative studies beyond the sample, some findings will also be backed up quantitatively. Thus, the third research question concerned with recommendations for practice is also addressed by means of a quantitative study building on behavioral experiments. It reads as follows:

Research Question 3:	**Which recommendations can be derived for the development of more sustainable products?**

1.2 Research Structure

To address the underlying research questions, the current manuscript builds on two empirical analyses that are embedded in seven consecutive chapters (see Figure 3). In the following *Chapter 2*, this dissertation's reference framework is established through introducing and delimiting the associated terminology of product development, the concept of sustainability, and consumer goods. *Chapter 3* maps the existing state of research on managing sustainability in product development using an extensive literature review. Relevant streams and findings in the literature are highlighted, and the research questions of this dissertation are substantiated. *Chapter 4* introduces this dissertation's research design that consists of a two-stage, mixed-methods approach. The method choices for the qualitative and the quantitative research phase are accounted for, and the fundamental assumptions and procedural requirements of Grounded Theory studies and behavioral experiments are proposed and related to each other.

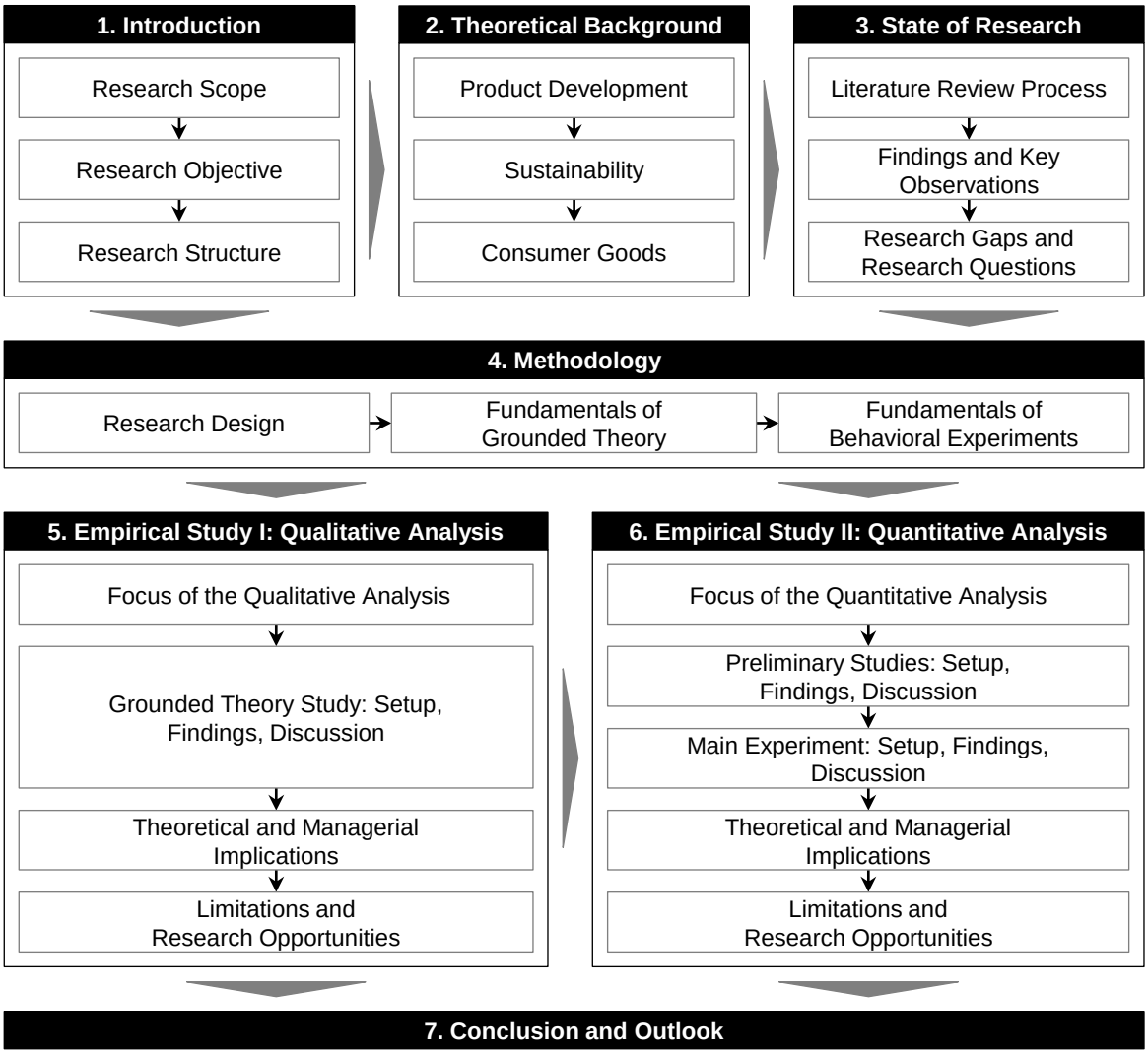

Figure 3: Structure of this Manuscript

Chapter 5 then reports details on the qualitative research phase. The focus and findings of the Grounded Theory study that mainly builds on data from interviews with product development managers are laid out. Implications for theory and the management of sustainable product development in practice are put forward. Also, opportunities for further qualitative and quantitative inquiries are highlighted and presented in the form of research propositions. *Chapter 6* reports the setup, findings, discussion, implications, and limitations of the quantitative research phase. It consists of three preliminary studies and one main behavioral experiment directly building on parts of the findings from the qualitative research phase. For this purpose, a shift of perspective is undertaken as the consumers' evaluation of product developers' efforts to improve and communicate product sustainability is investigated. More specifically, the roles of the exterior design and the material choice for consumers' sustainability evaluation are examined. *Chapter 7* concludes this dissertation through revisiting its underlying research questions and matching them with the main findings of the empirical studies. Further, an outlook is provided.

2 Theoretical Background

Before immersing into the dynamics of managing sustainability in the development of consumer goods, this dissertation's reference framework is to be established. For this purpose, the scope of the topic is defined, and associated terminological delimitations are put forward. Thus, the essential fundamentals of product development, the concept of sustainability, and the specifics of the consumer goods industry are introduced in the following. Of note, for each term, there is an abundance of definitions available in the literature. Since this chapter aims at providing a reasonable background of the terminology and not at discussing specific wordings, only the most relevant definitions are introduced.

2.1 Product Development

First, it is necessary to establish the understanding of product development that underlies this dissertation. This is accomplished by providing definitions for relevant terms, outlining a generic development process along with its most important activities, and demonstrating the importance of life-cycle thinking in product development.

2.1.1 Defining Product Development

A product is defined as "something sold by an enterprise to its customers" (Ulrich & Eppinger 2016, p. 2). Thus, a product can either be a physical artifact, a service, software, a process, or a combination of them (Hallstedt 2008, p. 3). This dissertation focuses on physical products that might be supplemented by services. For defining the development of such physical products, two major conceptual approaches have to be distinguished in the literature. Especially German authors follow an engineering-driven take on the subject: their understanding of product development often focuses on the activity of implementing predefined specifications into the geometric and material attributes of a product (e.g. Pahl et al. 2007, p. 4 f.; Ehrlenspiel 2009, p. 244). Thus, they rather focus on product development as a department. Other authors like Krishnan & Ulrich favor a much broader definition: they understand product development to be "the transformation of a market opportunity and a set of assumptions about product technology into a product available for sale" (2001, p. 1). Thus, they take a business process perspective as their definition covers all engineering tasks but extends to other necessary departments as well. Such an understanding is concordant with the cross-disciplinary view on product development prevalent in practice (Townsend et al. 2011, p. 374 f.). However, as Krishnan & Ulrich define "a product available for sale" as being the outcome of product development (2001, p. 1), they also consider the production process. Therefore, the definition provided by Otto & Wood (2001) is preferred to illustrate this dissertation's understanding of product

development. They also consider marketing and preparatory manufacturing tasks and define product development as being

„*the entire set of activities required to bring a new concept to a state of market readiness*" (Otto & Wood 2001, p. 5).

Several other management processes like innovation management, R&D[3] management, and technology management overlap with product development and have to be differentiated from each other (Specht et al. 2002, p. 16 f.; Gerpott 2005, pp. 54–56): *Innovation management* is concerned with the entire innovation process starting with basic research (i.e. gaining basic scientific insights without focusing on practical applications) and ending with introducing products into the marketplace. R&D management, technology management, and product development on the other hand are understood as covering only parts of the overall innovation process. *R&D management* is defined as only excluding the market phase. *Technology management*, on the other hand, focuses on the tasks of technology development (i.e. finding solutions for existing problems) and advance development (i.e. implementing new technologies into components). Finally, *product development* starts with a product concept, incorporates advance development and the actual development process, and ends with the product and the necessary production processes being ready for full-scale production. A graphical delimitation of the four management processes is depicted in Figure 4. As this dissertation focuses on the product development process, early innovation management tasks often subsumed as the "fuzzy front end" (Herstatt & Verworn 2001, p. 3) will not be considered. Also, the operational execution of full-scale production is beyond this dissertations' scope. However, the basic preconditions for the production process are already determined through product development activities.

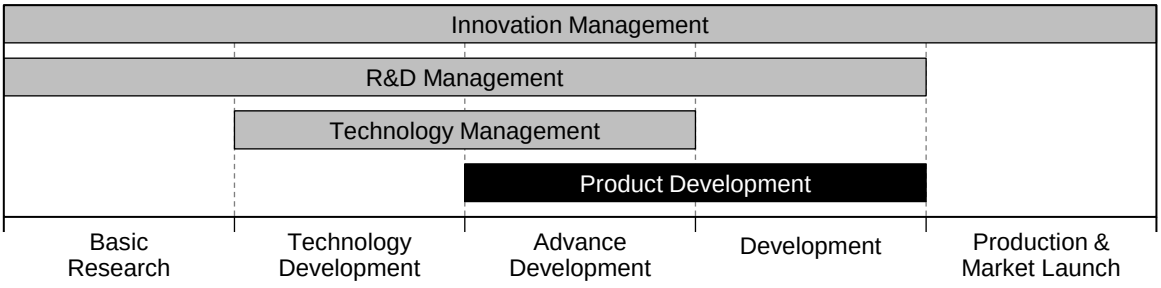

Figure 4: Terminology Delimitation in the Product Development Context (adapted from Specht et al. 2002, p. 16 f.; Gerpott 2005, pp. 54–56)

Product development projects in practice are as unique as their resulting products. Figure 5 showcases five exemplary product development projects along with the major figures

[3] R&D = Research and Development.

about product characteristics and the associated development efforts. It is evident that developing complex investment goods like airplanes can cost several billion USD, occupy thousands of developers and take several years until the product is ready for manufacturing (Tang et al. 2009, p. 77). Nevertheless, even quite simple consumer goods like screwdrivers consisting of as little as three unique parts necessitate considerable development efforts and therefore warrant a well-defined product development process.

	Stanley Screwdriver	Rollerblade In-Line Skate	iRobot Roomba	Tesla Model S	Boeing 777
					
Annual production volume	100,000	100,000	2 million	50,000	100
Sales lifetime	40 years	3 years	2 years	5 years	30 years
Sales price	$5	$150	$500	$80,000	$260 million
Number of unique parts	3 parts	35 parts	1,000 parts	10,000 parts	130,000 parts
Development time	1 year	2 years	2 years	4 years	4.5 years
Internal development team	3 people	5 people	100 people	1,000 people	6,800 people
External development team	3 people	10 people	100 people	1,000 people	10,000 people
Development cost	$150,000	$750,000	$50 million	$500 million	$3 billion

Figure 5: Attributes and Associated Development Efforts of Different Product Types[4] (adapted from Ulrich & Eppinger 2012, p. 5, 2016, p. 5)

Apart from the type of the product, development projects can be distinguished by their scope and level of innovativeness (Ulrich & Eppinger 2016, p. 55 f.): Developing *new product platforms* means creating a common basis for an entirely new family of products. *Derivatives of existing product platforms* are developed to trigger new markets with enhancements of existing product platforms. If a development project is about slightly modifying a product already on the market (e.g. for keeping the product competitive), these modifications are *incremental improvements* to existing products. Finally, *fundamentally new products* incorporate new technologies and trigger new and unfamiliar markets. The latter are high-risk projects since they are exposed to a high level of uncertainty and often fail to be successful in the marketplace.

2.1.2 Product Development Process

Regardless of the type of the product or the project's scope, a more or less standardized development process defining the sequence of activities to be undertaken is followed for most product development projects in practice (Albrecht et al. 2013, p. 32 f.). Since each of these processes is understood to be unique and individual (Albers et al. 2010, p. 15), it is

[4] See Appendix II for sources of the product pictures.

not possible to describe a detailed development process applicable for all industries (Otto & Wood 2001, p. 17). However, generic development processes outlining the most important tasks for every phase are proposed in the literature (see e.g. Wildemann 2005, p. 8; Bender & Gericke 2016, pp. 412–414). These process models are often similar to each other and only differ with respect to the number of phases and specific terminology. Figure 6 displays the process model put forward by Ulrich & Eppinger (2016, p. 14).

	Exemplary Design Tasks	Exemplary Marketing Tasks	Exemplary Manufacturing Tasks
Planning	▪ *Consider* product platform and architecture ▪ *Assess* new technologies	▪ *Articulate* market opportunity ▪ *Define* market segments	▪ *Identify* production constraints ▪ *Set* supply chain strategy
Concept Development	▪ *Investigate* feasibility of product concepts ▪ *Develop* industrial design concepts	▪ *Collect* customer needs ▪ *Identify* competitive products	▪ *Estimate* manufacturing cost ▪ *Assess* production feasibility
System-Level Design	▪ *Develop* product architecture ▪ *Define* major sub-systems and interfaces	▪ *Develop* plan for product options and extended product family	▪ *Identify* suppliers for key components ▪ *Perform* make-buy analysis
Detail Design	▪ *Choose* materials ▪ *Complete* industrial design control documentation	▪ *Develop* marketing plan	▪ *Define* piece-part production processes ▪ *Define* quality assurance processes
Testing & Refinement	▪ *Test* overall performance, reliability, and durability ▪ *Assess* environmental impact	▪ *Develop* promotion and launch materials ▪ *Facilitate* field testing	▪ *Facilitate* supplier ramp-up ▪ *Refine* fabrication and assembly processes
Production Ramp-Up	▪ *Evaluate* early production output	▪ *Place* early production with key customers	▪ *Begin* full operation of production system

Figure 6: Generic Product Development Process
(adapted from Ulrich & Eppinger 2016, p. 14)

Their generic product development process consists of six distinct phases covering every step from product planning to production ramp-up along with each phase's most important tasks for the departments product design, marketing, and manufacturing. Thus, it does not limit its focus to product engineering but also takes into account the tasks executed by other departments (e.g. perform field tests of prototypes in marketing or design of tooling in manufacturing). Nevertheless, a generic process model can only be a theoretical breakdown of a highly complex issue: First, in practice, the activities might not necessarily be executed in a linear fashion as most development processes in practice incorporate iterative elements (Bender & Gericke 2016, p. 405). Second, not all activities are relevant for every product type or project scope. Finally, it has to be kept in mind that virtually every

task is a challenging issue and, thus, also a long-established field of research of its own. For example, there are extensive bodies of literature on single tasks like defining the product architecture (e.g. Ulrich 1995; Fixson 2005), collecting customer needs (e.g. Urban & von Hippel 1988; Griffin & Hauser 1993), or setting up a supply chain strategy (e.g. Fisher 1997; Martin & Towill 2002).

2.1.3 Influence of Product Development on Product Life-Cycle

Historically, product development projects were primarily geared towards improving product functions and product quality. Later, attention was also paid to product costs (Kersten 1998, p. 415). Thus, around 1970 to 1980, research and practice alike began to investigate opportunities for decreasing product costs through constructive measures. During that period, the dictum that "70–80 percent of all product costs are already determined in early product development" emerged. It builds on two publications (Nißl 2006, p. 23): while the first one (i.e. Ehrlenspiel 1980) refers to a survey undertaken in 1978 with 42 participating companies from different industries, the second one (i.e. Bronner 1968) does not disclose any documented empirical foundation for its claims. Despite its weak substantiation, the dictum is still widespread today (see Lübke 2007, pp. 70–72 for an overview). Figure 7 provides a typical example of a corresponding distribution of determined and incurred product costs on the respective departments.

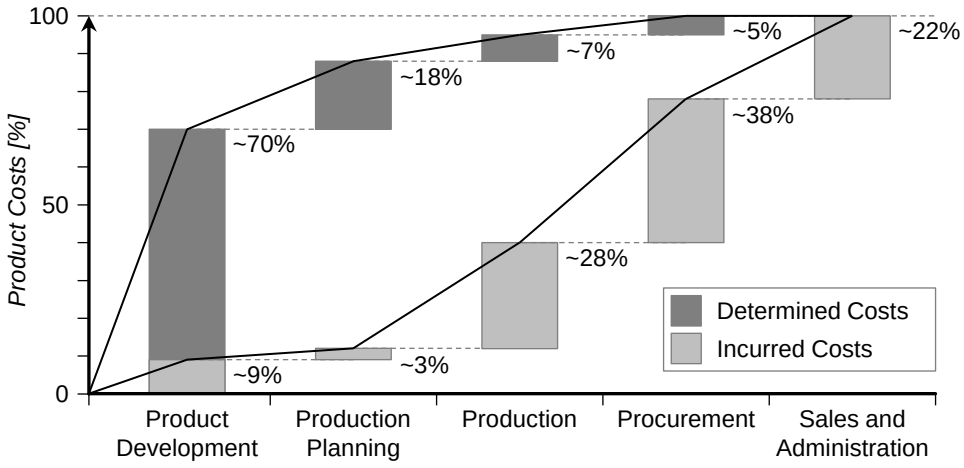

Figure 7: Determined and Incurred Product Costs per Department (adapted from Ehrlenspiel et al. 2014, p. 15)

Even though the general conditions for product development have changed quite a bit since 1978 (see e.g. Schäfer & Apostolov 2014, p. 374; Spath & Dangelmaier 2016, pp. 3–7), no comparable surveys have been undertaken to update Ehrlenspiel's findings (Nißl 2006, p. 25). While it is probable that today's distribution of determined and incurred product costs on departments will look different, it is likely that the general notion that a large share of the product costs is decided upon during product development still holds true.

When environmental and social issues gained importance during the 1980ies, the cost-dictum was extended: it became acknowledged that product development also plays a key role in determining the overall life-cycle[5] performance of a product (Hallstedt 2008, p. 1; Walther 2010, p. 130). However, especially the environmental and social impacts products can incur are often not as easily measurable as costs. Thus, product development's leverage can only be estimated. Nevertheless, it is evident that product development can at least theoretically influence the product's performance in all life-cycle phases (Ponn & Lindemann 2011, p. 278) and that the size of this influence depends on the product type. Figure 8 illustrates this for one specific aspect through comparing the shares of different life-cycle phases in the cumulated energy demand (CED)[6] of different consumer goods (Walther 2010, p. 153).

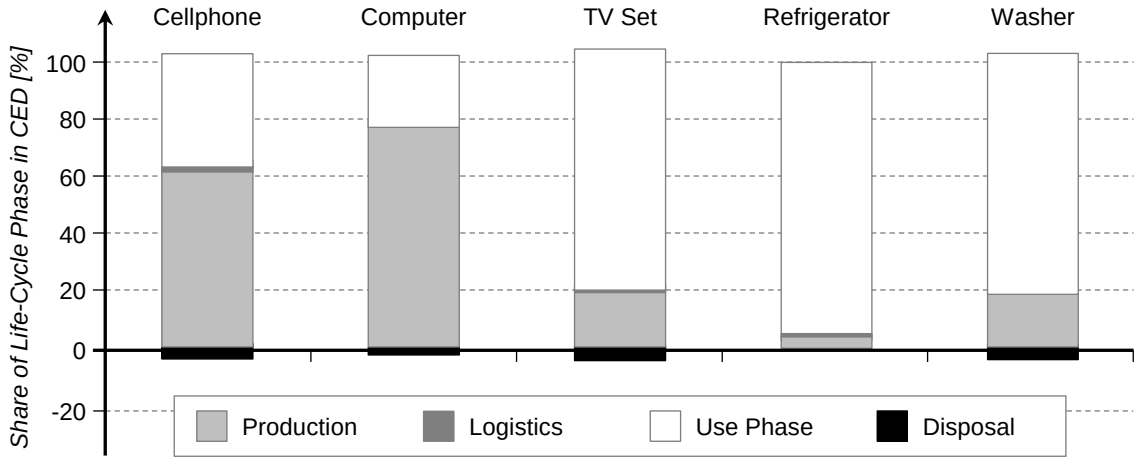

Figure 8: Cumulated Energy Demand of Exemplary Consumer Products across Life-Cycle (adapted from Walther 2010, p. 153)

In the case of computers, for example, most energy is used in production. Thus, product development could improve the CED through enabling the use of more energy-efficient production technology. Such an initiative is also directly beneficial for the company's financial bottom line. For refrigerators, on the other hand, more than 95 percent of the CED stems from the use phase. Here, product development could rather reduce the CED through improving the energy efficiency of the cooling system or influencing the users' behavior.

[5] The term „life-cycle" is used in different ways throughout the literature. From a marketing perspective, it charts the rise and fall of a product project's sales and profits starting with market introduction and ending with its withdrawal from the market (Belz & Peattie 2009, p. 56). From the perspective of an individual product, the life-cycle describes the product's life from the extraction of the raw-materials to the product's disposal (Belz & Peattie 2009, p. 56). This dissertation exclusively refers to the life-cycle from the perspective of an individual product (cradle to grave). Thus, depending on the user behavior and available opportunities for re- or upcycling, the life-cycles of two identical products most probably differ from each other.

[6] The CED is a widely-used single-score indicator for life-cycle impact assessment and "represents the direct and indirect energy use, including the energy consumed during the extraction, manufacturing and disposal of the raw and auxiliary materials" (Huijbregts et al. 2010, p. 2189). It only considers one aspect of a product's environmental performance. Examples of other indicators used in life-cycle analyses are abiotic depletion, ecotoxicity, human toxicity, acidification, and eutrophication (Choi et al. 2006, p. 125).

Finally, a product's disposal process is likely to consume energy but also can allow for reclaiming energy given that the product has been designed keeping an eye on reusability or recyclability of components and materials. Thus, energy gains with respect to a product's disposal can compensate some energy used for its production, logistics, and use.

Taken together, product development has a major stake in predetermining a product's environmental, social, and financial performance throughout its entire life-cycle. Even though the actual product performance is ultimately defined by other internal and external stakeholders that produce, use, and dispose the product, the groundwork is laid through numerous decisions made during the product development process.

2.2 Sustainability

In this section, the concept of sustainability along with definitory approaches is introduced and applied to the business context. Furthermore, it is put forward which understanding of sustainability is followed by this dissertation and how it relates to developing products.

2.2.1 Defining Sustainability

The concept of sustainability has its origins in silviculture. In 1713, von Carlowitz advocated a moderated exploitation of the woods since intensified mining activities had led to an increased demand for wooden boards (Hamberger 2013). He demanded that the amount of wood taken out of a forest should be geared to the forest's ability to regrow. At the beginning of the 20th century, the idea of sustaining the stock of scarce and slowly growing natural resources (through observing the "maximum sustainable yield") was transferred to fishery (Brown et al. 1987, p. 714; Clement et al. 2014, p. 21). Thus, following contemporary terminology, the first discussions about sustainability focused on environmental aspects.

Today's three-dimensional notion of sustainability arose in the context of society's growing awareness of global problems like poverty and environmental pollution during the second half of the 20th century (Mulligan 2015, p. 12 f.). In 1972, the think tank "Club of Rome" published its simulation study on the coactions of population growth, industrialization, environmental pollution, food production, and resource depletion (Meadows et al. 1972). They predicted that an unlimited growth of these factors would lead to a global collapse within the next 100 years (Meadows et al. 1972, p. 23) and thus advocated to strive for a state of equilibrium between economy and environment. A second milestone for raising awareness for sustainability issues on the macro level is the report "Our common future" that got published by the World Commission on Environment and Development (WCED) in 1987. Four years earlier, the WCED (the so-called Brundtland Commission) had been set up under the lead of the Norwegian Prime Minister Gro Harlem Brundtland. It aimed at

deriving recommendations for a “sustainable development” of the world to prevent a collapse as predicted by Meadows et al. (1972, p. 23). In its report, sustainable development was defined as

> “*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*” (WCED 1987, p. 43).

This definition builds on the two key concepts “needs” and “limitations”. Needs are understood as the “essential needs of the world’s poor, to which overriding priority should be given” whereas limitations are “imposed by the state of technology and social organization on the environment’s ability to meet present and future needs” (WCED 1987, p. 43). Later, the 1992 United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro and the subsequent 1996 Habitat II Conference in Istanbul further refined this definition by stating that sustainable development should incorporate the economic, social, environmental, cultural, and ethical development of the world (UN Habitat 1996). Since then, research has discussed these definitions intensively and – depending on the field of research and cultural background – specified it multiple times (see e.g. Dyllick & Hockerts 2002, p. 131; Belz & Peattie 2009, p. 12). However, some constituent characteristics for global sustainable development emerged over time: equitable access to resources for all people coexisting on the planet (intergenerational justice) as well as for today’s and tomorrow’s generations (intragenerational justice), satisfaction of human needs (anthropocentric focus), and gearing to the global society as a whole (Hort 2008, p. 33 f.; Belz & Peattie 2009, p. 11; Mulligan 2015, p. 21). The last and probably most discussed characteristic of the concept of sustainable development is the simultaneous, harmonious, and coequal consideration of the economic, environmental, and social dimensions. Thus, the cultural and ethical aspects of global sustainable development are seldom covered in the contemporary sustainability discourse (Flämig 2014a, p. 32).

The economic, environmental, and social dimensions represent public interests deserving protection through adequate political measures. *Economic sustainability* on the macro level is achieved through organizing the economy in a way that it serves as a stable basis for enduring prosperity and employment. From the supply side, this means using the production factors in an efficient way for providing goods and services. From the demand side, this means providing an income high enough to finance an adequate standard of living (Clement et al. 2014, p. 25; Kollig 2014, p. 11). *Environmental sustainability* is accomplished through preserving nature and environment for future generations. This incorporates conserving biodiversity and the countryside as well as the thoughtful use of natural resources (Clement et al. 2014, p. 25; Kollig 2014, p. 8 f.). Finally, *social sustainability* means meeting basic needs, poverty reduction, and equality of opportunities. Also, human rights and the right of

co-determination have to be ensured to achieve social sustainability (Clement et al. 2014, p. 25; Kollig 2014, p. 14 f.). Only if all three dimensions are equally addressed, global development can be considered sustainable. However, most sustainability aspects are at odds with each other and bear areas of severe conflicts.

Sustainable development as put forward by the Brundtland Commission is defined as a relative concept. Through simultaneously improving the three dimensions, a subject can be made more or less sustainable over time. Thus, sustainable development can be considered the process of making subjects less unsustainable. This perspective is embraced by authors endorsing the reformist approach aiming at maintaining the current economic system (i.e. common ways of production and consumption) while reducing the harms it entails (Belz & Peattie 2009, p. 13; Clifton & Amran 2011, p. 122).

A relative definition of sustainability evokes severe criticism from authors following the transformational approach as they assume the current economic system to be the cause of lacking sustainability. Thus, they strive for far more radical solutions that would transform extant societies and economies (Belz & Peattie 2009, p. 13; Clifton & Amran 2011, p. 122). Ehrenfeld, as one prominent example, argues that considering sustainability as a relative concept inevitably leads to “quick fixes” which he describes as myopic measures that try to make a subject less unsustainable. However, while these measures might indeed aim into the right direction, they ultimately treat the symptoms of the current unsustainable economic system instead of helping to solve the underlying problems (2008, pp. 17–21). Thus, he defines sustainability as

> “*the possibility that human and other life will flourish on the earth forever*” (Ehrenfeld 2008, p. 49).

From his point of view, “sustainability means nothing without an end in sight” (Ehrenfeld & Hoffman 2013, p. 15). Therefore, it should be considered as the absolute state of a system. Hence, a subject can either be sustainable or not sustainable, but it cannot be more or less sustainable compared to another subject. The absolute and the relative understanding of sustainability are illustrated in Figure 9.

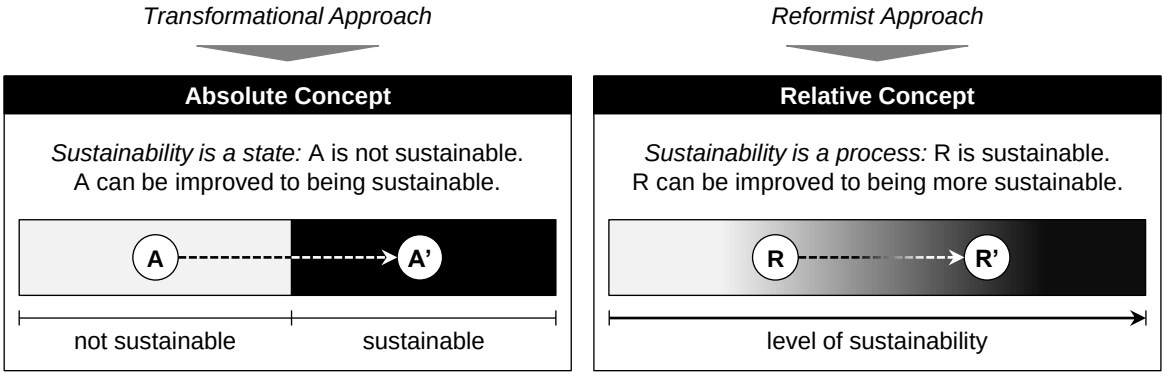

Figure 9: Absolute and Relative Understanding of Sustainability (adapted from Brockhaus 2013, p. 33)

Both approaches towards sustainability are eligible, and both groups of supporters produce compelling arguments for their respective approach. However, since the absolute approach lacks implementable concepts (Brockhaus 2013, p. 34), the relative take on sustainability is chosen as the theoretical foundation for the current dissertation. Nevertheless, it is acknowledged that in pursuit of more sustainable solutions, incremental improvements and "quick fixes" should only be among the first steps. The relative concept of sustainability will be specified to the business context in the next section.

2.2.2 Understanding of Sustainability in the Business Context

Two starting points for linking macro-level sustainability to the micro-level business context have to be differentiated (Clifton & Amran 2011, p. 124). First of all, a company can be considered sustaining itself through making decisions that allow for continuing its business. Second, a company can contribute to the global sustainable development through adjusting its decisions towards being more socially and environmentally sustainable. To accommodate such an inclusion of sustainable development goals into the business activities of a company, the concept of the Triple Bottom Line (TBL) was put forward by Elkington (1998). The TBL tries to expand the idea of economic accounting (i.e. the financial bottom line) to the social and environmental performance of a company:

> *"In the simplest terms, the TBL agenda focuses corporations not just on the economic value that they add, but also on the environmental and social value that they add – or destroy"* (Elkington 2004, p. 3).

Since the TBL makes the rather abstract concept of sustainable development more tangible for the business context, it was happily embraced by companies and today is often used as a synonym for sustainability by researchers and practitioners alike (Esty & Simmons 2011, p. 5; Hovorka et al. 2012, p. 62; Brockhaus 2013, p. 34). Figure 10 illustrates the three dimensions of the TBL. Sustainability can only be achieved through simultaneous improving all three dimensions. Some authors use different terms for describing the dimensions, e.g.

3P for people, planet, profits or 3E for economics, environment, and equity. However, despite some slight differences, the inherent meanings of all these approaches are concordant (Winter & Knemeyer 2013, p. 22).

The economic bottom line of the TBL pertains to the financial capital of a company (e.g. equity and debt) as well as its tangible capital like machinery and its intangible capital like reputation (Dyllick & Hockerts 2002, p. 133). Thus, it is similar to the traditional financial bottom line of companies. However, compared to corporate decision-making – which is often driven by rather short-term financial optimization – the TBL takes a long-term perspective (Brockhaus 2013, p. 36). An economically sustainable company would "guarantee at any time cashflow sufficient to ensure liquidity while producing a persistent above average return to the shareholders" (Dyllick & Hockerts 2002, p. 133).

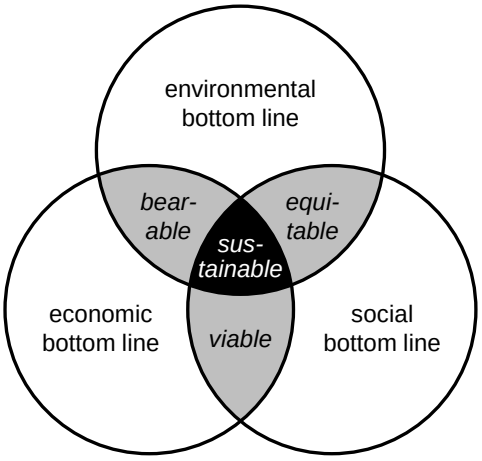

Figure 10: Triple Bottom Line
(adapted from Carter & Rogers 2008, p. 365)

The environmental bottom line of the TBL focuses on the kind and amount of resources a company consumes as well as on the environmental impact its economic activities unfold (Esty & Simmons 2011, p. 5). An environmentally sustainable company would "use only natural resources that are consumed at a rate below the natural reproduction, or at a rate below the development of substitutes." Furthermore, it would not "cause emissions that accumulate in the environment at a rate beyond the capacity of the natural system to absorb and assimilate these emissions" or "engage in activity that degrades eco-system services" (Dyllick & Hockerts 2002, p. 133). Finally, the social bottom line of the TBL pertains to sustaining the human capital of a company (e.g. through health and safety measures) as well as the societal capital (e.g. through considering other stakeholders' needs) (Baumgartner & Ebner 2010, p. 79 f.). Thus, a socially sustainable company would "add value to the communities within which they operate by increasing the human capital of individual partners as well as furthering the societal capital of these communities." Moreover, it would "manage social capital in such a way that stakeholders can understand

its motivations and can broadly agree with the company's value system" (Dyllick & Hockerts 2002, p. 134).

Even though the definitions provided above seem to collate a coherent picture of corporate sustainability, they are far from being applicable to the real-world business context without further ado. For example, nature's capacity for absorbing emissions is simply not known. Also, emissions are not solely caused by one company but result from activities undertaken by millions of businesses and consumers. Thus, since its introduction and its dissemination in the business world, the TBL has often been criticized for oversimplifying a complicated and dynamic issue. Norman & MacDonald, for example, make a strong case against the vagueness of the TBL as it might invite companies to appear to be committed to sustainability without actually changing questionable business practices (2004, p. 256 f.). Often, the environmental and social performance cannot be quantified beyond rough estimates and thus there is no straight-forward answer to the question of what a company's environmental or social bottom line is – even though the TBL's accounting terminology would imply that there should be an answer. Therefore, companies could adopt the TBL on paper without truly committing to anything in reality. Thus, Norman & MacDonald argue that the TBL is more or less a "good old-fashioned single bottom line plus vague commitments to social and environmental concerns" (2004, p. 256).

In parts, this criticism is justified because the TBL indeed holds several weaknesses and is, in fact, abused for greenwashing of irresponsible business practices (Pava 2007, p. 109). For example, the business model of an ammunition manufacturer does not get any more sustainable through supporting social causes expatiated upon in high-gloss sustainability reports. Also, TBL does not consider that most sustainability issues (child labor is a prominent example) are evaluated depending on the values and norms of the individual societies (Flämig 2014a, p. 33). However, it has to be taken into account that the rapid spread of the basic tenets and the language of the TBL (Hort 2008, p. 45) was one of the major enablers for sustainability breaching the "C-Suites" of large corporations (Ehrenfeld & Hoffman 2013, p. 1). Its use of "management lingo" breaks the concept of sustainability down in an applicable way for business – hence its success with corporate executives. Since this dissertation aims at exploring how companies deal with sustainability issues, it is only practical to follow the established language. Thus, the TBL's breakdown of sustainability into environmental, social, and economic dimensions will be employed as this dissertation's foundation for discussing sustainability.

Finally, sustainability in the business context has to be delimited from Corporate Social Responsibility (CSR). CSR encompasses "the economic, legal, ethical, and discretionary

(philanthropic) expectations that society has of organizations at a given point in time" (Carroll & Buchholtz 2006, p. 35). In practice, CSR-related actions often also pertain to environmental aspects (Flämig 2014a, pp. 39–41; Gallego-Álvarez & Quina-Custodio 2016, p. 226 f.). However, most CSR activities more or less focus on providing company resources for the benefit of the firm's local constituency. These measures are often temporary and seldom touch upon the company's core business (Hanusch & Birkhofer 2008, p. 212 f.). Thus, CSR is considered auxiliary to producing and selling products rather than tackling the sustainability concerns of the core business processes. Therefore, CSR is deemed to be subsumed by this dissertation's understanding of sustainability.

2.2.3 Understanding of Sustainability in the Product Development Context

As this dissertation deals with one specific business process, it has to be specified what sustainability means in the context of a product and its development. For the term "sustainable product" several divergent definitions exist. According to Ljungberg, a sustainable product "is a product, which will give as little impact on the environment as possible during its life cycle" (2007, p. 467). Since a product's impact cannot be zero, this definition comes up to the relative take on sustainability. Thus, some products will be less sustainable than others. However, Ljungberg focuses exclusively on the environmental bottom line. A more comprehensive definition is provided by Seuring & Müller as they also focus on the social dimension of a product as well as on the product's market success:

> *"Sustainable products is the term used to comprehend all kinds of products that have or aim at an improved environmental and social quality (…). The ultimate aim is to satisfy customers and gain a competitive advantage in the market"* (Seuring & Müller 2008, p. 1705).

Thus, a sustainable product features superior environmental and social performance compared to a similar product and it sells in the marketplace. Moreover, the wording "improved environmental and social quality" implies going beyond mere optimization of existing products. It is also understood to incorporate the idea of "enhancing the well being of nature and culture" through intelligent product design put forward by McDonough & Braungart (2002, p. 251). However, the phrase "sustainable product" can be misleading as it might appear to be referring to sustainability as an absolute concept. To emphasize the relative approach this dissertation takes towards sustainability, the phrase "more sustainable product" will be used for the rest of the manuscript.

For the term "sustainable product development", a variety of definitions exist as well. Van Weenen's suggestion, for example, is geared to the Brundtland Commission's macro-level definition of sustainable development and views sustainable product development from a societal perspective. He understands it as dealing with "elementary demands, essential

product functions, the systems in which products function, the nature, availability and selection of resources, and the distribution of those resources among nations and generations" (van Weenen 1995, p. 98). However, for this dissertation a definition applicable in the practical context of product development is necessary. Thus, the definition of product development by Otto & Wood (2001) put forward in Section 2.1.1 is adapted and sustainable product development is understood as

> *the entire set of activities required to bring a more sustainable product to a state of market readiness.*

Hence, sustainable product development is also delimited from previous approaches such as eco-design or DfE[7] (Byggeth et al. 2007a, p. 1) as these rather focus on incremental improvements to single products (Ny et al. 2008, p. 603 f.). Further, they do not challenge the basic product concept nor take into account social aspects or the entire supply chain (Boks & McAloone 2009, p. 442). Also, these approaches do not consider how improving single products can form a possible pathway towards sustainability (Hallstedt 2008, p. 2). Thus, the current dissertation exclusively focuses on the more comprehensive approach of sustainable product development.

2.3 Consumer Goods

In this section, consumer goods as the object of this investigation are introduced. For this purpose, the term consumer goods is defined, consumer goods categories are developed, and the importance of the consumer goods industry for the overall economy is spotlighted.

2.3.1 Defining Consumer Goods

In manufacturing industries, investment goods, consumer goods, and intermediate goods have to be differentiated. Investment goods are bought and used by companies as a factor of production. They are often highly individual and complex products purchased by professional buying centers through long-lasting and close relationships with the suppliers. Consumer goods, on the other hand, are

> *products developed for and purchased by the average consumer to satisfy their human wants* (Tomczak et al. 2003, p. 1161).

They can be characterized as rather standardized and less complex products bought by numerous individuals only loosely connected to the producing company (Backhaus & Voeth 2004, p. 8 f.; Hofbauer et al. 2009, p. 39). Consumer goods and investment goods are

[7] DfE = Design for the Environment.

further defined in Table 1. Finally, intermediate goods are used as input for the production of both investment and consumer goods.

Table 1: Definition of Investment Goods and Consumer Goods (based on Backhaus & Voeth 2004, p. 8 f.; Hofbauer et al. 2009, p. 39)

Characteristic	**Investment Goods**	**Consumer Goods**
Quantity and type of demand	few; derivative demand by mostly larger companies or organizations	many; original demand by consumers or small companies
Type of supply management	professionally, by multiple persons (buying center)	by individuals
Role of product individualization	high; supplier has to accommodate to individual customer requirements	low; rather standardized products
Intensity of buyer supplier relationship	close; often maintained for several years, often joint product development	loose; anonymous relationship
Systemic nature of products	high; often composed of several components; complex systems	low, predominantly single components

On their longevity, durable and non-durable consumer goods are to be distinguished (Tomczak et al. 2003, p. 1161). Durable consumer goods can be used multiple times and are bought less often. They typically are of high value. Consumers demonstrate strong involvement and are engaged in an intensive information search before purchasing durable consumer goods. Existing alternatives are consciously evaluated and purchasing advice or services are often used (Placzek 2007, p. 110). Typical examples of durable consumer goods are consumer electronics and bicycles. Non-durable consumer goods, on the other hand, can only be used one or few times. They are typically of low value and bought with a high frequency. Since involvement is low, consumers normally do not use purchasing advice and seldom search for information on the product features before purchasing. Often purchasing decisions are completely impulsive (Placzek 2007, p. 110). Typical examples of non-durable consumer goods comprise food and cleaning agents. However, a clear classification of products is not always possible and may even depend on the behavior of the individual consumer. Thus, Figure 11 illustrates consumer goods as a continuum with durable and non-durable as its poles.

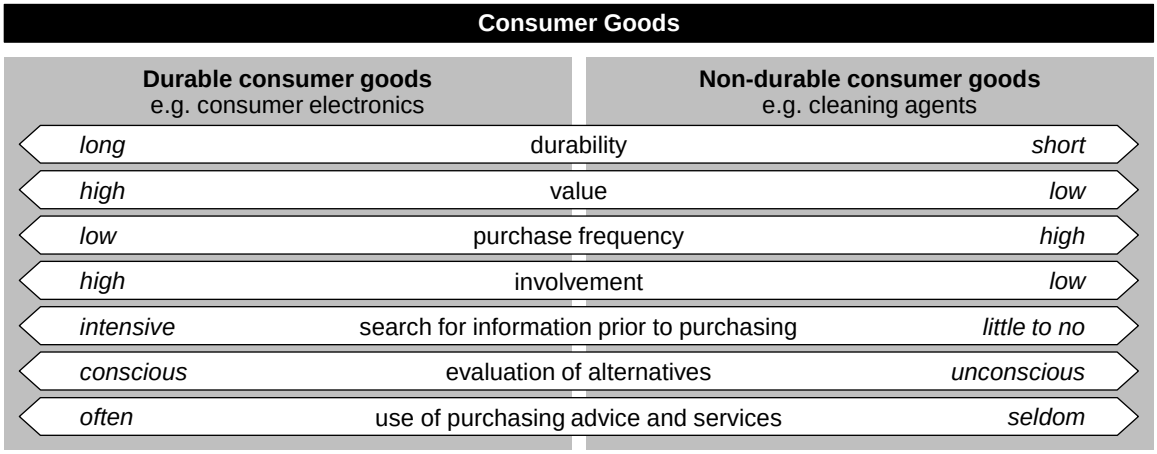

Figure 11: Distinction of Durable and Non-Durable Consumer Goods (adapted from Placzek 2007, p. 111)

From a sales perspective, consumer goods can also be distinguished by their turnover ratio into Fast Moving Consumer Goods (FMCG) and Slow Moving Consumer Goods (SMCG).[8] In fact, this classification is often used as a synonym for non-durable and durable consumer goods (Tomczak et al. 2003, p. 1161; Moretti & Murck 2014, p. 6). Again, an explicit product classification is difficult and contextual. Taking consumer electronics as an example, most authors define them as being SMCG (e.g. Kern 2010, p. 4). However, some rather consider them being FMCG (e.g. Meyr & Stadtler 2015, p. 61). For this dissertation, products are considered as being durable or slow moving if they can be used over a certain period without being expended.

2.3.2 Categorization of Consumer Goods

For a detailed analysis of product sustainability in the consumer goods industry, a more in-depth differentiation of consumer goods is deemed appropriate. Kern (2010, p. 4) differentiates 51 types of consumer goods. However, his typology is not deduced comprehensible and does not include exemplary products. As a result, some categories appear to be not definitive (e.g. giftware) or seem to overlap (e.g. perfume and fragrances). Another highly detailed categorization of consumer goods is provided through the consumer basket developed for calculating the German consumer price index (Destatis 2013). It also contains the average consumers' spending as well as exemplary products for each category. However, most categories are composed of consumer goods as well as related services and therefore would have to be split up. Finally, a group of categorizations of goods focuses on economic activities (e.g. Destatis 2008; Eurostat 2008). Hence, consumer goods, intermediate goods, and investment goods are summed up on their production technology and economic sector.

[8] FMCG are also often referred to as consumer packaged goods (CPG) (Schilling 2012, p. 20).

All extant categorizations are helpful, but none is suitable in its original form. Consequently, a categorization is developed for the current dissertation building primarily on the consumer basket (Destatis 2013) and some aspects of Kern's categories (2010, p. 4). It is mapped in Table 2 including exemplary products and the average share of consumers' spending for each category. Food was excluded since this dissertation focuses on non-food consumer goods (this restriction is substantiated in Section 5.1).

Table 2: Categorization of Non-Food Consumer Goods

Category	**Exemplary Products**	**Breakdown of Spending (%)**
Apparel	suit, dress, underwear, rompers, rain coat	19.4
Body care products	dental floss, shampoo, diaper, lipstick	6.7
Carpets and home textiles	carpet, laminate, blanket, towel, curtain	2.9
Consumer electronics	digital camera, TV set, loudspeaker	4.0
Domestic appliances	fridge, coffee maker, hair blower, washer	5.3
Footwear	athletic shoes, pumps, slippers, insole	4.6
Furniture and lighting	kitchenette, wardrobe, couch, table lamp	9.5
Home and garden commodities	wallpaper, paint, bulb, building material	6.1
Home and garden tools	lawn mower, screwdriver, drill, rake	3.0
Household articles	tumbler, tableware, ironing board, bin	1.9
Household commodities	detergent, baking paper, cleaning agent	2.8
Image and sound carriers	blank disk, photo album, Blu-ray disk	1.5
IT and communication devices	computer, printer, software, calculator	4.1
Jewelry and watches	necklace, wedding ring, alarm clock	2.0
Leisure and sports equipment	bicycle, racket, musical instrument, tent	2.7
Medical and therapeutic products	glasses, medicine, hot-water bag	10.8
Personal items	umbrella, baby stroller, briefcase, lighter	1.2
Printed products	book, newspaper, calendar, postcard	7.6
Stationery	ball pen, crayon, envelope, stapler	1.0
Toys	doll, parlor game, building blocks	3.1

The products included in the categories account for about a fifth of the average German consumers' spending. They are manufactured by a variety of companies representing a substantial share of the overall economy. The remaining consumers' spending comprises the costs for food, habitation, mobility, healthcare, insurance, and other services.

2.3.4 Consumer Goods Industry

Multinational consumer electronics companies like Samsung, Apple, and Sony as well as FMCG behemoths like Nestlé, Procter & Gamble, and Unilever shape the public perception of the consumer goods industry (Deloitte 2015, p. 10).[9] The German consumer goods industry features some global players as well (e.g. Henkel, Adidas, Dr. Oetker, and Maxingvest).[10] Despite containing these internationally recognized companies with multiple billions of annual turnover, the German consumer goods industry as a whole is characterized by a majority of small and medium-sized enterprises (SME) (Kern 2010, p. 16; Litchfield 2016). Kern calculates the average consumer goods company in Germany to achieve an annual turnover of EUR 28 million and to employ 110 people (2010, p. 16). Thus, most companies fall into the category of SME as defined by the European Commission (2015, p. 10).[11] However, large differences between the individual branches exist. The twelve German tobacco companies on average generate around EUR 500 million and employ more than 350 people. The much higher number of textile or publishing companies turn over less than EUR 20 million per year and employ less than 100 people on average (Kern 2010, p. 16).

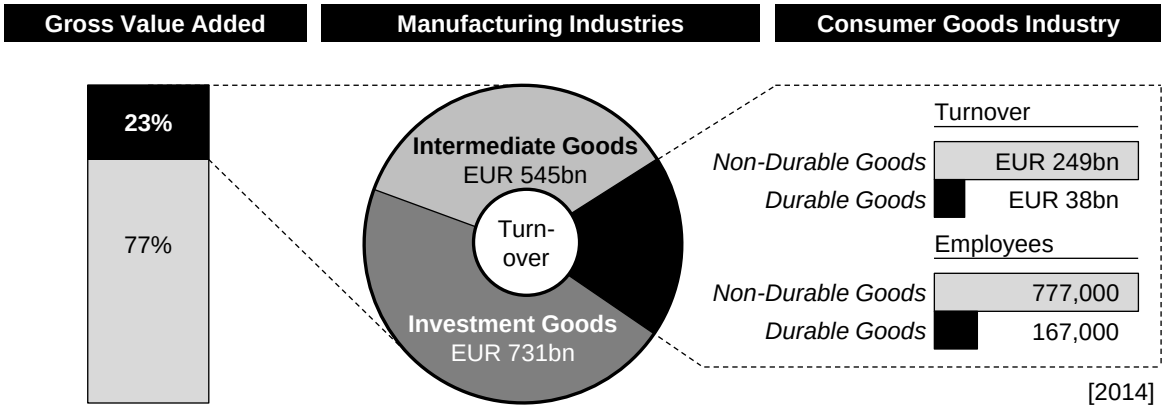

Figure 12: Importance of Consumer Goods Industry for German Economy (calculated based on data from Destatis 2016a, 2016b)

The consumer goods industry as a whole is of high relevance for the German economy (see Figure 12). In 2014, these companies employed next to one million people and produced and sold durable and non-durable goods worth nearly EUR 300 billion. This combined turnover comprises about a fifth of the overall manufacturing industries. Also, the demand for consumer goods to a large degree determines the demand for intermediate and

[9] Net Sales in 2013 (according to Deloitte 2015, p. 10): Samsung ($210bn), Apple ($171bn), Sony ($67bn), Nestlé ($99bn), Procter & Gamble ($83bn), Unilever ($66bn).

[10] Net Sales in 2013 (according to Deloitte 2015, p. 11 f.): Henkel ($22bn), Adidas ($19bn), Dr. Oetker ($14bn), Maxingvest ($13bn).

[11] A company is considered being an SME if it has a staff headcount of less than 250 persons and either an annual turnover of less than EUR 50 million or an annual balance sheet total of less than EUR 43 million.

investment goods (Kern 2010, p. 6). This holds true due to the large supply networks unfolding upstream from the consumer goods companies (Schilling 2012, p. 21 f.). Considering, for example, the production of plastics products like toys, intermediate goods like synthetic granules are needed as inputs and investment goods like injection molding machines are necessary to process the intermediate goods. The growth or decline of people's propensity to consume therefore immediately reflects on other manufacturing industries.

2.4 Summary of Theoretical Background

This section summarizes the theoretical background of the current dissertation laid out in the previous sections. First, the fundamentals of *product development* were introduced:

- Product development is understood as being the business process that deals with "*the entire set of activities required to bring a new concept to a state of market readiness*" (Otto & Wood 2001, p. 5). Thus, it also includes activities by departments like marketing or manufacturing.
- Product development has a decisive influence on a product's environmental, financial, and social performance. Every phase of a product's life-cycle can be impacted by specific constructive measures.

Second, the concept of *sustainability* along with its operationalization for the business context was presented:

- From a macro-level perspective, sustainable development is defined as "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" (WCED 1987, p. 43).
- Sustainability is understood as being a relative concept dealing with the process of simultaneously improving the environmental, economic, and social performance of an object. One object can be more or less sustainable compared to another one.
- The Triple Bottom Line is a frequently employed approach to adopt the concept of sustainability to the micro-level business context.

Third, this dissertation's understanding of the terms *more sustainable product* and *sustainable product development* were put forward:

- A more sustainable product has or aims at "*an improved environmental and social quality (…). The ultimate aim is to satisfy customers and gain a competitive advantage*

in the market" (Seuring & Müller 2008, p. 1705). Thus, a more sustainable product goes beyond mere optimization that aims at doing less harm.

- Sustainable product development is the process dealing with the *entire set of activities required to bring a more sustainable product to a state of market readiness*.

Finally, *consumer goods* as the object of investigation and the German consumer goods industry were characterized:

- Consumer goods are *products developed for and purchased by the average consumer to satisfy their human wants* (Tomczak et al. 2003, p. 1161).
- They are differentiated into durable and non-durable goods even though a clear classification is contextual and should be made along multiple dimensions.
- The consumer goods industry is of high importance for the economy as the demand for consumer goods to a great extent also determines the demand for other manufacturing industries.

3 Mapping the State of Research on Sustainable Product Development

In this chapter, the state of research on managing sustainability in product development is explored. For this purpose, a thorough literature review is conducted. First, the review process is described. The review's findings are presented afterward by pointing out relevant streams and findings in the literature. Finally, research needs are outlined, and the research questions of this dissertation are derived.

3.1 Literature Review Process

Literature reviews can be distinguished into so-called systematic reviews and traditional reviews. A systematic approach is of particular importance in evidence-based research like medicine, education, or psychology (Borrego et al. 2014, p. 45). In such reviews, the process of data collection is disclosed and described comprehensible to avoid possibilities of cherry picking or skewing the results. Particularly for medical studies, extensive guidelines have been set up to improve the quality of systematic reviews (e.g. Higgings & Green 2011). Recently, systematic reviews have also gained popularity in other domains like management research (Tranfield et al. 2003, p. 214 f.).

Conducting a systematic review starts with formulating a specific research question and outlining the search field before the actual retrieval process (Briner et al. 2009, p. 25; Denyer & Tranfield 2009, p. 681). It is common practice to delimit the search field by the choice of databases and search terms. Sometimes, systematic reviews are also limited to certain publication levels (e.g. journal ranks) or a specific quorum of citations. To reduce bias, multiple researchers should be involved in the research process (Denyer & Tranfield 2009, p. 685 f.). Often, a panel of experts providing articles or search terms and specialized librarians also support the retrieval of relevant studies (e.g. Durach et al. 2015, p. 121). However, a systematical selection of articles does not automatically lead to a thorough review. Specifically, it can be observed that a considerable share of reviews claiming to be systematic hold severe methodological flaws – even in evidence-based research like medicine (Garg et al. 2008, p. 255). In other fields, it even seems that "systematic" is sometimes confused with "showing extensive flowcharts and long lists of journals" while deemphasizing the actual analysis and synthesis of the individual studies.

This literature review aims at mapping the state of research on sustainability in product development by pointing out relevant streams and gaps within the extant literature of this multidisciplinary field. Thus, the research question for this review is comparably broad. Moreover, confinements like citation quorums or journal ranks are perceived as arbitrary

and not appropriate for this review. Such an approach could exclude major parts of the body of knowledge from the analysis since books, conference papers, or technical reports should also be considered as relevant sources (Denyer & Tranfield 2009, p. 684). Also, this review does not follow a specific process model and respectively does not claim to be comprehensively systematic. However, following best practice, the details of the study are disclosed as follows: (1) definition of search field, (2) selection of databases and search terms, (3) execution of literature search, (4) analysis and presentation of the findings.

(1) Definition of search field: As introduced before, several concepts related to sustainable product development exist (e.g. eco-design or DfE). These concepts solely focus on incremental, environmental optimization of single products. However, this review exclusively focuses on articles that address a three-dimensional understanding of sustainability.[12] Moreover, the review is limited to articles relevant to practice. Therefore, textbooks or existing research on educating and sensitizing engineering students regarding sustainability will not be considered. However, it is acknowledged that this aspect is important for the dissemination of knowledge on sustainable product development. Since the review was conducted in January 2015, only studies published in 2014 or before are considered.

(2) Selection of databases and search terms: For this review, the databases and search engines EBSCOhost, Scopus, DeepDyve, and Google Scholar were chosen. They were amended by literature catalogs compiled within the research networks Mendeley and ResearchGate. The search terms were formulated in both English and German. Each term (connected by the Boolean expression “AND”) was used to search in keywords and titles of the articles. Figure 13 illustrates the search terms along with the databases used.

Databases	
EBSCOhost	Scopus
DeepDyve	Google Scholar
Mendeley	ResearchGate

Search Terms	
sustain* product development	Nachhaltig* Produktentwicklung
sustain* product design	Nachhaltig* Produktdesign
sustain* engineering	Nachhaltig* Innovation*
sustain* innovation	

Figure 13: Databases and Search Terms Used for Literature Review

(3) Execution of literature search: For each result, the title and abstract were screened, and scientific studies related to sustainability in product development were imported into a reference manager for subsequent analysis. Supplementary to the database search, some

[12] A subsequent literature review on sustainable product development by Thomé et al. (2016) also includes studies on eco-design and green product development. Around 1,500 individual articles are reviewed. Facing such high numbers, the review necessarily has to be focus on keyword analysis. Such an approach clearly provides an interesting overview but is not deemed helpful for this review’s purpose. Instead, the nature, content, and contribution of the relevant articles are to be assessed beyond the articles’ keywords.

frequently cited or relatively new articles were checked for additional references. At the end of the search, the database of selected studies contained 173 individual articles. Another four articles had to be excluded because their full-texts were not accessible.

(4) Analysis and presentation of findings: All 173 articles were analyzed and categorized. Their main topics were coded to point out relevant streams in the literature. A categorization put forward by Baumann et al. (2002, p. 410) was then adapted to classify the articles. Four scopes were defined: Articles covering the product development process as such are summed up as level 1. Level 2 deals with the link between product development and other departments like corporate strategy or marketing. Product development and its interactions with supply chain partners (e.g. consumers or suppliers) are discussed in articles assigned to level 3. Finally, level 4 deals with product development in external contexts beyond the own supply chain (e.g. policy-making). The articles assigned to level 1 (product development) were further distinguished into four categories depending on their thematic focus (i.e. product aspects, process aspects, strategy aspects, and implementation aspects). Figure 14 provides an overview of the categorization as it will be used to structure the following presentation of the review's findings.

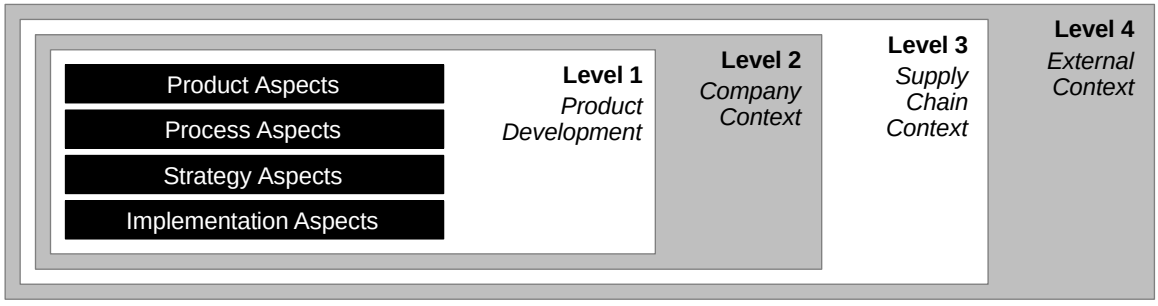

Figure 14: Categorization Scheme for Literature Review

3.2 Findings from the Literature Review

In this section, the findings from the literature review are detailed. First, a summary of the reviewed body of literature is provided as proposed by Denyer & Tranfield (2009, p. 686). The relevant literature streams for each of the four levels are pointed out afterward. Finally, the findings are summed up through presenting key observations and distinct research needs derived from them. Also, the research questions for this dissertation are specified.

3.2.1 General Observations

Before the state of research on managing sustainability in product development is presented, the "demographics" of the literature body are laid out through illustrating the articles' distribution on years, outlets, and geographical regions. First mentioned in 1995, only little attention was dedicated to sustainability in product development until around 2006.

From then on, researchers began to shift their predominant focus from solely environmental aspects (e.g. under the headline of eco-design) to the more comprehensive concept of sustainability (Boks & McAloone 2009, p. 438 f.). This shift is reflected in the number of reviewed articles per year that document the growing attention over time (see Figure 15).

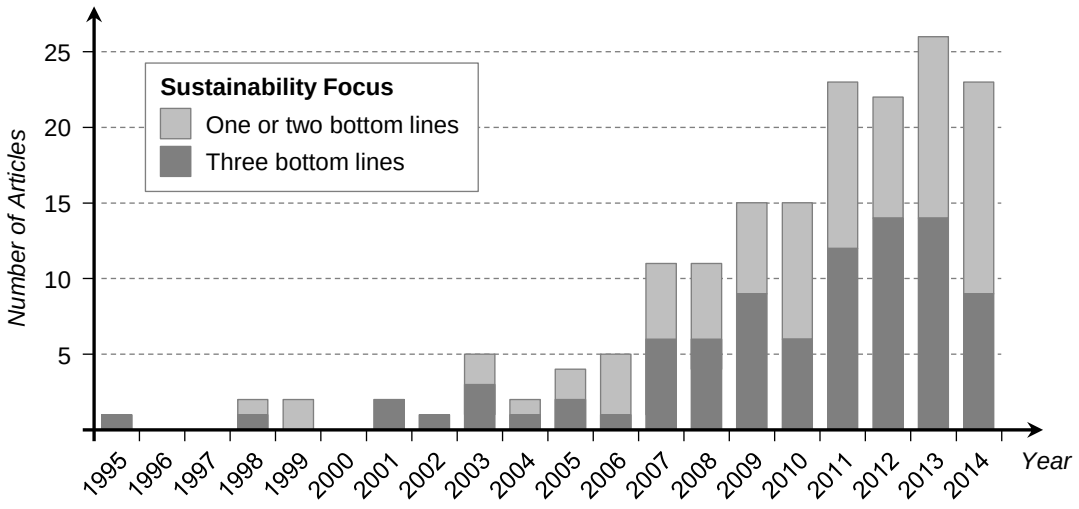

Figure 15: Distribution of Articles Regarding Year of Publication

All articles reviewed use the phrase “sustainability” as this was one major selection criteria. As a matter of fact, most authors acknowledge the importance of taking a TBL perspective and equally addressing environmental, economic, and social problems. However, almost half of the publications, in fact, limit their focus to one or two bottom lines (see Figure 15). While these one- or two-dimensional approaches cannot always be delimitated clearly (Hanusch 2011, p. 27), it is evident that almost all deal with environmental issues. Reviews of research on sustainability issues from other fields already provided similar findings (Carter & Easton 2011, pp. 52–54; Winter & Knemeyer 2013, p. 31 f.).

Because the literature review was not confined to specific journals, the articles stem from a high variety of outlets including peer-reviewed journals, conference proceedings, and anthologies (see Figure 16). About a third of the articles were released through two journals (i.e. *Journal of Cleaner Productio*n and *International Journal of Sustainable Engineering*) as well as the conferences by CIRP[13] and ICED[14]. The other two-thirds of the articles stem from around 80 outlets ranging from the *Journal of Business Ethics* to proceedings on air-breathing engines. This small level of concentration underlines the multidisciplinary character of the field and endorses the rejection of a systematic approach for this review.

[13] CIRP = College International pour la Recherche en Productique.

[14] ICED = International Conference on Engineering Design.

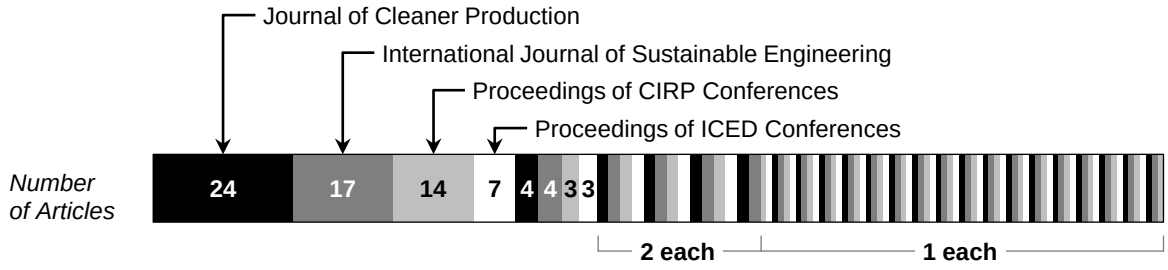

Figure 16: Distribution of Articles on Different Outlets

In a third step, the articles were classified as being empirical studies, conceptual contributions, reviews, or position papers. Figure 17 reveals the breakdown of the articles on their nature and scope. Conceptual papers covering process aspects (i.e. tools to support product development) make up for more than half of the reviewed literature (n = 89, 51 percent). Another focus is placed on reviewing these tools (n = 11, 6 percent). Furthermore, a distinguished group of articles is dedicated to empirically investigating implementation issues (n = 16, 9 percent). Most of them are success factor studies.

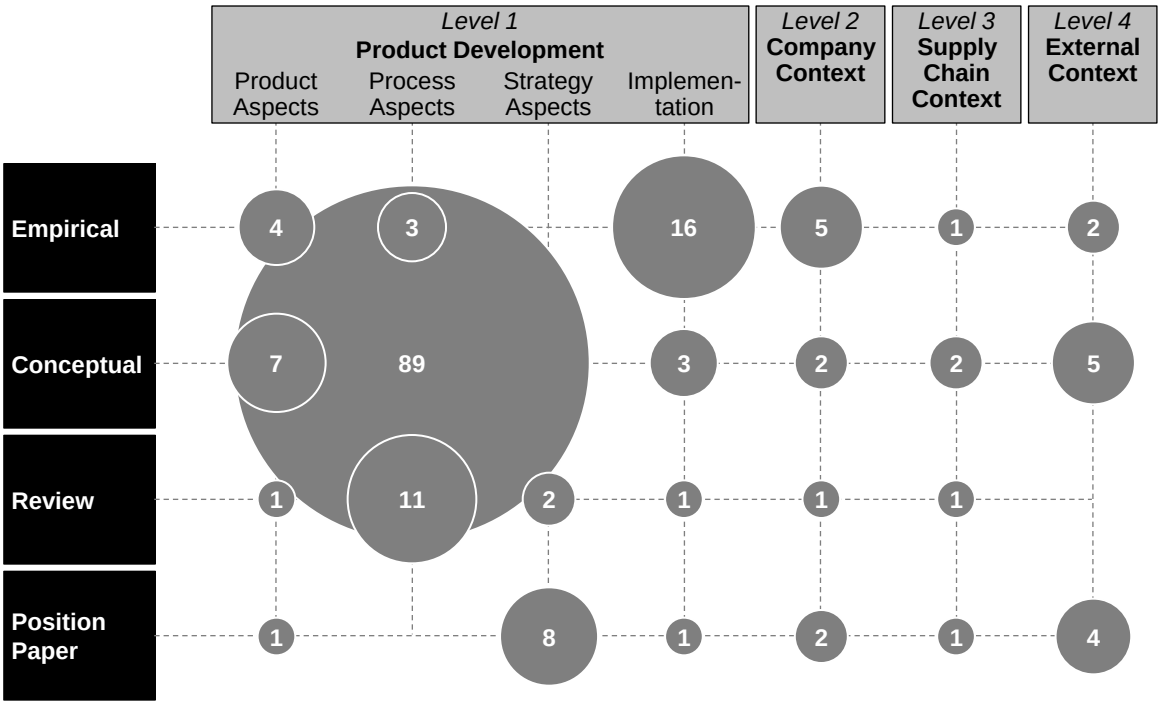

Figure 17: Categorization of Articles on their Nature and Content

Finally, the geographical origin of the articles was investigated. For this purpose, the number of articles associated with authors from a specific geographic area was counted. Again, the articles were differentiated depending on their nature into conceptual contributions, empirical studies, or reviews and position papers. If articles were co-authored in different countries, they were counted once for each of the countries. The result of this

classification is depicted in Figure 18 showing the absolute number of articles per region as well as the shares of the different types of work.

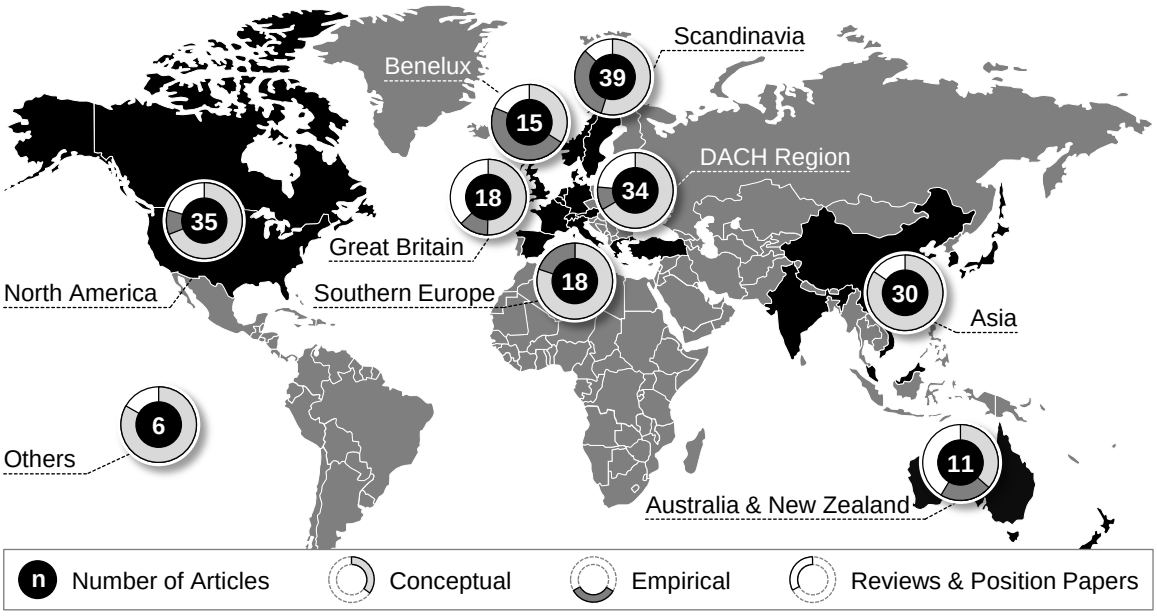

Figure 18: Origin and Nature of Articles

It is evident that Scandinavia and the Benelux States relatively speaking are the powerhouses of research on sustainability in product development. This is also supported by the comparatively high share of empirical work. Some of these countries are known for setting high priorities on sustainability research in other fields as well (Chiras 2016, p. 4 f.). Authors from Asia or Southern Europe, on the other hand, focus largely on conceptual contributions. North America and the DACH region (Germany, Austria, and Switzerland) are also centers of conceptual research. However, when interpreting the article count for the DACH region, it has to be taken into consideration that ten articles were written in German. They would not be included in a comparable review originating from the rest of the world.

After mapping the field of sustainable product development with respect to the "demographics" of the literature body, relevant streams of the literature are pointed out within the next sections. The categorization introduced in Figure 14 will be used to present the findings. Since not all articles will be discussed in detail, Appendix III contains a list of all 173 articles included in this review.

3.2.2 Level 1 – Product Development

Articles assigned to level 1 deal with product development as such and cover product aspects, process aspects, strategy aspects, and the implementation of sustainable product development practices.

Product Aspects

Articles dealing with product aspects cover (1) sustainability properties of different materials, (2) product service systems (PSS), and (3) examples of more sustainable products. The articles discussing *material issues* are highly specific. They cover such diverse topics as environmental and social risks related to certain materials (Gaugler 2013), toxicity metrics of materials (Ogunseitan & Schoenung 2012), and possible applications for innovative materials like wood polymer composites (Venkatesh et al. 2013) or synthetic fibers (Subic et al. 2009) from a sustainability perspective. With respect to *PSS*, several authors investigate how products and services could be linked up to produce more sustainable solutions (e.g. Maxwell & van der Vorst 2003; Thompson et al. 2011a; Ny et al. 2013). Overall, PSS are seen to help breaking new ground regarding product sustainability. However, it is acknowledged that PSS are not implementable for all types of products. The third group of articles covers *examples* of more sustainable products: Dangelico & Pujari (2010) analyze several cases of manufacturing companies that consider sustainability for their products. Luthe et al. (2013) dig into the development of skis and illustrate how sustainability was considered during an actual development project and which improvements were achieved. Tingström et al. (2006) follow a similar approach and investigate the development of an eco-efficient power capacitor.

Process Aspects

Contributions dealing with process aspects comprise reviewing, proposing, and advancing methods for the development of more sustainable products. As was revealed in Figure 17, these contributions make up for 60 percent of the overall literature. A method is understood as a “planned, rule-based procedure prescribing the way in which certain activities are to be performed in order to achieve a certain goal” (Lindemann 2009, p. 57; translated by Graner & Mißler-Behr 2012, p. 160). Adapting a typology by Baumann et al. (2002, p. 415) the methods were categorized into (1) checklists and guidelines, (2) frameworks and methodologies, (3) rating and ranking tools, (4) analytical tools, and (5) software and expert systems. The sixth group of articles deals with reviewing methods.

The first group of methods is characterized as *checklists and guidelines*. They are of a qualitative nature and are rather easy to understand and use. Examples of checklists are the list of product properties essential for ensuring efficient disassembly that was empirically derived by Johansson (2008) or the compilation of sustainability information relevant for product development along with its assigned stakeholders and life-cycle phases (Aschehoug & Boks 2013). The template for sustainable product development proposed by Ny et al. (2008) is an example of a guideline. It helps to gain a quick overview of the main

sustainability challenges and opportunities related to a development project by providing some triggering questions.

Simple quantitative methods are subsumed as *rating and ranking tools*. They typically offer a set of pre-defined measurement scales and help to roughly assess design alternatives. For example, Hanusch (2011) identifies criteria to evaluate the social sustainability of products and investigates whether these can be influenced through constructive measures. De Silva et al. (2009) compile some factors having an impact on the sustainability of consumer electronic products. After quantifying and weighing these factors, product alternatives can be compared to each other or competitors' products. Another example is the tool developed by Askham et al. (2012). It features a set of indicators allowing for a combined evaluation of economic indicators and environmental aspects.

The third group of methods is summarized as *frameworks and methodologies*. They are more comprehensive qualitative approaches and often come with a toolkit containing some intertwined checklists or simple rating tools. Frameworks comprise "Design for X" approaches as reviewed by Arnette et al. (2014) or adapted by Bevilacqua et al. (2007). Other examples of this group of tools are methods that support the decision-making process (Heintz et al. 2014) or help to define a company's roadmap towards sustainable innovation (Flores et al. 2008).

More comprehensive quantitative methods are subsumed as *analytical tools*. To facilitate well-informed decisions in product development, they aim at measuring the sustainability impact of different design alternatives or materials as precisely as possible. Examples are the weighted fuzzy sustainability assessment method by Ghadimi et al. (2012) or the decision-making support by Inoue et al. (2012) that also takes into account uncertainties in the early phases of the design process. Often, analytical tools combine some established approaches. For example, Halog (2004) integrates life-cycle analysis (LCA), life-cycle costing (LCC) and quality function deployment (QFD) to support the selection of sustainability alternatives.

The fifth group of methods comprises *software and expert systems*. They aim at facilitating the handling of vast data volumes necessary for assessing sustainability in product development. However, they are not developed for commercialization purposes and, therefore, are seldom more than prototypes. Examples are the material selection expert system that supports the filtering of material alternatives put forward by Zarandi et al. (2011) and the sustainability design system for electrical products by Abdalla & Ebeid (2011).

A further group of articles covering process aspects of product development comprises *reviews of existing methods*. Some reviews' findings ultimately serve as justification for the subsequent development of more comprehensive methods (e.g. Grießhammer et al. 2004; Clancy et al. 2013a; Gremyr et al. 2014). Other authors analyze and characterize methods to facilitate the selection and combination of adequate support for each development phase (e.g. Buchert et al. 2014b). Ness et al. (2007) review sustainability assessment methods and analyze if these go beyond considering environmental factors. They find that only a minority of methods also integrate social and economic aspects.

Strategy Aspects

Articles assigned to this section go beyond operational aspects and deal with the strategic alignment of product development. The key message of all associated articles is the need to refocus product development from minimizing environmental impacts (i.e. doing less harm) to truly fostering product sustainability (van Weenen 1995). For this reason, Klöpffer (2003) calls for extending life-cycle thinking onto social factors. Hanusch & Birkhofer (2008), as well as Charter (1998), also advocate the consideration of social and ethical factors in product development even though they acknowledge that constructive measures might have an only limited direct influence on the social sustainability of products. Burschel (2003) approaches the topic from a product design perspective and suggests to reclaim design traditions like Bauhaus to foster product sustainability. Finally, McDonough & Braungart (2002) introduce the basic idea of the cradle to cradle concept. They propose to refocus product development from limiting liabilities to creating sound products that can enhance the well-being of the environment and society without offsetting economic growth.

Implementation

Some other articles cover the implementation of sustainable product development. On the conceptual side, Hallstedt et al. (2010) and Hynds et al. (2014) develop *methods* that help to assess the state of integration of sustainability into product development processes. These approaches also allow companies to benchmark themselves as they are making progress. Most other authors empirically investigate the *state of integration in practice*. Almost all focus on identifying challenges (e.g. Lee-Mortimer & Short 2009; Petala et al. 2010; Curwen et al. 2012) or success factors (e.g. Aschehoug & Boks 2011; Hallstedt et al. 2013) without referring to concrete, operational development practices. Only a few articles investigate how companies implement sustainability in product development. Verhulst & Boks (2012a) analyze case studies to examine different approaches companies take and identify two distinct trajectories. The same authors also investigate the role of individual employees and specifically their resistance against sustainability for the successful implementation of sustainable development practices (2012c, 2014).

3.2.3 Level 2 – Product Development in Company Context

The articles assigned to level 2 deal with product development issues within the overall company context and cover a wide variety of topics. For example, Gerstlberger et al. (2014) study the interrelation of sustainable development strategies and activities dedicated to improving the energy efficiency of production facilities. They demonstrate that trade-offs occur when only one aspect is emphasized. Also considering production activities, Diegel et al. (2010) demonstrate how additive manufacturing technologies could foster sustainability in product development. The impact of company culture on sustainability management is explored by Bieker (2005). He analyzes two cases of R&D departments for developing solutions to better incorporate the notion of sustainability. Some articles cover the impact of sustainability on companies' business models. Verhulst & Boks (2012b) investigate the emergence of sustainable business models after companies implement strategies for sustainable product design. Boons & Lüdeke-Freund (2013) review the extant literature on business models and their relation to sustainable innovation. Furthermore, they set up a list of requirements for a company's business model to foster sustainable innovation. The role of the designer in creating a sustainability-driven business is explored by Esslinger (2011). Finally, De Coster & Bateman (2012) investigate different development strategies for sustainable products to contribute to companies' business planning.

3.2.4 Level 3 – Product Development in Supply Chain Context

While most authors acknowledge that suppliers play a major role in product sustainability since they are responsible for materials' sustainability performance, only a few articles deal explicitly with product development in a supply chain context or with collaboration issues. For example, Dangelico et al. (2013) examine through a survey within the Italian textile industry whether collaboration with supply chain partners has a positive influence on the integration of environmental sustainability into new product development processes. Sticking to textiles, Armstrong & LeHew (2011) compare apparel supply chains with those of other industries and evaluate the transferability of existing concepts for sustainable product development. Moreover, Dewulf (2003) discusses whether supply chain management or design is the crucial phase for considering sustainability. Following this discussion, Metta & Badurdeen (2013) propose a framework to coordinate decisions between those two disciplines.

3.2.5 Level 4 – Product Development in External Context

Exceeding the scope of the immediate supply chain of a company, some articles shed light on the role of external stakeholders for sustainability considerations in product development. For example, it is investigated how market reactions towards sustainability should be accounted for (Bisilkas et al. 2012). From a policy-making point of view, Ekins

(2010) evaluates the chance of sustainability policies becoming an important driver for technological transitions towards sustainability. Deutz et al. (2010) showcase the limited influence of municipal waste management on minimizing waste landfill and advocate product design as a promising opportunity for policy interventions. Other authors take an economic perspective: Cooper (1999) and Hoedl (2012) investigate the interrelations between sustainable product development practices and the economic environment. Moreover, Masera (2001) examines the impact of sustainable product development in local micro and small enterprises on the situation of communities in developing countries. Finally, research on sustainable product development itself is investigated by Boks & McAloone (2009). They identify four distinct transitions the field took to become an acknowledged scientific research area and outline possible future transitions.

3.3 Key Observations

As has been demonstrated, sustainable product development is of growing interest for academia from different fields. Summing up the findings from the literature review, eleven key observations are put forward. They are presented in Table 3 along with four research needs derived from those observations and will be detailed in the following.

Table 3: Key Observations and Research Needs

	Key Observations	**Research Needs**	
A	The lion's share of the literature is about developing tools for evaluating design alternatives and supporting decision-making on product sustainability.	Investigate how conceptual research can better contribute to improving the practice of sustainable product development.	I
B	Apart from a small number of established methods (e.g. LCA or DfE) literature reports that companies use almost none of the tools provided by academia.		
C	About half of the articles reviewed claim to be dealing with sustainability while not going beyond environmental factors.		
D	Only a few examples of successfully considering sustainability for mass market products are reported.	Investigate if and how sustainability is considered in product development departments.	II
E	Literature reports that in practice sustainability improvements are rather incremental. Developing PSS is seen as a promising way to more progressively improving sustainability.		
F	Studies about success factors for implementing sustainable product development only seldom cover operational development practices.		
G	Most authors take an industrialized country perspective. Issues from developing countries (e.g. products for the base of the pyramid) are seldom considered.		
H	Only a few authors take a supply chain perspective or at least consider interrelations between product development departments and other departments.	Investigate which internal and external stakeholders influence sustainable product development and how this influence is accounted for in practice.	III
I	Most articles presume that consumers value product sustainability and buy whatever developers come up with. The role of market dynamics is seldom considered.		

Key Observations		Research Needs	
J	The implementation of sustainable product development is predominantly dealt with from a methods and process perspective.	Investigate if and how the individuality of product developers influences sustainable product development.	IV
K	Only a small number of articles deal with the role of individual product developers for implementing product sustainability.		

Key Observation A: The lion's share of the literature is about developing methods for evaluating design alternatives and supporting decision-making on product sustainability. As is displayed in Figure 17, more than 50 percent of the body of literature on sustainable product development is devoted to such methods. Furthermore, the number of such contributions is expected to grow as sustainability further gains in importance (Buchert et al. 2014b, p. 413). Similar observations are made by Baumann et al. (2002) in their review of eco-design. They analyze more than 150 different eco-design tools and reason that academia spends more time on developing new tools than on testing and improving the ones that already exist (Baumann et al. 2002, p. 421). This also seems to hold true for contemporary research on sustainable product development. In general, most research on sustainability issues is conceptual in nature while empirical studies are limited (Ozanne et al. 2016, p. 3).

Key Observation B: Apart from a small number of established methods like LCA or DfE, literature reports that companies use almost none of the methods provided by academia (Baumann et al. 2002, p. 418 f.; Hallstedt 2008, p. 35 f.; May et al. 2012, p. 444). This striking gap between development and actual usage of methods is attributed to a number of reasons: First, most methods appear to be too complex for everyday use in terms of required previous knowledge or necessary input data (Hopkins 2010, p. 80; Alblas et al. 2014, p. 520 f.; Petersen 2015, p. 105). This is also critically acknowledged by some methods' authors (Woll et al. 2011, p. 853). Second, most of them are not adaptable to specific company needs and therefore are difficult to implement into established development processes (Byggeth et al. 2007a, p. 2; Petala et al. 2010, p. 181; Clancy et al. 2013a, p. 383). Finally, it is most likely that many methods are simply not recognized by practitioners (May et al. 2012, p. 444). Similar observations were also made for method usage in product development beyond this dissertation's sustainability focus (Graner & Mißler-Behr 2012, p. 179). However, it has to be acknowledged that method development commonly suffers from a serious dilemma: effective methods are expected to allow for highly specific and transparent assessments while they also have to be easy to use and applicable to a broad spectrum of situations (Ness et al. 2007, p. 506).

Key Observation C: About half of the articles reviewed claim to be dealing with sustainability while not going beyond environmental factors. In part, this can be attributed to the fact that

constructive measures often have limited impact on social sustainability (Hanusch & Birkhofer 2008, p. 219) and that social factors are hard to quantify. This is also observed in other fields of research where it is easy to describe social drawbacks but hard to pinpoint suitable measures (e.g. Hackius & Kersten 2014, p. 268 investigate sustainability issues in truck loading docks). It is simply easier to deal with measurable, single environmental impacts of a product like CO_2-emissions than to handle sometimes intangible and subjective aspects like its senior-friendliness or the working conditions during its manufacturing. However, academia should contemplate if it is appropriate to keep this narrow focus while criticizing companies for not truly embracing sustainability.

The key observations A, B, and C are mostly concerned with the contemporary way of doing conceptual research on sustainable product development. While this type of work represents the majority of contributions, they seem to have only limited impact on companies. Therefore, the following research need is derived:

Research Need I:	**Investigate how conceptual research can better contribute to improving the practice of sustainable product development.**

Key Observation D: Only a few examples of successfully considering sustainability for mass market products are reported. However, submissions for several sustainable product awards (like Bundespreis Ecodesign or the Green Product Award) or a look at the shelf of any retail store makes clear that there are numerous products on the market that at least feature some sustainability aspects. The experiences product developers of these products already gained might provide valuable starting points for companies just getting engaged with product sustainability.

Key Observation E: Literature reports that in practice sustainability improvements are rather incremental. This is attributed to the reactive approach most companies take as they are mostly focused on limiting environmental impacts of already existing products (e.g. Dangelico & Pujari 2010, p. 477 f.) Developing PSS is seen as a promising way to overcome these limitations and to more progressively improving sustainability (e.g. Ny et al. 2013, p. 428). Frequently cited examples for PSS are car sharing services (e.g. Spangenberg et al. 2010, p. 1487) or toy libraries (e.g. Phipps et al. 2013, p. 1230 f.). However, for most products, it remains elusive how they could be transferred into commercially successful PSS. Also, extant PSS are often driven by new market participants instead of the products' manufacturers.

Key Observation F: Studies about success factors for implementing sustainable product development rarely cover operational development practices. Instead, most of the success

factors remain on an abstract level (e.g. “support by top management” or “consideration of full life-cycle”). While these factors might be critical, such high-level recommendations are of little help to companies struggling to break down the fuzzy concept of sustainability into explicit requirements for product developers.

Key Observation G: Most authors take an industrialized country perspective. Issues from developing countries (e.g. products for the base of the pyramid) are seldom considered. However, developing new concepts for well-known products for use in developing countries might yield significant sustainability gains. One example is a radically new concept of a refrigerator developed by Whirlpool. It is designed for use in rural areas and holds little environmental impact (Boks & McAloone 2009, p. 439). Such new ideas and the voluntary return to basic product functions could also constitute additional benefits for products aiming at industrialized countries’ markets.

The key observations D, E, F, and G deal with different perspectives on the implementation of sustainability into companies’ development processes and their output in the form of more sustainable products. In this frame, it becomes clear that implementing sustainability is a highly challenging activity (Gmelin & Seuring 2014a, p. 175) and companies face major difficulties in this respect (Alblas et al. 2014, p. 533). Even though some authors already began to investigate empirically how companies do it rather than proposing how they should do it, this field of research deserves higher attention among scholars (Sutcliffe et al. 2009, p. 298). Therefore, the following research need is derived:

Research Need II:	**Investigate if and how sustainability is considered in product development departments.**

Key Observation H: Only a few authors take a supply chain perspective or at least consider interrelations between product development departments and other departments. However, developers in practice do not work on new products in isolation. Especially the supply side should be taken into consideration as already the choice of materials determines a good share of a product’s sustainability-related impacts. Also, stakeholders that are not part of the immediate supply chain of a product (e.g. NGO or legislation) can exert considerable influence on product development (Gmelin & Seuring 2014a, p. 166).

Key Observation I: Most articles presume that consumers value product sustainability and buy whatever developers come up with. The role of market dynamics is seldom considered, and most tools developed do not account for customer requirements. However, companies engaged in sustainability improvements soon notice that “green” itself does not sell (Boks & McAloone 2009, p. 434). It rather can be seen as a way to augment products with good

overall performance (Esty & Winston 2006a, p. 240). Studies have shown that consumers often (falsely) expect trade-offs between sustainability and functional performance – sustainability can, in fact, be a liability for products (Luchs et al. 2010, p. 28 f.) Therefore, product developers have to find ways that allow for improving sustainability while preserving product quality and functional performance in the eye of the customer.

The key observations H and I are concerned with the role of different internal and external stakeholders as their take on sustainability can increase the complexity of developing new products (Gmelin & Seuring 2014a, p. 166). However, since their impact on product development in practice is a more or less neglected area of research until today, the following need for further research is derived:

Research Need III:	**Investigate which internal and external stakeholders influence sustainable product development and how this influence is accounted for in practice.**

Key Observation J: The implementation of sustainable product development is predominantly dealt with from a methods and process perspective. Accordingly, authors focus on providing supportive tools, analyzing and adapting existing process models, or identifying organizational roadblocks. It is assumed that any company can implement these contributions, and company-specific or human factors play no decisive role. In fact, such simplifying assumptions are a major roadblock for the actual use of new methods in development processes of any company.

Key Observation K: Only a small number of articles deal with the role of individual product developers for implementing product sustainability (e.g. Verhulst & Boks 2012c). However, ultimately the success of the implementation is at the mercy of the people making the design decisions. Thus, human factors like resistance against change can thwart or even prevent sustainability considerations. However, the spirit of individual developers can also act as a crucial impulse for improving product sustainability.

Even though the key observations J and K suggest that human factors with respect to implementing sustainability in product development receive little attention in academia until now, it is considered one of the next important fields of research (Boks & McAloone 2009, p. 445). Also from a greater supply chain perspective, the people dimension is considered a highly undervalued field of research (Wieland et al. 2016, p. 207). Therefore, the following research need is derived:

Research Need IV:	**Investigate if and how the individuality of product developers influences sustainable product development.**

Based on the key observations and the research needs derived, the objective and research questions of this dissertation will be presented in the next section.

3.4 Research Objective and Research Questions of this Dissertation

The review of the extant literature on sustainability management in product development demonstrated that contemporary research is more concerned with providing methodological support for companies than analyzing what these companies are doing and what their true needs are. Consequently, understanding companies' approaches towards sustainability is seen as a crucial prerequisite for appropriate conceptual contributions. For this reason, the research objective of this dissertation is defined as follows:

Research Objective:	**Gaining a better understanding of how product sustainability is accounted for in product development and contributing to the further adoption of sustainability principles through identifying best practice examples.**

Three research questions are derived from this objective. They coincide in part with the research needs II and III outlined above. The first question aims at analyzing different paths companies choose for sustainability considerations. The scope of the question is not limited to development practices but also incorporates internal and external stakeholders and their leverage on the development of more sustainable products:

Research Question 1:	**Which approaches are taken by companies for the development of more sustainable products?**

The second research question is concerned with roadblocks product development departments hit when defining and realizing their individual approaches towards sustainability. It is to be analyzed if and how these roadblocks coincide with the different approaches or company specific factors:

Research Question 2:	**Which challenges do product developers have to meet in the context of developing more sustainable products?**

Building upon these findings, the third research question aims at contributing to the further adoption of sustainability principles in product development:

Research Question 3:	**Which recommendations can be derived for the development of more sustainable products?**

After introducing the theoretical background and the state of research on sustainable product development, the employed methodology of the empirical studies of the current dissertation is presented in the next chapter.

4 Methodology

In this chapter, the methodology for the empirical analysis of this dissertation is put forward. The analysis constitutes a mixed methods approach, and the corresponding research design is introduced first. Afterward, the research methods are presented, and their choice is substantiated.

4.1 Research Design

A research design comprises the conceptual design of data collection and data analysis as well as the selection of empirical material to tackle the underlying research questions (Flick 2010, p. 252). Mostly based on the kind of empirical material, research can be distinguished into qualitative and quantitative studies. In short, qualitative research is about the “what”, while quantitative research is about the “how much” (Dabbs Jr. 1982, p. 32). Thus, *qualitative studies* build on qualitative information like sentences or narratives and aim at exploring the meaning and character of the phenomenon under study (Dabbs Jr. 1982, p. 32; Blumberg et al. 2011, p. 144). They are mostly of inductive nature as they start with a limited number of observations and aim at shaping a generalizable theory out of the data. Examples of qualitative research methods are ethnography, Grounded Theory, and semiotics (Myers 2009, p. 8). *Quantitative studies* on the other hand base their accounts on quantitative information like numbers and figures and aim at measuring the assumed meaning and character of the phenomenon (Dabbs Jr. 1982, p. 32; Blumberg et al. 2011, p. 144). They are mostly of deductive nature as they start with a theory and aim at falsifying it for the cases under study. Examples of quantitative research methods are simulations, and laboratory experiments (Myers 2009, p. 8). However, it has to be kept in mind that most research problems can be approached from a qualitative and a quantitative angle and that both kinds of studies can yield meaningful findings (Myers 2009, p. 9; Blumberg et al. 2011, p. 144). In fact, in many cases, it has proven beneficial to combine positivistic, quantitative and interpretive, qualitative methods and data. Such a *mixed-methods approach* is promising e.g. if researchers aim at triangulating their findings, if they try to explain findings from a previous analysis, or if they want to quantitatively test hypotheses that were generated from qualitative data (Bryman 2006, pp. 105–107).

This dissertations’ empirical analysis follows a mixed-methods approach as it consists of a qualitative and a quantitative study to shed light on the research questions. First, a qualitative analysis with the goal of constructing theory on the way product developers from consumer goods companies deal with product sustainability is conducted. Hence, this study looks into the first two research questions derived from the literature analysis in the previous chapter. Additionally, a quantitative analysis that further investigates how product

developers can influence consumers towards buying more sustainable products is conducted. It aims at yielding insights into the third research question specified in the previous chapter. Figure 19 summarizes the research design of the current dissertation along with details on the data sources and the respective survey periods.

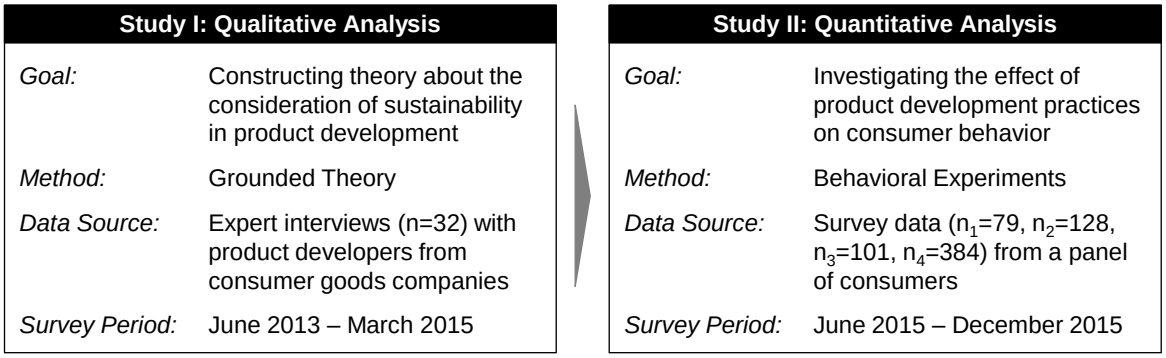

Figure 19: Research Design of the Current Dissertation

Both studies are intertwined as the quantitative analysis is based on parts of the findings from the qualitative analysis. In the following sections, the fundamentals of the research methods employed for the analyses are introduced.

4.2 Fundamentals of Grounded Theory

For the qualitative analysis, a Grounded Theory approach is applied. This section first provides an introduction to the fundamental assumptions and analytic tools of Grounded Theory. Afterward, Grounded Theory is substantiated as a suitable approach for addressing the underlying research questions of this dissertation.

4.2.1 Development and Origin

Grounded Theory was conceptualized at a time when operationalization, quantification, and measurability of phenomena through quantitative research methods had become predominant (Fendt & Sachs 2007, p. 431). Qualitative research approaches were largely dismissed as being unsystematic and anecdotal (Charmaz 2014, p. 6 f.). Thus, Barney Glaser and Anselm Strauss published “The Discovery of Grounded Theory” (1967) as a reaction to this strong influence of positivism in the social sciences (Suddaby 2006, p. 633). In the years before they had investigated the issue of dying in hospitals and specifically how hospital staff and patients dealt with it (Glaser & Strauss 1965). This topic had received little attention from academia until then and was even barely talked about in practice. Glaser and Strauss worked on developing theories grounded in their observations from a variety of hospital situations. During that course, they started to define a set of systematic analytical strategies that could also be applied to other fields of research (Charmaz 2014, p. 5 f.). Their approach hit a nerve and became a major precursor for the resurgent popularity of

qualitative research methods in the following decades (Charmaz 2014, p. 8). Today, Grounded Theory is reckoned as a well-established, mostly inductive[15] way to systematically collect and analyze qualitative data and to carve a theory about the investigated phenomenon out of the data. It is successfully applied in a variety of domains from law (e.g. Tränkle 2007) to industrial engineering (e.g. Nakhosteen 2009).

Since its introduction, the original method of Grounded Theory has been advanced several times by both Glaser (1978, 1992, 2008) and Strauss together with Corbin (1990, 2008) as well as other authors (Goulding 2002; Clarke 2005; Charmaz 2014). Doing so, both fathers of Grounded Theory shaped two distinct streams (see Jones & Noble 2007, pp. 85–93; Denk et al. 2012, p. 763 for a detailed comparison): while they still share fundamental assumptions, Glaser promotes a puristic approach whereas Strauss advocates a rather pragmatic take on Grounded Theory. Glaser objects to using any tools or previous knowledge for analytical purposes to let the theory emerge freely. He accuses those still doing so of "forcing" the data (1992). Strauss (1987) and later Corbin & Strauss (1990, 2008) favor a more realistic, less abstract, and more flexible approach to Grounded Theory and provide a number of tools and recommendations that can (but do not necessarily have to) be used for constructing theory. Their approach is employed for this dissertation and referred to during the introduction of the fundamentals of Grounded Theory within the next sections.

4.2.2 Methodological Overview

Before the core principles of Grounded Theory are introduced in detail, Figure 20 provides a simplified overview of the major elements necessary to construct[16] a Grounded Theory. Starting with a research question, data collection, data analysis, and construction of theory are interrelated activities and are repeated until theoretical saturation is reached. Finally, the theory is contextualized with the extant literature. For Grounded Theory studies, it is usually not necessary to do an extensive literature review before setting out in the field. In fact, it is seldom possible to determine beforehand which salient problems will be discovered during the journey (Corbin & Strauss 2008, p. 35).

[15] Corbin & Strauss (2008, p. 326) clarify that Grounded Theory is not purely inductive: "This method is inductive in the sense that findings are derived from data. It's deductive in the sense the concepts and the linking statements are interpretative; that is, constructed by the analyst from data."

[16] Glaser & Strauss (1967) originally used the phrase "discovering theory" implying that there is one objective truth to be found (Fendt & Sachs 2007, p. 445). However, Charmaz cautions that researchers rather construct theory as they are always influenced by "past and present involvements and interactions with people, perspectives, and research practices" (2014, p. 17). Later, this is also acknowledged by Corbin & Strauss stating that "objectivity in qualitative research is a myth" (2008, p. 32).

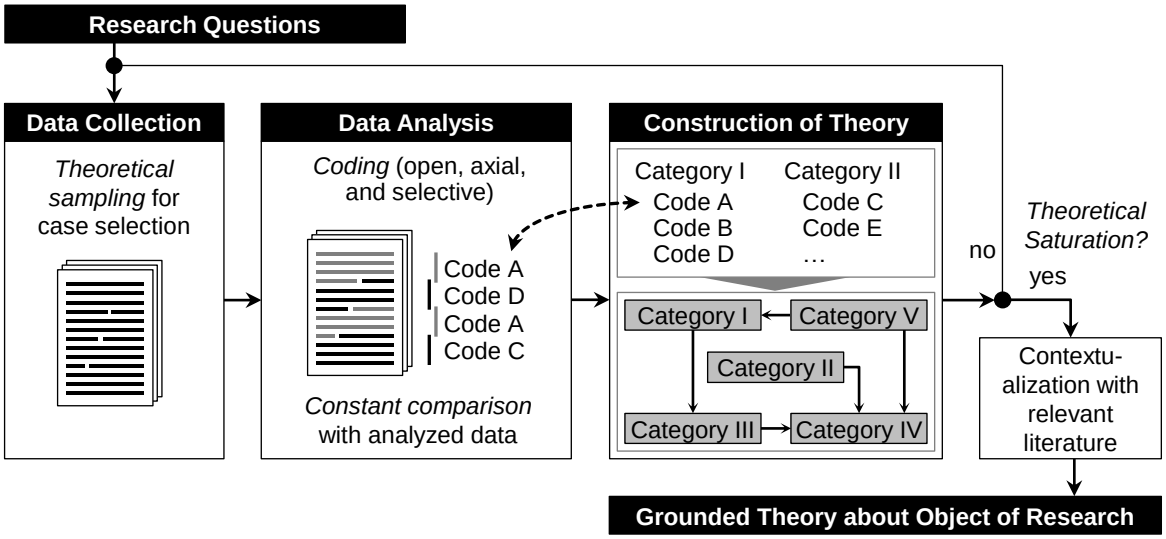

Figure 20: Process of Constructing a Grounded Theory (adapted from Petersen et al. 2016a, p. 335)

In the following, the activities and procedures related to each element of Grounded Theory are explained in detail. However, Corbin & Strauss themselves caution that "techniques and procedures are tools, not directives" and that the analytical process "should be relaxed, flexible, and driven by insight gained through interaction with the data rather than being overly structured and based only on procedures" (2008, p. 12). Alternatively, as Fendt & Sachs (2007, p. 451) put it: "(…) make sure the method serves the researcher, not that the researcher serves the method."

4.2.3 Data Collection and Theoretical Sampling

For Grounded Theory studies, useful data can be collected from a wide variety of sources. Researchers are advised to work with anything that helps to illuminate the research question (Corbin & Strauss 1990, p. 5). Nevertheless, Charmaz cautions that quality and credibility of the empirical material has to be ensured (2014, p. 32 f.). Most of the time data from interviews or observations are used for constructing a Grounded Theory. However, other possible data sources comprise of videos, documents, drawing, newspapers, or letters among others (Corbin & Strauss 2008, p. 27). As stated before, in Grounded Theory, data collection, data analysis, and theory construction are interrelated activities constituting a circular process. Thus, other than in quantitative research, the data is not collected in its entirety before its analysis begins. Therefore, traditional sampling strategies are dismissed for Grounded Theory studies as case selection is rather driven by theoretical considerations than by the goal of achieving representativeness. This approach is called *theoretical sampling*. After a piece of data has been analyzed, it is decided upon the working results which additional data is critical for refining and advancing the theory under construction

(Corbin & Strauss 2008, p. 144 f.). Thus, the criteria for sampling are likely to change as the study progresses (Pratt 2009, p. 859).

Like most Grounded Theory studies, this dissertation primarily builds on interview data. Depending on a study's purpose, structured interviews for reliably measuring theoretical concepts have to be distinguished from semi-structured or unstructured interviews allowing for exploring respondents' viewpoints (Blumberg et al. 2011, p. 265 f.). For interviewing in Grounded Theory, it is advised to start with only a few open-ended questions to invite the participants to share their unbiased perception of the topic (Charmaz 2014, p. 65). Later, relevant issues can be discussed in more detail. However, researchers should be careful always to explore the participants' take on the issues rather than interrogating them (Charmaz 2014, pp. 68–71). Corbin & Strauss even recommend conducting unstructured interviews as those happened to be the most data dense interviews in their research projects (2008, p. 27).

4.2.4 Data Analysis and Construction of Theory

The data analysis should start with the first pieces of data being collected (Corbin & Strauss 1990, p. 6). It consists of (1) coding the data and (2) constant comparison with already analyzed data. *Coding* is understood as the process of developing concepts from the collected data (Corbin & Strauss 2008, p. 65). Three basic steps of coding are to be distinguished: open, axial, and selective coding (Corbin & Strauss 1990, p. 12). However, an actual procedural separation of these analytical steps would be artificial as they go hand in hand in practice (Corbin & Strauss 2008, p. 198).

- *Open coding* means analytically breaking down the raw data line by line and labeling the resulting segments with descriptive codes. Each segment is assigned to a preliminary concept (Corbin & Strauss 2008, p. 195). Thus, concepts are directly derived from the data and represent the researcher's notion of the participants' words or observed incidents. Similar concepts are then grouped to form categories and subcategories. They are further refined by defining properties (characteristics shared by all concepts of a category) and dimensions (variations of properties along a range) (Corbin & Strauss 2008, p. 45 f.).

- During *axial coding*, categories are further refined and related to each other. These relationships are constantly challenged with every bit of new data. For identifying relevant contextual factors, Corbin & Strauss propose a coding paradigm (2008, p. 89 f.). It enables to question each category's phenomenon systematically regarding its causal conditions, the evoked interactions, and emotions as well as the resulting consequences.

- Finally, *selective coding* deals with selecting a core category that resembles the central theme of the findings and that all other categories refer to (Corbin & Strauss 1990, p. 14).

Concepts and categories are developed and verified through *constant comparison* of fresh data with already analyzed data. Thus, each concept "earns its way into the theory by repeatedly being present in interviews (…) in one form or another" (Corbin & Strauss 1990, p. 7). By challenging the working results over and over again, differences and similarities between varying contexts are expatiated on, and the categories' properties and dimensions are carved out. Constant comparison starts as soon as the first concepts are developed from the data. It only ends with comparing the constructed theory with the extant literature.

Corbin & Strauss define a theory as "a set of well-developed categories (themes, concepts) that are systematically interrelated through statements of relationship to form a theoretical framework that explains some phenomenon" (2008, p. 55). Hence, constructing theory means lifting the data to a higher level of abstraction (Suddaby 2006, p. 636). One important tool for relating categories and thus giving meaning to the data is writing *theoretical memos*. Memos are running logs of the researcher's efforts to construct theory, i.e. of ideas and thoughts that emerged throughout working with the data (Corbin & Strauss 2008, p. 108). Memos should be written about concepts, categories, and their interrelations from the start. During the research process, they have to be constantly updated, refined, and sorted. Another tool for facilitating the construction of theory is drafting diagrams like the *conditional/consequential matrix* (Corbin & Strauss 2008, pp. 90–95). It is a conceptual guide that helps the researcher to grasp the interactions of micro and macro conditions and consequences about the phenomenon under investigation.

4.2.5 Theoretical Saturation and Sample Size

Data collection and thus construction of theory end when theoretical saturation is reached. Saturation indicates that "gathering fresh data no longer sparks new theoretical insights, nor reveals new properties of these core theoretical categories" (Charmaz 2014, p. 213). Thus, saturation is not necessarily reached when no new categories themselves are emerging. In fact, it also pertains to the properties and dimensions of the categories. However, due to the "indeterminate, messy nature of saturation" (Suddaby 2006, p. 639), it is often used as a shallow excuse for terminating data collection after a small number of cases (Corbin & Strauss 2008, p. 113). However, even for larger numbers, deciding saturation has been reached is far from easy. Thus, some authors try to offer guidance and voice recommendations on appropriate sample sizes for qualitative studies. They range from eight interviews for a homogenous sample (McCracken 1988, p. 17) to an amount of

12–20 (Carter & Jennings 2002, p. 150), an amount of 20–30 (Creswell 2013, p. 157) or 30–50 interviews (Morse 1994, p. 225). Literature also contains examples of Grounded Theory studies with more than 400 interviews (Pettigrew 2002, p. 114). However, other than in quantitative research – where significance levels and desired effect sizes allow for computing suitable sample sizes – qualitative approaches like Grounded Theory lack a "magic number" of necessary observations to build convincing theory (Pratt 2009, p. 856). Despite the numerous recommendations, saturation ultimately depends on the nature of the study as well as the researcher's perception of theory density and its quality (Glaser & Strauss 1967, p. 62; Suddaby 2006, p. 639).

4.2.6 Research Validity

Qualitative research is threatened by subjectiveness since an accepted "boilerplate" for conducting and evaluating qualitative studies is missing (Pratt 2009, p. 856). Therefore, proving the validity of both the research process and the findings is of high importance for the credibility of the study. However, there is an ongoing debate in the literature by which criteria qualitative research should be evaluated (see e.g. Wrona & Gunnesch 2016, p. 739 for an overview): Some authors advocate adapting the standard quality criteria from quantitative research (i.e. objectivity, reliability, and validity) to demonstrate the trustworthiness of qualitative studies. Others dismiss any unified quality criteria in reference to the individual knowledge and experiences any researcher brings to the table. The third group of authors develops independent criteria to address the specifics of qualitative research.

For the author of this dissertation neither using criteria from quantitative research nor forgoing any quality control at all seems reasonable. Consequently, a criteria set developed by Mayring (2002, pp. 144–148) is employed. He puts forward six criteria that should be addressed through adequate measures to ensure the validity of the *research process*: (1) detailed documentation of the research process, (2) argumentative validation of interpretations, (3) adherence to systematic analytical procedures, (4) proximity to the object of research, (5) discussion of findings with participants, and (6) triangulation. In addition to the research process, the *research findings* should also be evaluated to ensure high quality. For Grounded Theory, Glaser & Strauss emphasize that the quality of a theory should predominantly be assessed by the way it was constructed (1967, p. 5). However, they also define the four criteria fit, understanding, generality, and control to assess theory quality (Glaser & Strauss 1967, pp. 237–249). These criteria were then extended by Flint et al. (2002, p. 106). They are employed to demonstrate the actions taken to assure high quality of the findings of this dissertation's Grounded Theory study. Table 4 provides an overview of the quality criteria for evaluating the research process and its findings.

Table 4: Criteria to Address for Ensuring Validity of Research Process and High Quality of Findings (based on Flint et al. 2002, p. 106; Mayring 2002, pp. 144–149)

Scope	Criteria
Research Process	Detailed documentation of the research process
	Argumentative validation of interpretations
	Adherence to systematic analytical procedures
	Proximity to the object of research
	Discussion of findings with participants
	Triangulation
Research Findings	Credibility (i.e. findings have to be acceptable representations of the data)
	Transferability (i.e. findings from one study in one context have to apply to other contexts)
	Dependability (i.e. explanations have to be of high stability and consistency)
	Confirmability (i.e. interpretations must be the result of the participants and the phenomenon as opposed to researcher bias)
	Integrity (i.e. interpretations must not be influenced by misinformation or evasions by participants)
	Fit (i.e. findings must fit with the substantive area under investigation)
	Understanding (i.e. participants must buy into findings as possible representations of their world)
	Generality (i.e. findings must discover multiple aspects of the phenomenon)
	Control (i.e. organizations must have influence on the aspects of the theory)

4.2.7 Substantiation of Method Choice

As was put forward in Section 3.2, the extant literature on sustainable product development focuses on developing and evaluating tools. The product developers' perceptions and attitudes towards the implementation of sustainability as well as resulting drivers and roadblocks have so far been largely ignored. A qualitative research method and more specifically Grounded Theory is considered to offer a suitable approach for contributing to this research need.

The application of Grounded Theory is feasible, whenever "researchers have an interesting phenomenon without explanation and from which they seek to discover theory from data" (Suddaby 2006, p. 636). More specifically, Grounded Theory enables researchers to build theory of "process, sequence, and change pertaining to organizations, positions, and social interaction" (Glaser & Strauss 1967, p. 114). Furthermore, Grounded Theories distinguish themselves through "linking well to practice" and therefore are especially suitable for investigating work situations like decision-making, change, or individual behavior (Locke 2001, p. 95). This is not surprising as Grounded Theory originates from studying work accomplished in complex organizational environments (Locke 2001, p. 95). Taken together, Grounded Theory allows to record, interpret, and abstract the subjective experiences of a study's participants into theoretical statements about the phenomenon under research

(Fendt & Sachs 2007, p. 432). For this reason, Grounded Theory is considered well-equipped to help answering the underlying research questions of the current dissertation and is preferred over other qualitative research methods. Accordingly, Grounded Theory will be used for building theory on considering sustainability during the development process of consumer goods.

4.3 Fundamentals of Behavioral Experiments

For the subsequent quantitative analysis, behavioral experiments will be designed, executed, and analyzed. This section introduces the core elements of behavioral experiments and substantiates the method choice.

4.3.1 Methodological Overview

Experiments are designed to help validate theories (e.g. about the behavior of individuals or organizations) from a variety of domains (Brockhaus 2013, p. 68). They allow for examining the effect of varying an independent variable on a depended variable (Blumberg et al. 2011, p. 308; Eckerd 2016, p. 1). Thus, other than approaches that merely detect correlation (e.g. surveys), experiments enable researchers to find evidence of causality (Knemeyer & Walker Naylor 2011, p. 296 f.).

Three *types of experiments* are to be distinguished (Croson 2002, p. 925) as they can either be designed to address theories, investigate previously identified anomalies, or testbed policies. First, experiments for addressing theories empirically test the predictions deduced from theory. Thus, they seek to provide evidence for the explanatory value of a theory. However, most of the time experiments do not test point predictions generated from the theory but rather comparative static predictions between different treatments (Croson 2002, p. 926). It is important to note that according to Popper's concept of falsification, a theory cannot be conclusively proven (2005, pp. 64–67). Instead, experiments are a way to falsify theories by challenging their assumptions. Hence, they can also be conducted to compare the explanatory value of competing theories. Second, experiments that are designed to investigate previously identified anomalies aim at explaining observations that are not consistent with their predictions. Thus, such experiments are often follow-up studies to further investigate findings that are "difficult to rationalize" (Croson 2002, p. 930). Third, experiments that testbed policies examine whether a policy has the projected consequences or leads to any undesired side effects. Often, multiple policies are compared to each other (Plott 1994, p. 4; Croson 2002, p. 934). This dissertation's experiments aim at validating hypotheses derived from the findings of a qualitative empirical study. Thus, they correspond to the first type of experiments that address a theory.

Figure 21 illustrates the most relevant aspects of any *experimental design*. First, it has to be ensured that the effect to be observed is solely caused by the hypothesized cause. Thus, anything that may also affect the dependent variable has to be held constant (Blumberg et al. 2011, p. 311). Controlling for such interfering variables is possible in a laboratory environment but hard to do in the field. Thus, field experiments are often called "quasi-experiments" (Knemeyer & Walker Naylor 2011, p. 297). Second, after choosing appropriate participants, they are exposed to one of the predefined treatment of the independent variable under investigation (e.g. to a specific drug level in a clinical trial). It is important to assign the participants randomly as this ensures measuring the effect of the manipulation instead of accidentally measuring the effect of preexisting differences between groups of participants (Blumberg et al. 2011, p. 312). Third, the dependent variable is measured. Performing comparative statistical analyses like a t-Test or an ANOVA[17] then allows for providing evidence of possible causality. More specifically, it has to be tested if the variance of the dependent variable for each experimental condition is significantly lower than the variance of the entire sample. However, also other statistical procedures like regressions or structured equation modeling can be of use for analyzing the data (Bachrach & Bendoly 2011, p. 7). Usually, manipulation checks are included in an experiment. Through such additional variables, researchers can check if the manipulation worked as expected or if it went unnoticed by the participants (Knemeyer & Walker Naylor 2011, p. 299; Eckerd 2016, p. 3). It is also possible to manipulate more than one independent variable (Blumberg et al. 2011, p. 320). In this case, the data has to be analyzed for both the main effects of the independent variables on the dependent variable and interaction effects between the independent variables.

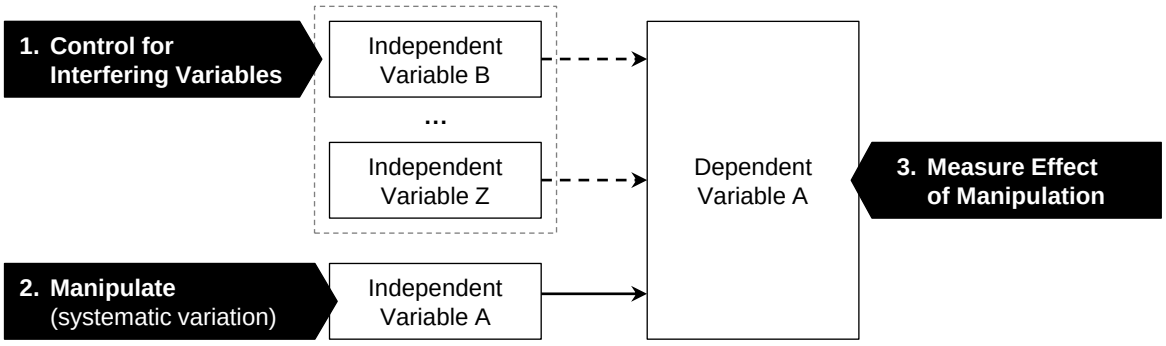

Figure 21: Basic Steps of Conducting an Experiment

For *assigning participants* to the treatments of the independent variable, between-subjects and within-subjects designs have to be distinguished (Greenwald 1976, p. 314). Between-subjects experiments aim at comparing the behavior of participants that were subjected to

[17] ANOVA = Analysis of Variance.

a specific treatment with the behavior of a control group (e.g. one group receives the actual drug while the other group is provided with a placebo). Within-subjects experiments, on the other hand, aim at comparing the change in the participants' behavior before and after they were exposed to the treatment. This dissertation's experiments will be designed as between-subjects experiments since this is more in line with the sustainability-related hypotheses to be tested. In fact, between-subjects experiments have proven to be particularly suitable for topics that might be affected by social desirability bias.

Experiments investigating the nuances of human behavior (i.e. judgments and decision-making) relate to the class of behavioral experiments (Knemeyer & Walker Naylor 2011, p. 296). Other than e.g. experiments in medicine, behavioral experiments often come in the form of a scenario-based role-play (Eckerd 2016, p. 2). Thus, participants are asked to assume a predefined role and make their decisions in response to the scripted information they are provided with (Rungtusanatham et al. 2011, p. 9). This information constitutes the *vignette* of a behavioral experiment and sets the scene for the observations. Vignettes are particularly important for experiments that ask students to assume the role of working professionals (e.g. Brockhaus 2013 uses business students as a proxy for supply chain professionals) and might have to be quite substantial. However, a highly detailed vignette increases the risk of unintentionally skewing the findings though improper wording. Hence, numerous publications are dedicated to helping to craft suitable vignettes (e.g. Stolte 1994; Wason et al. 2002). Since the current dissertation's experiments ask the participants to evaluate consumer goods based on a product picture they see, and this is assumed to be an intuitive task, no extensive vignette has to be crafted.

To shed light on a research question, it is recommended to conduct *multiple experiments* (Knemeyer & Walker Naylor 2011, p. 299). Especially in marketing research it is common to analyze assumed effects step-wise through first pretesting the applicability of the manipulation and then gradually raising the complexity of the study (e.g. Luchs et al. 2010). Also in the field of sustainability, it has become good practice to conduct multiple experiments to analyze how sustainability impacts decisions and judgment (e.g. Brockhaus 2013; Luchs & Kumar 2015). This dissertation's quantitative research phase follows the lead as it consists of three experimental preliminary studies and one main experiment.

4.3.2 Research Validity

Like qualitative research, also quantitative studies should be subjected to a rigorous evaluation of their trustworthiness. For this purpose, the quality criteria objectivity, reliability, and validity are commonly employed. *Objectivity* is ensured if the findings do not depend on any subjective influence the researcher might consciously or unconsciously exert (Wrona

2006, p. 207). *Reliability* of experimental findings implies that the participants' behavior is consistent and robust over time (Creswell & Plano Clark 2011, p. 211). Thus, the findings of a study could be replicated in a comparable research setting (Eckerd 2016, p. 3). Recent research in psychology has demonstrated that reliability is often a problem in experimental research since, in fact, many findings could not be replicated (Open Science Collaboration 2015, p. 943). *Validity* is also of particular importance for experimental studies and has to be differentiated into internal and external validity (Campbell & Stanley 1966, p. 5). Internal validity implies that the experimental design is suitable for investigating the hypothesized causal relationship between the variables (Croson 2002, p. 928 f.). This especially pertains to controlling any other variable that might interfere with the effect under study (Blumberg et al. 2011, p. 314). Thus, internal validity is best achieved in a controlled laboratory environment. External validity is concerned with being able to generalize the findings across populations and situations (Campbell & Stanley 1966, p. 5). Thus, a study should be evaluated by the degree to which the findings apply to situations outside of the controlled experimental setting. One issue that might impact the external validity of an experimental study is the use of student samples as a proxy for working professionals (Knemeyer & Walker Naylor 2011, p. 297). Overall, balancing internal and external validity of an experiment is challenging since improving one aspect is likely to jeopardize the other one (Campbell & Stanley 1966, p. 5).

4.3.3 Substantiation of Method Choice

Several approaches for deductively testing theory developed from qualitative data are available. Among them are structured equation modeling, experimental designs, surveys, simulations, and the analysis of archival data. The choice of a suitable approach should be based on the purpose of the study, the nature of the underlying theory, and the availability of appropriate samples (Flynn et al. 1990, p. 255). Since this dissertation's quantitative research phase deals with consumers' responses to product developers' sustainability initiatives, surveys and experiments are considered meaningful ways to illuminate the research question. However, sustainability-related research is often threatened by a social desirability bias – respondents claim that they want to act in favor of sustainability, but they are not willing to make any true sacrifices. While this might be a problem for survey-based research (e.g. as demonstrated by many surveys about sustainable consumption that rather measure exaggerated claims instead of actual purchasing behavior), experiments are a way to detecting and handling the effect of bias through exposing participants to different sustainability-related treatments and observing their behavior. Such an approach has also been successfully employed in previous studies (e.g. Brockhaus 2013; Paharia et al. 2013; Luchs & Kumar 2015). Thus, behavioral experiments are a well-tried way of investigating

consumer responses to sustainability issues and, thus, are employed for the quantitative research phase of the current dissertation.

4.3.4 Introduction to Amazon Mechanical Turk as Participant Pool

As has already been established in Section 4.3.1, selecting suitable participants is crucial for successful experimental research. To recruit participants for this dissertation's experiments, the crowdsourcing service Amazon Mechanical Turk (AMT) will be used. Recently, this platform has become a popular way of collecting survey and experimental data (Paolacci & Chandler 2014, p. 184). However, since this form of recruitment is still relatively new, AMT will be introduced in the following.

AMT was created for Amazon's internal use in 2005. The idea behind the service was splitting tasks that are difficult to automate (e.g. labeling product pictures) among many human workers (Landers & Behrend 2015, p. 152). Today, AMT is also open to external so-called "requesters". They hire so-called "workers" to perform a wide variety of tasks including transcription of sales receipts or business cards, market research, or assessing the sentiment of texts (Schmidt 2015, p. 167). These tasks are called HITs (Human Intelligence Tasks) and are typically a matter of minutes. The rewards requesters pay to workers for HITs start at $0.01 and typically do not exceed $1 (Paolacci et al. 2010, p. 412). Even though studies have demonstrated that some workers are willing to accept HITs paying as little as $0.04 per hour (Buhrmester et al. 2011, p. 411), from an ethical point of view the estimated hourly rate should be matched to minimum wage. Submissions can be rejected by the requester if quality criteria are not met. In this case, workers are not rewarded and get a negative rating. In 2014, around 500,000 workers from 190 countries were registered on AMT. However, most of them come from the United States and India (Paolacci & Chandler 2014, p. 184 f.). Requesters can restrict HIT-access to workers that e.g. stem from a specific country, have already completed a specific number of HITs, or exceed a minimum HIT-approval rate.

Since at least 2009 AMT is used for sampling participants for research projects in a variety of domains (Landers & Behrend 2015, p. 152). According to Google Scholar around 7,500 articles published in 2014 and 2015 mention AMT. This is not surprising given the unique advantages this service provides for researchers (Mason & Suri 2012, p. 2 f.): First, AMT offers access to an enormous and yet relatively stable subject pool. Second, it enables conducting studies at low costs compared to traditional recruitment methods. Finally, since it takes little time to sample the desired number of participants, the cycle of construction of theory and hypothesis testing is shortened considerably. However, concerns are regularly voiced about the generalization of the findings, and at least one scientific journal (i.e. the

Journal of Vocational Behavior) is known to forbid contributions employing AMT samples (Landers & Behrend 2015, p. 143). To counter such apprehensions, several authors analyze the demographics of the AMT workforce and compare it to the populations they are drawn from and to other samples frequently used by researchers (see Paolacci & Chandler 2014, p. 185 for an overview). In short, it is found that AMT workers (as all internet users) are younger, better educated, and less religious as their respective populations. Thus, there is a systematic bias that might have to be factored in for specific studies. However, AMT workers are considered more representative than for example undergraduate samples traditionally used in many academic disciplines (Stewart et al. 2015, p. 479).

To evaluate its suitability as a participant pool for research projects, a group of authors got engaged in replicating traditional judgment and decision-making experiments on AMT. Paolacci et al. (2010, p. 416 f.) for example replicated the “Linda” study by Tversky & Kahneman (1983) amongst others and found no significant differences when comparing the findings to those of traditional subject pools. Therefore, AMT studies – if carried out carefully – are proven to generate data of high quality. This is specifically attributed to the intrinsic motivation of workers and AMT’s incentive scheme (Paolacci & Chandler 2014, p. 186).

Taken together, AMT is deemed an appropriate subject pool for the current dissertation’s quantitative research phase. Consequently, it is used to compose the samples of consumers for the experiments introduced in Chapter 6.

5 Exploring the Way Product Development of Consumer Goods Companies Deals with Product Sustainability

The Grounded Theory approach introduced in Section 4.2 has been employed to explore how product development of consumer goods companies deals with sustainability issues. This chapter presents the execution, findings, implications, and limitations of the qualitative research phase.

5.1 Specifying the Focus of the Qualitative Analysis

Given the diverse meanings of and claims towards sustainability and its varying importance in different industries (Alblas et al. 2014; Kiron et al. 2015; Unruh et al. 2016), the focus of the Grounded Theory study is delimitated to the development of consumer goods. The underlying reasons are twofold:

- First, from a market perspective, product sustainability is assumed to play a larger role in B2C[18] markets than in B2B[19] markets since consumer goods are purchased by a wide range of consumers with highly individual attitudes on sustainability. Industrial goods, on the other hand, are characterized by a more formalized demand and rather rational purchasing decisions often made by multiple persons (Backhaus & Voeth 2004, p. 8 f.; Homburg 2012, p. 1027). Thus, from a strategic point of view, engaging in the sustainability discourse is considered of higher relevance for consumer goods companies than for companies from other industries (KPMG 2012, p. 5; Hayward et al. 2013, p. 22). As a result, especially consumer goods companies are making an effort to improving the social, environmental, and economic performance of their products (e.g. Mizera 2013a, 2013b).

- Second, looking at the product development process, the development of most consumer goods is assumed to be less complex compared to industrial goods (Webster Jr. 1978, p. 23; Ulrich & Eppinger 2016, p. 5). Furthermore, industrial goods are often tailored to the demand of specific customers, pass through longer life-cycles and have to be evaluated together with complementary products (Ponn & Lindemann 2011, p. 14 f.). Thus, product developers from the consumer goods industry are assumed (1) to be able to oversee the sustainability-related pitfalls and opportunities of their products more easily and (2) to have more degrees of freedom to move the needle on the products' sustainability performance.

[18] B2C = Business to Consumer.

[19] B2B = Business to Business.

Within the consumer goods industry, the focus is limited to the development of non-food products. Sustainability in the food industry is perceived to be affected by domain-specific conditions (e.g. the high importance of health issues, the ethics of industrial livestock farming, or sentiments towards genetically modified crops). Moreover, while the food industry has a large stake in global sustainable development[20], their challenges rather lie in production and consumption than in "classic" product development (Garnett 2013, pp. 30–34). Therefore, food is excluded from the analysis. Thus, companies active in the consumer goods categories presented in Section 2.3.1 constitute the object of investigation for the Grounded Theory study.

5.2 Employed Methodology

A Grounded Theory study should typically disclose details of the research process instead of only reporting the findings (Corbin & Strauss 1990, p. 16 f.). Thus, this section specifies the activities undertaken during the research process. First, details on sampling and data collection are laid out. The data analysis and saturation considerations are presented subsequently. Finally, measures taken to ensure research validity are introduced. Even though the actual research process was characterized by iterative phases of sampling, data collection, and data analysis (see Section 4.2.2), the activities are presented in a linear fashion. Since it is deemed helpful to expose one's research process and findings to the scrutiny of other researchers (Corbin & Strauss 1990, p. 11), parts of the data collection, data analysis as well as the construction of theory were supported by Dr. Sebastian Brockhaus from Weber State University (Ogden, UT, USA). However, since the coding process was performed by this dissertation's author only, no intercoder reliability as for example proposed by Kurasaki (2000) was calculated.

5.2.1 Data Collection and Theoretical Sampling

This study's sampling process aimed at composing different perspectives on improving the sustainability performance of products among consumer goods manufacturers. Key informants were selected based on their involvement in product development projects in the consumer goods industry and approached for potential participation. Following Charmaz (2014, p. 197), an initial sample of six diverse companies with the purpose of achieving high contrast between the cases was composed. This starting point allowed for testing the interview protocol and gaining a first overview of the field. After the sixth interview, the sampling strategy was changed to theoretical sampling as put forward by Corbin & Strauss (2008, p. 143 f.). Table 5 introduces the interviewees contributing to the Grounded Theory

[20] For example, food behemoth Tyson Foods was the second biggest polluter of waterways in the U.S. from 2010 to 2014. Tyson Foods dumped more pollutants than Cargill Inc., Koch Industries Inc., and ExxonMobil Corporation combined, each being infamous sources of pollution on their own (Furlong 2016).

study in chronological order along with the consumer goods category their companies are active in.[21] In almost all cases the heads of the product development departments of the investigated companies were chosen as interviewees as they are most of the time also responsible for the overall development process and, thus, for the integration of different departments. Most interviewees possess engineering or natural sciences degrees.

Table 5: Participants of the Grounded Theory Study

#	Consumer Goods Category	Position	#	Consumer Goods Category	Position
1	Household commodities	General Manager | Marketing Manager	17	Toys	Senior Manager Product Development
2	Apparel	Procurement and Sustainability Manager	18	Home and garden commodities	Head of Product Development
3	Household commodities	Head of Product Development	19	Leisure and sports equipment	Head of Product Development
4	Leisure and sports equipment	Head of Product Development	20	Stationery	Head of Product Development
5	Medical and therapeutic products	Head of Product Development	21	Body care products	Team Leader Product Development
6	Household commodities	Vice President Product Management	22	Domestic appliances	Head of Product Development
7	Domestic appliances	Head of Product Development | Designer	23	Federal authority	Expert for Sustainable Consumption
8	Household articles	Head of Product Development	24	Body care products	Manager Basic Research
9	Domestic appliances	Head of Research & Development	25	Consumer electronics	Director of Product Development
10	Household articles	Product Manager	26	Home and garden tools	Head of Product Development
11	Furniture and lighting	Director Product & Sourcing	27	Home and garden tools	Head of Research & Development
12	Household commodities	Head of Product Development	28	Home and garden commodities	Head of Product Development
13	Stationery	Director Research & Development	29	Consulting	Consultant for Sustainable Products
14	Personal items	Head of Design	30	Consumer electronics	Head of Product Design
15	Stationery	Head of Research & Development	31	Leisure and sports equipment	Manager Product Development
16	Personal items	Chief Executive Officer	32	Body care products	Manager Research & Development

Following the principles of theoretical sampling, it was assessed which kind of additional data was needed to further advance the research right after every round of data collection. For example, interviewees repeatedly brought up the problem of consumers being confused

[21] Some companies operate in more than one consumer goods category. In this case, the interviewee's area of expertise or the top-selling category is reported.

by an overwhelming amount of sustainability-related product labels and certificates. Thus, a representative from a federal authority engaged in product sustainability (#23) was sampled to add another point of view on the issue. Further, participants from many different product categories were included. For example, two experts in charge of developing power tools (interviews #26 and #27) were sampled to match their experiences and approaches to experiences previously shared about other electrically powered consumer goods. Through sticking to the principles of theoretical sampling, it was ensured that the sample's composition mirrors different perspectives on the challenge of developing more sustainable products.

Figure 22 illustrates the sample with respect to the companies' annual turnover, their number of employees and their product category. A good portion of the interviewees represents SME. This distribution is similar to the structure of the consumer goods industry in Germany as introduced in Section 2.3.3. However, the current study's sample is composed to be representative from a theoretical perspective. It should not be considered representative in a statistical sense.

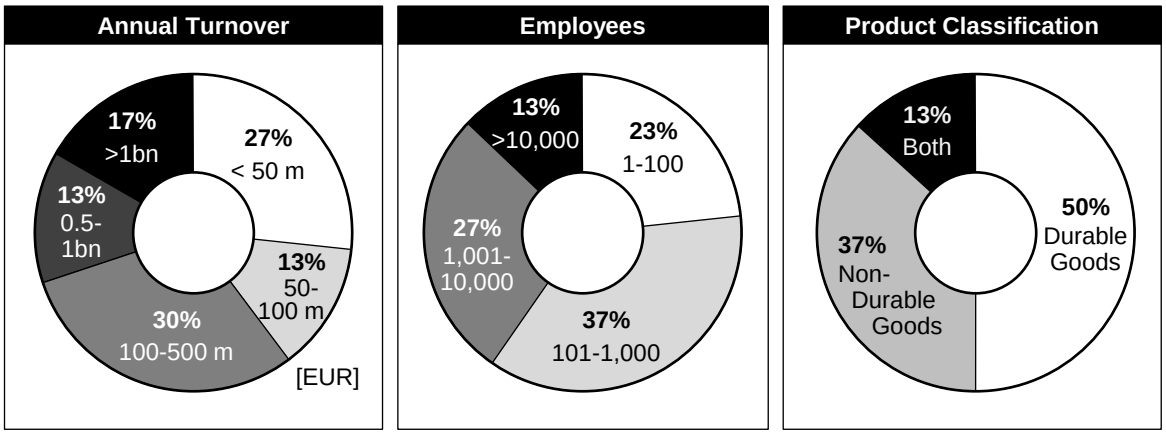

Figure 22: Sample Composition of the Grounded Theory Study[22]

Data collection primarily implied conducting in-depth semi-structured expert interviews. An individual can be considered an expert if he or she has an overview of the knowledge in a specific domain and thereby shares the knowledge of the domain's specialists (Hitzler 1994, p. 25 f.). This definition is valid for all interviewees listed in Table 5. A semi-structured interview protocol was developed to frame the discussion and to operationalize the research questions while also leaving room for the exploration of emerging themes (Charmaz 2014, pp. 62–64). The protocol included 15 open-ended questions organized into three thematic sections. At the start, the characteristics of the development processes implemented in

[22] Interviews #23 (Federal Authority) and #29 (Consulting) have been excluded from the charts. Also, four of the companies do not publically disclose their turnover; their figures have been estimated.

each company were inquired. Afterward, the questions dealt with the understanding, strategic role, and drivers for sustainability on the corporate level. As a final point, the transfer of sustainability principles into actual products was investigated. Care was always taken to follow wherever the participants led the discussion. Accordingly, the questions were adapted, and new aspects were incorporated depending on the interview progress and the company characteristics. The first modifications to the protocol were made after conducting six preliminary interviews to validate the design of the interview protocol. Some last revisions were made after interview sixteen. Appendix IV displays the final version of the interview protocol.

Overall, 32 interviews were conducted from June 2013 to March 2015. They lasted between 25 and 140 minutes with a median of 68 minutes. Potential interviewees were primarily identified and contacted through the business network XING. If possible, the interviews were conducted at the respective companies. However, due to long distances and scheduling conflicts 20 interviews were conducted via telephone. To create an informal atmosphere and avoid selective information sharing, interviewees were assured of anonymity and confidentiality (Corbin & Strauss 2008, p. 30 f.; Gioia et al. 2012, p. 19). To facilitate data analysis, all but two interviews were recorded with the participants' agreement. The recordings were then transcribed verbatim for analysis. Also, relevant "off the record" post-interview comments (Warren et al. 2003, p. 106 f.) were documented after the interview.

Supplementary data on sustainable product development within the sampled companies was collected before each interview from publically available sources like corporate websites, sustainability reports, or articles. In several cases, the interviewees themselves provided additional internal documentation (e.g. development guidelines or analyses of more sustainable materials). These secondary data sources supplied a rich context for exploring the complexity of sustainability-related issues in product development of consumer goods companies.

5.2.2 Data Analysis and Construction of Theory

Data analysis followed the guidelines established by the Straussian school of Grounded Theory (1990, 2008). It was conducted through coding activities and constant comparison parallel to data collection. To avoid potential biases of individual researchers and thereby ensure the validity of the findings, parts of the data analysis were carried out by multiple researchers (Corbin & Strauss 1990, p. 11).

The coding activities followed the three steps of open, axial, and selective coding as already elaborated on in Section 4.2.3. During open coding, transcripts as well as supplementary

data were each analyzed line-by-line resulting in around 5,500 coded paragraphs. Figure 23 illustrates open coding using an excerpt from an interview with a household commodity manufacturer. During axial and selective coding, groups of similar codes were analyzed jointly and compared to each other traveling back and forth between different data sources. Thus, codes were consolidated and grouped into more theoretical and abstract categories. At the end of this consolidation process around 1,800 first-order codes remained. Subsequently, issues linking different categories were investigated to gain an understanding how the emerging themes were interrelated. Memo writing was employed throughout the data analysis to capture emerging ideas and interpretations. Once the theoretical model of sustainable product development was established, the data was reexamined to make sure the theoretical perspective is supported.

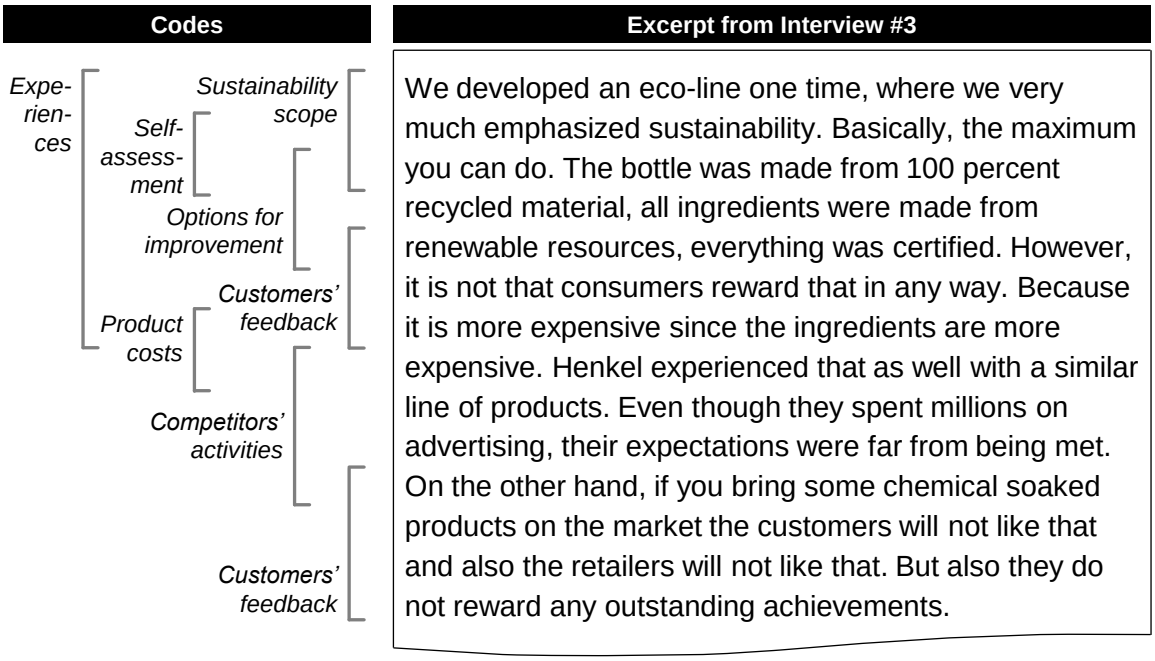

Figure 23: Exemplary Illustration of Open Coding
(following suit on Böger 2010, p. 98; Wente 2013, p. 82)

At the end of the data analysis, interviews with an overall length of more than 35 hours resulting in about 700 standard pages of transcript had been coded. To support the organization and analysis of the interview data and supplementary material, the software "MAXQDA 11" was used. Specifically, MAXQDA facilitated the coding, memo writing, organization, and sorting of codes as well as the visualization of code-relations. The use of software for qualitative data analysis is a common way to enforce a systematic procedure and to increase research validity (Kuckartz 2010, p. 14). This notion is also supported by Corbin & Strauss (2008, p. xii).

5.2.3 Theoretical Saturation and Sample Size

For this study, data collection and analysis were finalized after conducting 32 interviews. Since the last five interviews revealed only limited new insights, it was decided that theoretical saturation had been achieved. Moreover, by then the categories had emerged clearly and formed a coherent picture of how companies approach the development of more sustainable consumer goods. Also, the categories' properties and dimensions appeared to be consistent. Thus, the main indicators for theoretical saturation were satisfied (Glaser & Strauss 1967, p. 61 f.; Corbin & Strauss 2008, p. 148). Since the sample size of this study additionally exceeds most recommendations presented in Section 4.2.5, the author of this dissertation is confident that theoretical saturation has been reached.

5.2.4 Research Validity

Several measures were taken throughout data collection, data analysis, and construction of theory that address the validity of the research process. Table 6 lists these measures along with Mayring's criteria set introduced in Section 4.2.6 (2002, pp. 144–148).

Table 6: Measures Taken to Ensure Validity of Research Process

Criteria	Measures
Detailed documentation of research process	▪ Existing preconditions are documented in detail (Chapter 2 and 3). ▪ Data collection, data analysis, and construction of theory are documented in detail within this dissertation. ▪ Research process was traced through the software MAXQDA.
Argumentative validation of interpretation	▪ Emerging interpretations are documented within this dissertation. ▪ Evidence for interpretations is provided through power and proof quotes taken from the interviews.
Adherence to systematic analytical procedure	▪ Analytical tools and procedures provided by Grounded Theory were employed: theoretical sampling, constant comparison, memo writing, and different stages of coding.
Proximity to the object of research	▪ Interviews were conducted on-site if possible. Some interviewees presented prototypes of more sustainable products being under way. A plant visit supplemented several interviews. ▪ Additional data sources provided by interviewees (e.g. internal presentations or process charts) were included in the analysis. ▪ Semi-structured interviews allowed for incorporating new aspects coming up throughout the interview.
Discussion of findings with participants	▪ Emerging concepts and intermediate findings were discussed with subsequent participants after their interviews.
Triangulation	▪ Findings were mirrored with additional publically available data sources (e.g. sustainability reports and magazine articles). ▪ Researcher triangulation was performed for parts of data collection, data analysis, and construction of theory.

Also, several measures were taken to ensure high quality of the research findings. Table 7 introduces these measures along with the quality criteria put forward by Flint et al. (2002, p. 106) that were introduced in Section 4.2.6.

Table 7: Measures Taken to Ensure High Quality of Research Findings (following suit on Flint et al. 2002, p. 106; Brockhaus et al. 2013, p. 172 f.)

Criteria	Measures
Credibility Findings have to be acceptable representations of the data	▪ Interviews were conducted and analyzed over a period of 22 months allowing for a detailed data analysis and construction of theory. ▪ Researcher triangulation was performed for parts of data collection, data analysis, and construction of theory. ▪ Participants were provided with a summary of the interpretations and feedback was gathered.
Transferability Findings from one study in one context have to apply to other contexts	▪ Theoretical sampling has been employed. ▪ Only saturated themes were evolved into theory. ▪ Findings were mirrored with two participants experienced in the consumer and industrial goods industry (#23 and #29).
Dependability Explanations have to be of high stability and consistency	▪ Participants were asked to reflect past as well as recent events. ▪ Long data collection period of 22 months ensured avoidance of impromptu conclusions.
Confirmability Interpretations must be the result of the participants and the phenomenon as opposed to researcher bias	▪ Researcher triangulation was performed for parts of the data collection, data analysis, and construction of theory. ▪ Participants were provided with a summary of the interpretations and feedback was gathered.
Integrity Interpretations must not be influenced by misinformation or evasions by participants	▪ The participants were guaranteed of anonymity. ▪ Interviews were of a non-threatening nature. ▪ Data triangulation with additional publically available data sources was performed (e.g. sustainability reports and magazine articles).
Fit Findings must fit with the substantive area under investigation	▪ Addressed through measures used to address credibility, dependability, and confirmability. ▪ Semi-structured interview protocol allowed for incorporating issues important to the interviewees.
Understanding Participants must buy into findings as possible representations of their world	▪ Participants were provided with a summary of the interpretations and feedback was gathered. ▪ Intermediate findings were presented at two conferences (SSP 2015 in Stuttgart and Life Science Colloquium 2015 in Hamburg) and feedback was accounted for in the construction of theory.
Generality Findings must discover multiple aspects of the phenomenon	▪ Interviews were of sufficient length and structured in a way that allowed for discussing the phenomenon from multiple perspectives.
Control Organizations must have influence on the aspects of the theory	▪ Interviewees are executives and have a direct influence on internal processes and, thus, on products being developed.

5.3 Summary of the Findings of the Qualitative Analysis

In this section, the findings of the qualitative analysis are presented. Individual parts of the findings have already been published in papers by Petersen et al. (2015a, 2015b, 2016a, 2016b) and Brockhaus et al. (2016b).

For a well-structured and coherent description of the findings of qualitative research, figures or so-called concept maps providing an initial overview are an effective way to guide the readers through the findings (Pratt 2009, p. 860; Gioia et al. 2012, p. 21; Maxwell 2013, p. 54). Accordingly, the explanatory model that emerged from the codes throughout the data

analysis is depicted in Figure 24 and will be used to structure the subsequent description of the findings: At the beginning, based on several internal and external conditions, six different types of approaches towards sustainability on a corporate level are to be distinguished. These approaches determine the handling of sustainability during product development. Specifically, they directly influence the understanding of product sustainability within the development departments. It is shaped by the use of sustainability terminology, product developers' expectations towards the evolution of the importance of product sustainability, and the influence they believe to have on product sustainability. The nature of this understanding determines how product sustainability is conceptualized for a companies' product portfolio. This conceptualization is the core category of the findings. The product range considered, the way the exterior is designed, and the level of innovation emerged from the data as constituents of the conceptualization. Subsequently, the analysis revealed several options developers are aware of to facilitate the conceptualization with respect to manufacturing, utilization, and products' end-of-life. For the implementation of some of these options, three major challenges emerged from the data: managing sustainability in product development is often not codified properly, trade-offs between different options have to be solved, and the assessment of decisions from a life-cycle perspective is a difficult task. For commercialization, a lack of in-house acceptance for sustainability efforts, unpredictable consumer behavior, and the importance of communicating these efforts in a credible way were identified as major challenges. Altogether, these individual aspects resemble an approach of how consumer goods companies consider sustainability in product development.

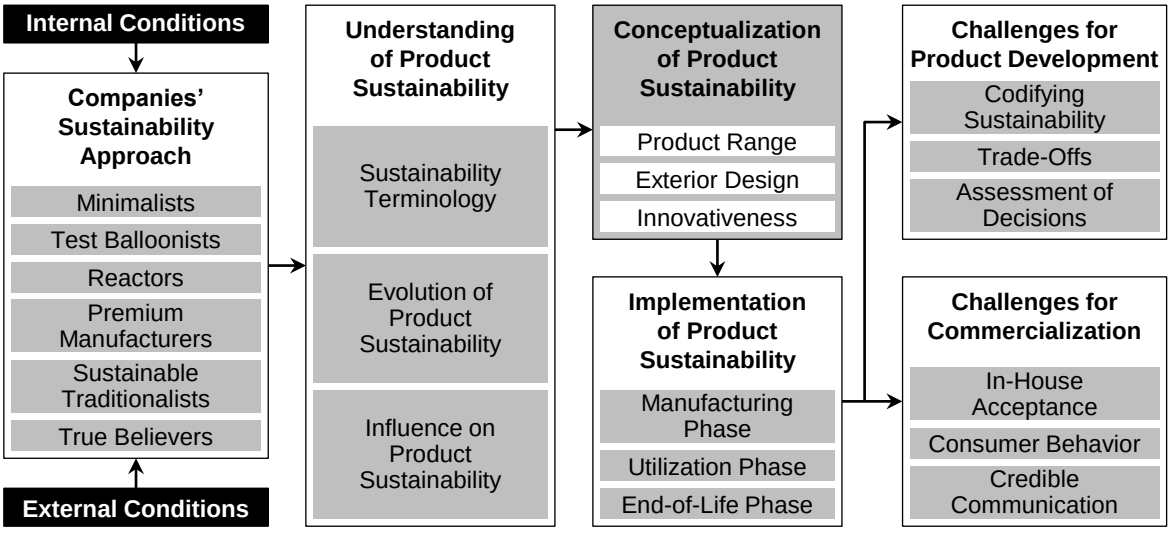

Figure 24: Explanatory Model of Companies' Approaches towards Sustainable Product Development

In the following sections, the findings of the Grounded Theory study are detailed in keeping with the structure depicted in Figure 24. In each subsection, excerpts of data (i.e. power

quotes) and the respective interpretations are presented side by side as recommended by Pratt (2008, p. 501) and Gioia et al. (2012, p. 23). These interpretations are then mirrored with the extant literature. Finally, data interpretations and findings from the literature are distilled and abstracted into propositions. These are statements about the observed phenomena that can be judged being true or false (Blumberg et al. 2011, p. 32). However, before testing them empirically, they have to be concretized and operationalized. Additional quotes from the interviews supporting the propositions (i.e. proof quotes, Pratt 2008, p. 501) are presented in Appendix V. Since all interviews were conducted in German-speaking countries, the data excerpts were translated for this manuscript. Care was taken not to skew the participants' statements; multiple proofreaders reviewed all translations. To ensure anonymity of the interviewees, brand names or product details within the quotes were replaced by universal descriptions.

5.4 Companies' Sustainability Approaches

Throughout the interviews, it became apparent that the way sustainability is considered in product development is determined by the overall corporate approach towards sustainability. Different approaches in practice are resulting from several external conditions (e.g. consumer expectations, competitors' activities, and regulations) as well as internal conditions (e.g. competitive strategy, ownership, and commitment of top management). Observations in other industries – e.g. in logistics – have already demonstrated that especially company specifics are formative for sustainability activities (Flämig 2014b). Moreover, companies' approaches towards sustainability and related difficulties also depend on the experience the company already gained in managing sustainability. To be able to characterize the relevance of external and internal conditions and experiences for managing sustainability in a nutshell, a company typology was crafted following the recommendations by Fleiß (2010, pp. 8–15) and Kelle & Kluge (2010, pp. 91–107). Typologies are particularly useful for categorizing extensive explorative material without setting aside detailed case explanations (Mayring 2002, p. 132). One way to develop a typology of different cases is to construct a feature space of characteristic properties and systematically combining these features (Lazarsfeld & Barton 1951, pp. 169–190). For typifying companies' sustainability approaches, codes from the Grounded Theory analysis were used as features. Table 8 lists them.

Table 8: Codes Considered for Crafting the Typology

Code Families	Codes
External conditions	▪ Governmental interventions pertaining to sustainability ▪ Competitors' sustainability activities ▪ Consumers' expectations towards corporate sustainability ▪ Influence of media on corporate sustainability ▪ Influence of NGO on corporate sustainability
Internal conditions	▪ Relevance of sustainability aspects for corporate strategy ▪ Driving forces of sustainability within the company ▪ Organizational implementation of responsibility for sustainability

Since eight codes along with their respective parameter values were chosen as the foundation of the typology, a comprehensive aggregation of similar feature combinations was necessary (Fleiß 2010, p. 6). As the ultimate result of this stepwise process of pragmatic reduction, six principal groups of feature combinations emerged from the data. These groups resemble six different types of companies' approaches towards sustainability. They were termed Minimalists, Test Balloonists, Reactors, Premium Manufacturers, Sustainable Traditionalists, and True Believers. Figure 25 illustrates the differences between the individual types regarding companies' continuous sustainability effort.

Figure 25: Sustainability Approaches and their Level of Continuous Effort

The current typology is summarized in Figure 26. *Minimalists* only consider sustainability if this equally improves operational efficiency or at least does not incur extra costs. Companies trying to consider sustainability only for a specific area of their business are *Test Balloonists*. *Reactors'* sustainability activities are entirely motivated by external pressure and, thus, thoroughly advertised. *Premium Manufacturers* focus on fostering product longevity and quality. They also regularly engage in CSR activities that are not related to their core business processes. Companies evolving their traditional business model towards sustainability are *Sustainable Traditionalists*. Finally, *True Believers* are companies founded on sustainability principles. Therefore, they have other prerequisites than companies starting to implement sustainability into their established processes.

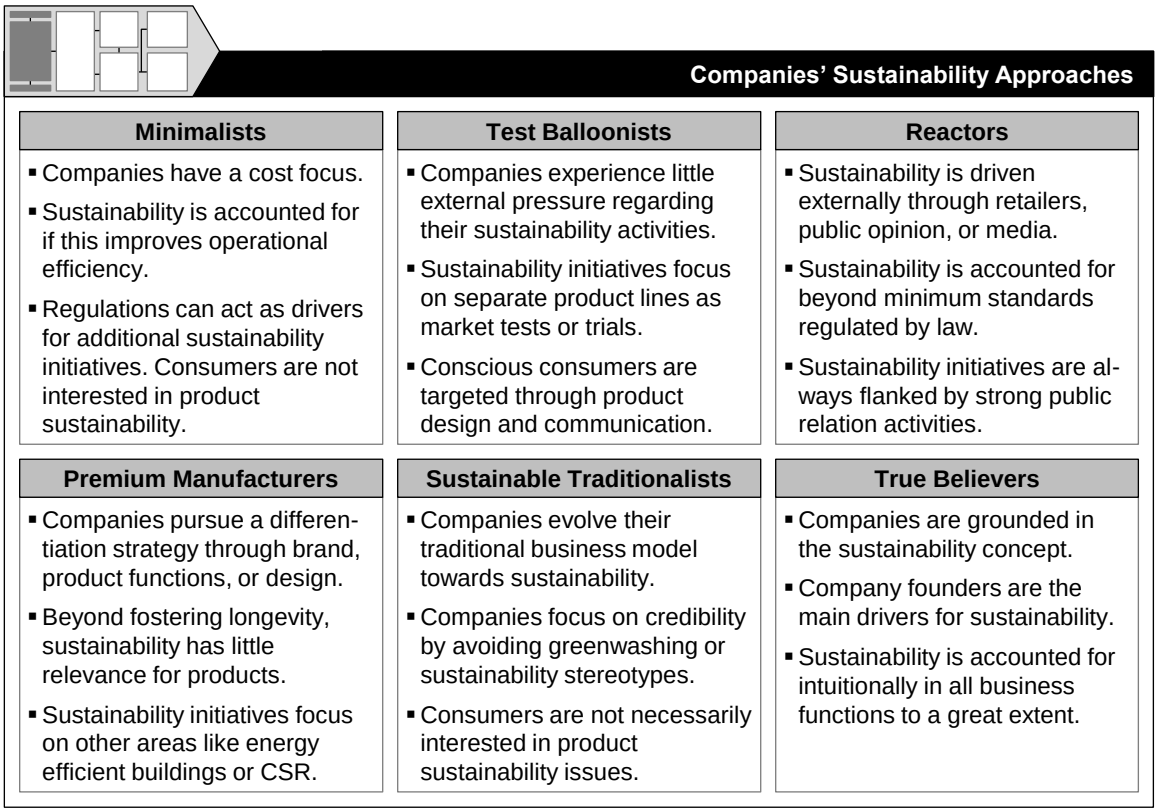

Figure 26: Typology of Companies' Sustainability Approaches

The typology is developed based on approaches that were observed during the interviews. However, it has to be kept in mind that the types might not occur mutually exclusive in practice. For example, there might be Sustainable Traditionalists out there following environmental stereotypes for the exterior design of their product like Test Balloonists would do. Nevertheless, the typology provides a suitable foundation for linking product development practices to the overall companies' approach towards sustainability. The six types of approaches along with relevant external and internal conditions are described comprehensively in the following sections.

5.4.1 Minimalists

Minimalists are companies pursuing a cost leadership strategy regarding Porter's generic strategies (1998, pp. 35–40). In most cases, they produce and sell durable consumer goods. Minimalists target consumers on the look for the lowest product price in conjunction with an acceptable product quality. These consumers are not interested in sustainability in any way and reveal their priorities at the retailer's shelf:

> *The consumers we want to address are not interested in sustainability at all. The purchasing decision is entirely driven by the product's price. #**7, Domestic appliances***

Thus, increasing energy efficiency in production or cutting down on the material is a day-to-day cost-saving routine. Lower environmental impacts resulting from these activities are

more or less unintended by-catch. Minimalists argue that any sustainability efforts beyond process optimization would inevitably result in additional financial or time expenses. Subjected to a strong focus on low costs, sustainability plays virtually no decisive role for any department:

> *We are certainly a cost-accounting-driven company, and I am not aware of any area where sustainability plays a major role for us.* ***#5, Medical and therapeutic products***

> *Unfortunately, I have to say that one does not exactly embrace sustainability because sadly this is always related to additional costs.* ***#14, Personal items***

If Minimalists further improve sustainability with respect to their operations or products, these activities are frequently driven by regulations (e.g. the Energy Efficiency Directive (EED) or the directive for the Registration, Evaluation, Authorization, and Restriction of Chemicals (REACH) by the European Union):

> *To be honest, the main drivers are the laws; the laws and regulatory constraints, because in most cases we would not do this voluntarily. Because it is always an economic disadvantage for us.* ***#27, Home and garden tools***

Focusing on costs, Minimalists often move their production to low-cost countries. That is why social aspects like labor conditions receive high attention within the companies. Accordingly, avoiding sweatshops and scandals with foreign workers are seen as risk management measures and insurance against damages to their reputation. In general, risk management is a strong motivator for sustainability considerations (Brønn & Vidaver-Cohen 2009, p. 94; Brockhaus 2013, p. 92 f.).

> *For us, it would be the worst publicity possible to find our products associated with child labor or some questionable factory without any labor standards.* ***#5, Medical and therapeutical products***

While Minimalists are not striving towards becoming any more sustainable beyond minimum standards, interviewees also report that they are only seldom perceived as being unsustainable companies. Thus, public attention or rather the lack thereof is not providing an incentive for sustainability initiatives:

> *There are some impulses, but I would classify them as being weak. I do not think that our products are sensed as being unsustainable.* ***#14, Personal items***

Therefore, Minimalists are not tempted to target consumers through sustainability-oriented marketing activities. Sustainability is simply not relevant for corporate communication.

5.4.2 Test Balloonists

Test Balloonists are often medium-sized companies not standing in the spotlight of public attention and also not experiencing any consumer requirements regarding sustainability:

> *I think the automotive industry is much more focused on publically. And also the huge clothing companies – or whoever passes a certain threshold – they are much more in the spotlight than we are.* ***#17, Toys***

Other than Minimalists, Test Balloonists start to implement sustainability into their processes and products beyond mere cost-saving measures. However, they do not react to an actual market demand for more sustainable products or public expectations towards corporate sustainability. Sustainability is rather seen as being an important business trend stemming from the context of big publicly traded companies. Even though sustainability appears fuzzy and abstract to most Test Balloonists, they try to follow this trend somehow:

> *We obviously see an emerging trend here (…). It would be negligent in a way if we didn't consider this for our product portfolio and make this a reality.* ***#13, Stationery***

However, sustainability is not considered to the same extent within all departments. Instead, Test Balloonists focus on one sustainability aspect or business area. Often, they tend to develop, produce, and sell separate product lines incorporating some sustainability features. This approach is seen as a particularly appropriate way to communicate commitment to sustainability beyond the inevitable win-win measures undertaken for example in production to save energy or material costs:

> *With this line of sustainable products, we want to show that we care about sustainability also beyond our internal processes.* ***#10, Household articles***

These products are separated from the rest of the product portfolio and most of the time are short-term market tests. Often, the level of innovation is rather incremental (e.g. a material is replaced by a similar, but recycled material). Test Balloonists proactively offer these products targeting conscious consumers willing to pay extra for product sustainability. For this purpose, they often design their products following "green" stereotypes. Once they are on the market, Test Balloonists often realize that the number of conscious consumers is much lower than most surveys promise. As a result of poor market performance, companies regularly end up canning their test balloons after just a short time:

> *We developed an eco-line one time where we very much emphasized sustainability. (…). However, it is not that consumers reward that in any way.* ***#3, Household commodities***

> *In the end, the consumers did not embrace it as we hoped they would. That is why we said: OK, either we are not ready yet, or the consumers do not look for these kinds of products with our brand. And then we pulled the project for now.* ***#17, Toys***

However, two distinct positions of coping with low sales figures have to be distinguished for Test Balloonists. For the first group of companies, the test balloons are rather short-lived experiments. They do not have the chance to act as a stimulus for considering sustainability

across the entire organization. These Test Balloonists expose inconsistent behavior towards sustainability as they sense no or only little market demand for their more sustainable products and then disappointedly take these test balloons off the market after actually experiencing consumers' indifference. As a result, sustainability considerations do not play a major role in product development for a long time. In some cases, this behavior can be explained through the origin of such test balloons as sometimes employees personally engaged in sustainability issues act as impetus. They are intrinsically motivated and manage to successfully defend their pet projects against internal resistance but fail to inspire other departments as well.

The second group of companies, however, consider their test balloons to be long-term opportunities to gain technological know-how regarding new materials or production technologies and to learn about sustainability opportunities related to their products. They put considerable effort into their test balloons and have come to terms with low sales figures for the time being. Their long-term goal is to set sustainability up as a base criterion for the entire product range, thus moving towards becoming Sustainable Traditionalists. Test balloons are seen as a necessary first step in this direction.

5.4.3 Reactors

Companies standing in the spotlight of public attention often cultivate a reactive approach to managing sustainability. These Reactors' activities towards being more sustainable receive high public attention for instance because of the companies' size or their products (e.g. chemical companies are often perceived as "bad" companies regarding sustainability). Other than Minimalists and Test Balloonists, Reactors do consider sustainability for all processes and products, possibly exceeding minimum standards regulated by law. However, these considerations are frequently driven by external stakeholders. For example, high expectations by the public are seen as important drivers for sustainability efforts. Reactors often stand out in terms of size or branch and feel that other standards are being applied to them than to smaller companies (e.g. Minimalists or Test Balloonists). Especially publicly traded companies sense high public expectations with respect to their responsibility for the environment and society. For this reason, Reactors are careful not to make any mistakes and to avoid negative publicity. Dealing with sustainability and talking about it are seen as suitable countermeasures:

> *The first move we made was the usual, improving social standards in our supply chain. I have to be honest though; we were forced to do this, more than anything voluntarily. We had a case of child labor years ago (…) and that of course unleashed high waves. In this context, we got engaged with sustainability.* ***#2, Apparel***

Also, powerful retail chains can drive reactors to engage in product sustainability. REWE for example, Germany's second largest retailer[23], established its own sustainability label program (Pro Planet) in 2010. It features private label products having some positive environmental or social aspects. However, for most of these programs the implementation of positive aspects remains the responsibility of the manufacturers:

> *There is a dynamic coming from the media and consumers demanding more sustainability. (…) And then the retailers jump on the bandwagon. They are all over this thing and are touting their efforts: 'Everyone look here! All this sustainability is happening because of us!' And then they are slapping this onto their private labels like there is no tomorrow.* ***#1, Household commodities***

> *It's really a challenge to keep up with some of the retail giants. They can just impose their sustainability guidelines, and that basically becomes the industry standard.* ***#2, Apparel***

Another motivation to consider sustainability aspects is the media. Especially test magazines like Öko-Test or Stiftung Warentest drive Reactors towards exceeding regulations regarding product ingredients. Even if the use of some substances is legal up to certain concentrations, this might not be acceptable for test magazines:

> *The ranges defined by REACH are sometimes large as barn doors. Regarding ingredients, Öko-Test is driving us to have an even better look at what actually goes into our products.* ***#21, Body care products***

Reactors perceive sustainability as something they are more or less forced to consider. They react to public expectations concerning sustainability, competitors' activities, and consumer requirements. As a result, these companies often strategically emphasize sustainability issues and staff them with considerable workforce. Communicating every bit of this sustainability effort to live up to stakeholders' demands is of high importance to Reactors. The resulting excess of sustainability-related public relations is also considered being a risk management strategy – possibly unsustainable business practices might go unnoticed alongside the phalanx of success stories.

5.4.4 Premium Manufacturers

Premium Manufacturers are often well-established, medium-sized companies and produce expensive durable goods. Their products stick out regarding functionality, design, or brand image. Furthermore, Premium Manufacturers set their priorities on superior product quality, thus pursuing a differentiation focus in terms of Porter's generic strategies (1998, p. 37 f.). For these companies, sustainability is mainly understood as an effort to improve quality and thereby expand product lifetime:

[23] Turnover in 2015: EUR 39.6bn (Statista 2016).

> *Our products get passed on from one generation to the next generation. That is certainly an important part of our brand. And that is also what we in product development understand as sustainability**. #19, Leisure and sports equipment***

Product longevity is seen as an important driver for consumers' purchasing decisions. Sustainability efforts beyond that like cutting down on material usage or influencing the way consumers use the products are not exactly appreciated. Often, consumers are skeptical towards sustainability issues:

> *Our products are bought because of their functions and the design. Sustainability does not make a difference for our consumers. #**25, Consumer electronics***

> *Sustainability is of no importance in our business. And if you discuss it, then the consumer says: 'Well, don't you have any other issues?' #**26, Home and garden tools***

Even though sustainability issues are of little relevance for consumers, sustainability improvements like using plastics from renewable sources are seen as interesting opportunities and are constantly monitored. However, Premium Manufacturers are worried about possible quality drawbacks and hesitate to substitute traditional materials. If the alternatives will one day enable the same quality level, Premium Manufactures declare they would use them without hesitation, however, also without explicitly sharing the change with the consumers:

> *We would not promote it or endue it with some label. But we would sure do it. However, issues like this have no impact on our sales forecast for the next decade. #**20, Stationery***

While sustainability is of low importance on the product level, Premium Manufacturers often promote sustainability in other business areas. For example, new corporate buildings are regularly designed to meet highest energy efficiency standards. Furthermore, Premium Manufacturers are often known to set high priorities on the well-being and satisfaction of their employees. Also, they see themselves as an integral part of their native region and emphasize CSR activities:

> *Companies considering themselves as being premium suppliers do try to give something back regarding social issues. #**4, Leisure and sports equipment***

Other than Minimalists, Premium Manufacturers usually still produce in their native region and prefer to source materials through long-standing regional supply relationships. Therefore, they have little trouble observing social working standards. It can be concluded that unlike Reactors or Test Balloonists, the emergence of the sustainability concept had little effect on Premium Manufacturers. Issues like product longevity, caring for their employees, and responsible behavior have always been core values for such companies. Sustainability initiatives expatiated on by competitors are seen as myopic reactions to

ambiguous public expectations. Moreover, Premium Manufacturers feel to have already achieved a high sustainability level by doing as they would do anyway. Thus, they refrain from joining sustainability chants.

5.4.5 Sustainable Traditionalists

Sustainable Traditionalists are also companies with a long corporate history and tradition. Other than Premium Manufacturers, they understand sustainability as a long-term competitive advantage. They aim at progressively adjusting their products and processes according to sustainability principles and therefore abandon questionable practices long before the regulatory hammer falls. Sustainable Traditionalists seek to avoid sustainability stereotypes and work hard to appear as trustworthy as possible:

> *The stories you hear from the eighties and nineties, like the eco-paper getting dyed for a more grayish and environmental look, these things are over. We do not want to do that (…). And if we would bring a product to market colored dirty brown-grey, the color you get when you mix them all, that would not be our product, and it would not fly in the marketplace.* ***#15, Stationery***

The companies' realignment is driven by corporate management and the companies' owners. They perceive sustainability as being a game-changer, and they are highly engaged in the transformation process. Taking their mission – turning the company's traditional orientation upside down – seriously, sustainability is seen as every employee's responsibility and not as something to be taken care of by a designated functional unit:

> *Our executive director says that sustainability must not be assigned to a staff function. Then everyone in the company would say: 'Let them take care of it.' For him, it is clear that it starts from the top – with him.* ***#12, Household commodities***

> *There is no need for a staff function urging people to please consider sustainability. Sustainability is a core value for our company.* ***#22, Domestic appliances***

Sustainable Traditionalists are well aware that they are limited in pushing sustainability if they try to meet the challenge on their own. Thus, they collaborate closely with their key suppliers and sometimes also with research institutions or material start-ups as these participants explain:

> *For our line of more sustainable products, we got a few selected partners to change things up and start working with recycled materials. We brought this up with them and helped them find opportunities to source materials accordingly. But this only worked because we have these great long-term relationships with some of our suppliers.* ***#15, Stationery***

> *There are a few instances where we include our trusted suppliers in product development efforts to improve the sustainability performance of one of our products when things get really complex. We actually draft cooperation and non-disclosure agreements for a fixed period.* ***#12, Household commodities***

Like Test Balloonists, Sustainable Traditionalists most of the times face little market demand for more sustainable products. They want to target mass markets and try to avoid communicating their sustainability efforts through stereotyped product design. However, as sustainability is an abstract concept to most consumers, they sometimes sense difficulties in communicating their commitment through other channels:

> *We will have to put forward that we are actually working in that field. I think many medium-sized companies have that problem. They put comparatively high effort in it but talk too little about it.* ***#9, Domestic appliances***

Only some consumers buy these companies' products because of their superior sustainability performance. Instead, most of them are not looking for more sustainable products and decide based on other criteria. Often, they have no idea how much effort went into pushing the sustainability performance of the products:

> *We continuously work on getting better and better regarding sustainability. (…) Even though some improvements might only be relevant for one percent of our consumers. (…) You know, when buying our product, who thinks about how it was produced and what energy sources were used? (…) We are not talking about cars or smartphones. We speak of convenience goods.* ***#12, Household commodities***

Like Minimalists or Test Balloonists, Sustainable Traditionalists face little to no external pressure to care about sustainability. Neither the companies themselves are in the spotlight of public interest nor their products are perceived as problematic or trigger high sustainability involvement by the consumers. Accordingly, Sustainable Traditionalists invest in sustainability as a source of long-term competitive advantage. Higher expenses and lower margins in the short-term are considered an investment rather than an annoyance:

> *We would go for the more sustainable option even if this implied having 10 percent or 20 percent lower margins on our products. We would put up with that; this is a clear directive from our management.* ***#15, Stationery***

Sustainable Traditionalists' sustainability efforts are not only supported but explicitly driven by management. These companies are often family-owned and -run. Thus, margin sacrifices for the sake of sustainability improvements do not have to be explained or justified to external shareholders like Reactors' management would have to do.

5.4.6 True Believers

Companies grounded in the sustainability principles are True Believers. They are mostly of small to medium size and are usually still run by their founders. True Believers do not perceive sustainability as some negotiable product feature but as a core value for all company activities. Thus, sustainability is not regarded as "an expense to be shouldered,

an initiative to be undertaken, or a department to be built" (Williams 2015, p. 138). True Believers reveal an intuitive understanding of sustainability:

> *We have been eco-freaks from the start, we never really thought about it. We have no plan. We just do it because it is our conviction. #**8, Household articles***

> *Sustainability is something anchored deep inside the company and not something driven by some trend or greenwashing activity. #**32, Body care products***

Since such companies are usually built around the idea of an innovative, sustainable product, the company founders are often highly involved in product development. Facing trade-offs between sustainability aspects, they often decide for environmental or social performance. True Believers take a firm, non-negotiable stance towards sustainability:

> *I consider it a luxury to say: 'This material is more expensive, but since it is more environmentally friendly we take it anyway.' That is a shared luxury. #**8, Household articles***

True Believers are also deeply rooted in their native region and are aware of their responsibility as a company. They often source from their immediate neighborhood even though this incurs higher costs:

> *When we run out of material, then I call our local carpenter (…). And I am sure that he will be 30 or 40 percent more expensive than some carpenter at the Czech border. However, we are really into this regional thinking. #**16, Personal items***

Even though True Believers set high standards for product sustainability, they do not necessarily promote their products as being superior sustainable like Test Balloonists or Reactors would. However, they do perceive more aggressively communicating sustainability activities as becoming a required marketing standard for the competition and fear the loss of their pioneer halo in the eye of the consumer:

> *We have been eco-freaks for years, and now suddenly this topic is hot. And now, large enterprises start their planned campaigns. And sometimes I get the feeling that they will pass us on the left and the right because they do it systematically. It always felt natural for us, and it has always been this way. And therefore, we struggle to leverage it. #**8, Household articles***

Companies truly embracing the idea of sustainability do not need regulations, public interest or other external pressure as driving forces. However, since they were founded on sustainability principles, they have different prerequisites than all "traditional" companies working on implementing sustainability into their established business models and organizational structures.

5.4.7 Remarks on the Typology

Since almost all interviewees are leading the product development departments and are the owner of the development process at the respective case companies, their take on product development is not limited to specific technical questions. Instead, they also incorporate the market perspective and the overall company strategy towards sustainability. Throughout the interviews, participants emphasized the outstanding importance of the different approaches companies utilize with respect to handling sustainability on the corporate level for the alignment of all product development activities. For example, if a company follows a Minimalist approach and ignores the ongoing public discourse about sustainability, it is unlikely that their product development department will be allowed to invest into improving product sustainability. To be able to grasp this influence of the different company approaches, the typology presented in the last sections was crafted. Granted, there are other typologies or maturity models of corporate sustainability behavior to be found in the literature (e.g. Baumgartner & Ebner 2010, pp. 81–87; Dyllick & Muff 2016, pp. 162–168; UN Global Compact 2016, p. 31). Even though they are designed from other perspectives, some overlap is apparent. However, they do not allow an efficient connection to product development practices. The current typology, on the other hand, allows for investigating and comparing different sustainability policies in product development by setting them into perspective with relevant company characteristics. For example, it pinpoints how product development should be adjusted to an evolving company approach or how it even could act as a stimulus for the entire organization. Accordingly, the company typology will function as a reference framework for the presentation of product development's take on sustainability.

5.5 Understanding of Product Sustainability

Shifting the focus from the company level to product development, this section covers the interviewees' individual professional understanding of product sustainability. It results from their company's approach towards sustainability as well as individual values and attitudes. It is characterized by the interplay of three aspects: sustainability terminology, evolution of sustainability, and influence on sustainability. Figure 27 summarizes the findings.

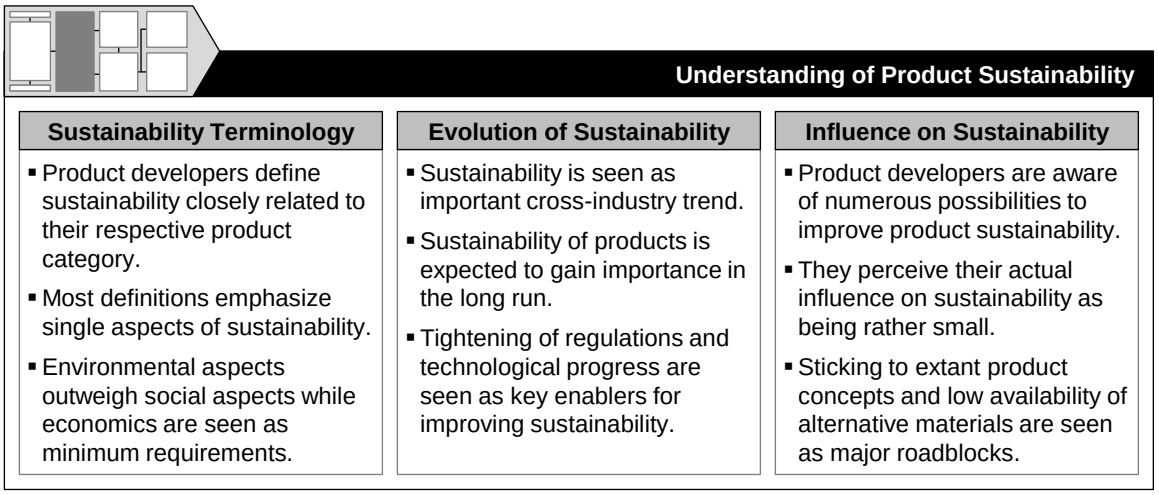

Figure 27: Findings for Category “Understanding of Product Sustainability”

First, sustainability terminology covers the nature of sustainability and discloses which issues product developers subsume under the heading of sustainability and how they weigh them. Second, product developers’ expectations towards the evolution of the importance of product sustainability and the role of driving forces are discussed. Finally, product developers’ understanding of sustainability is shaped by the degrees of freedom they experience when making design decisions in their everyday work.

5.5.1 Sustainability Terminology

Before specific sustainability issues were dealt with, the definition and perception of sustainability were discussed with all interviewees. First, the individual connotations of sustainability were inquired without revealing the researcher’s opinion to avoid skewing participants’ statements. Then, a common understanding was established to ensure comparability between the interviews.

Overall, participants share an understanding of sustainability similar to the TBL approach. They are aware that sustainability is a multidimensional concept collating economic, environmental, and social aspects. However, participants express different opinions on the question if sustainability is a status to achieve or rather a performance to improve. Some participants from companies only little experienced with sustainability management consider sustainability to be something that can be implemented and is then documented through certificates and labels. Thus, to them, sustainability is an absolute concept and therefore a status their products can achieve. However, most of the interviewees agree that in their corporate contexts sustainability implementation cannot be achieved by simply moving a lever. They consider sustainability to be the result of an ongoing process that takes time – especially in well-established companies:

> *Being an old dinosaur, we have to change. For us, sustainable development is actually a continuous process because you cannot tear everything down in an instant. Of course, you have to take your consumers along.* ***#12, Household commodities***

While being aware of the TBL dimensions, most interviewees are not overly concerned with terminology or the academic discourse about relative and absolute approaches to sustainability. Instead, they quickly illustrate their definitions through mentioning several product characteristics and how these could be modified to enhance sustainability. These improvements range from using recycled materials across sourcing from local manufacturers to extending the lifespan of products. However, differences exist between product categories. While interviewees in charge of non-durable goods also emphasize aspects related to the logistics or packaging of their products, developers of durable goods focus mostly on material issues or working conditions in low-cost countries. Respectively, participants reveal a hands-on take on sustainability. Thereby, it becomes apparent that economic and environmental factors seem to outweigh the social aspects of sustainability. However, participants indicate that this is less a result of their personal priorities but of their perceived area of influence as product developers. Taken together, the nature of their products determines how interviewees concretize the notion of sustainability:

> *I think that is the biggest issue about sustainability: it always has to be reevaluated for every product, for every product group, and for every industry. Automobile manufacturers or a detergent company have entirely different criteria that they apply.* ***#11, Furniture and lighting***

> *If you go for lower material usage or rather for energy saving measures truly depends on the product and the production process.* ***#29, Consulting***

The literature supports the two most important observations regarding sustainability terminology. First, it is confirmed that environmental and economic aspects until today outweigh social aspects in the context of product development research (Thomé et al. 2016, p. 2205). This is attributed to extant criteria of socially sustainable products as they feature only indirect reference to actual products and are restricted in terms of improvements through design changes (Hanusch & Birkhofer 2008, p. 219). Also, the understanding of sustainability, as well as the relevance of single aspects, typically depends on the audience that is being addressed (Short 2008, p. 22). Second, Alblas et al. (2014, p. 538) showcase that it is of high importance to acknowledge the various meanings and consequences sustainability has for different industries and companies. Based on the findings from data analysis and literature, the following proposition emerges:

Proposition 1:	**Product developers' understanding of product sustainability appears largely unaffected by the academic discourse and instead refers to the type of products they are in charge of.**

5.5.2 Evolution of Product Sustainability

While discussing sustainability terminology, almost all participants brought up their expectations on the evolution of sustainability and its relevance to their everyday work. Even though their companies currently operate on different maturity levels with respect to sustainability, all interviewees anticipate sustainability to become an increasingly important factor in the long run. Those working for Sustainable Traditionalists and True Believers comprehend sustainability as a major possibility to gain competitive advantage within their mature markets. Most other interviewees grasp sustainability at least as an upcoming trend that is here to stay:

> *I believe sustainability is an emerging trend. And if you miss jumping on this trend, in five years you might stand there with the egg on your face if you are not on top of the game by then.* ***#30, Consumer electronics***

This trend is not necessarily perceived as predominantly driven by consumer behavior; much to the contrary as this is often referenced as a major inhibitor for sustainability initiatives throughout the interviews (this will be explained in detail in Section 5.9.2). Still, most interviewees expect sustainability to eventually become crucial for their consumers' purchasing behavior. However, they are not able to articulate why and when this change of mind should occur. Product developers seem to share the looming feeling that the sustainability discourse might suddenly pick up speed and that they might miss the bus on product sustainability if they procrastinate any efforts:

> *Altogether, the consumers are moving into a direction where sustainability gets more important and will also be necessary for our products someday. This is by no means to be ignored.* ***#21, Body care products***

Another reason why sustainability is of growing relevance for the everyday work of product developers is seen in further developments with respect to tightening laws and regulation. Some interviewees indicate, for example, that the introduction of REACH or the extension of EED onto new product categories already moved sustainability-related issues up on their agendas. Also, interviewees not yet affected by specific sustainability regulations expect them to come sooner or later. Again, they are not able to explain why and when this should happen but share the vague fear of falling behind:

> *In the long-term with 100 percent certainty, there will be legislative requirements; I truly believe that. And most of the time the industry reacts like a pile of headless chicken. Everyone suddenly dashes off.* ***#17, Toys***

Taken aside growing external pressure, all interviewees share the belief that technological progress (e.g. advances in bio-based materials or additive process technologies) will yield new possibilities for sustainability improvements. This interviewee states that most options

for sustainability improvements he encounters in his daily work cannot be implemented in an economically beneficial way. However, he quickly relativizes this pessimistic view on future developments:

> *This is clearly a strategy to ensure survival for companies. Those firms that don't look into alternatives will be in trouble. Even though it may not make monetary sense just yet, because of the long development lead times, it is wise for us to start looking into this now.* ***#28, Home and garden commodities***

The extant literature supports the findings from the data analysis. Taking a bird's eye view, a high number of authors evaluate sustainability as an important cross-industry trend and expect that public attention for sustainability will likely increase (e.g. Fawcett et al. 2011, p. 119; Dyllick & Muff 2016, p. 157). Also, sustainability is seen as an important trend for the consumer goods industry (Priess et al. 2013, p. 6). Regarding consumer behavior, a growing appreciation of more sustainable products and also an increase in actual sales is expected (e.g. Steinemann et al. 2013, pp. 35–39) even though the absolute number of truly conscious consumers and the growth rates are still rather small. Shifting the focus on product development, Alblas et al. (2014) find that while incentives for sustainable business practices are absent or fuzzy in their case companies' environment, product developers reveal a strong belief in sustainability being an important driver for future business. Accordingly, the findings of the data analysis in conjunction with the extant literature lead to the following proposition:

Proposition 2:	**Product developers share the vague belief that product sustainability is to gain importance by means of changing consumer behavior and tightened regulations.**

5.5.3 Product Developers' Influence on Product Sustainability

During the discussion of the future importance of sustainability, several interviewees from Reactors, Premium Manufacturers, Minimalists, and Test Balloonists appear skeptical on actually possessing exercisable leverage for the improvement of product sustainability. Their doubts are less based on unpredictable consumer behavior or technological feasibility but more a result of different company-specific inhibitors. For example, some participants stated only to have limited influence on the sustainability of their product as major improvement options with respect to their established product concept are rare. This may seem uncritical since almost all interviewees agree that sustainability progress also can mean making a lot of small steps instead of working on huge leaps forward. However, sometimes participants indicate that measures undertaken are too marginal to move the needle on overall product sustainability. Hence, sustainability improvements that are

implemented by product developers can appear to have next to no influence when looking at the whole product life-cycle:

> *I am personally engaged here because this is a topic close to my heart. I want to see us use compostable materials to package all of these products. However, that is more like a drop in the bucket. That does not make the product sustainable.* ***#31, Leisure and sports equipment***

> *The feasibility of more sustainability on a product level… well, the CPG behemoths might have other possibilities there, but for us? Dream on…* ***#17, Toys***

This concern is exacerbated when product developers experience decisions made out of their area of influence that have a strong negative impact on overall product sustainability. This is particularly the case if companies are not deeply committed to sustainability but initiatives to improve product sustainability are driven by individual developers. Some interviewees appeared to be discouraged by such examples. One participant contrasts his perceived influence on product sustainability with the impact of the business-driven decision to use air transport instead of the much more environmentally friendly sea transport for shipping their products from the Asian manufacturers to the European markets:

> *Even if you consider a blister packaging that is not exactly favorable for the environment: how big is its impact compared to air transportation of the products to Europe?* ***#25, Consumer electronics***

An even more important issue emerging throughout the interviews is the problem of the lack of company power due to size and minimum order quantities. More than half of the companies from the sample are small or medium-sized, and most of them experience difficulties to source intermediate goods they deem more sustainable. Collaboration is seen as opportunity to overcome such roadblocks:

> *It has to be a collaborative effort, especially for completely new and innovative things. That's impossible without the right supplier.* ***#21, Body care products***

However, close collaboration with suppliers is the exception rather than the rule throughout the sample. Often, interviewees compare their company to automobile manufacturers regarding hypothetical order quantities to illustrate their limited possibilities and the lack of interest from the suppliers' side. Even when it comes to only source material, sustainability requests do not always resonate well with the supplier base, as this interviewee points out. His company is a well-known player in the international furniture markets. However, he is only able to source whatever suppliers offer to him:

> *If we would like to source chipboard made exclusively from Western European spruce, then we are allowed to ask for it… however, it is not like that is going to happen.* ***#11, Furniture and lighting***

The notion that product developers believe to have little exercisable scope to enhance product sustainability is to some extent contrary to their perception about the evolution of sustainability: if the people developing the products expect product sustainability to become more important and at the same time experience few degrees of freedom to actually incorporate sustainability features, the question ‘Who else could make a difference then?’ emerges. While the individual inhibitors may indeed pose considerable barriers for the product developers, it seems that some interviewees (especially those working for companies not truly committed to sustainability) somehow try to let themselves off the hook. At the same time, these interviewees often have (sometimes quite radical) ideas how product sustainability could be improved. However, they seem to be unsatisfied about the gap between their personal interest and their actual activities regarding product sustainability and try to blame it on issues that are allegedly out of their reach. This interpretation is supported by the fact that participants working for Sustainable Traditionalists or True Believers perceive their influence on product sustainability as rather high. While these companies expose an entirely different take on sustainability, they most probably face the same difficulties about technological feasibility, consumer behavior, or material sourcing but somehow manage to cope with them.

Thorough literature analysis returned the result that behavioral aspects in sustainable product development have only seldom been investigated until now. As introduced in Chapter 3.3, most authors focus on providing tools to support the development of more sustainable products or analyze the implementation of sustainability into existing development processes. Product developers’ attitudes and behaviors in a sustainability context are less often subjected to research to date. Two of the rare exceptions are Verhulst & Boks (2012c) and (2014). They manage to shed a first light on the important role of human factors in successfully implementing sustainable product development practices and yield meaningful findings for companies being on their way towards considering sustainability. In general, however, literature assumes product developers can and want to implement every sustainability initiative that is technologically feasible. Company-specific and individual inhibitors for such initiatives receive little to no attention. Based on the empirical findings, the following proposition for further research emerges:

Proposition 3:	**Product developers believe to have little exercisable leverage to enhance product sustainability in their routine development tasks.**

5.6 Conceptualization of Product Sustainability

Following sustainability terminology, it was discussed with all participants how they do or at least would implement the notion of sustainability into products. It was found that product

sustainability is conceptualized in different ways. By conceptualizing it is expressed what interviewees make of sustainability for their entire product range without referring to specific development practices or concrete sustainability improvements. The conceptualization emerged as core category from the analysis since concrete development practices and related challenges are closely tied to the companies' broader take on product sustainability. The findings are summarized in Figure 28.

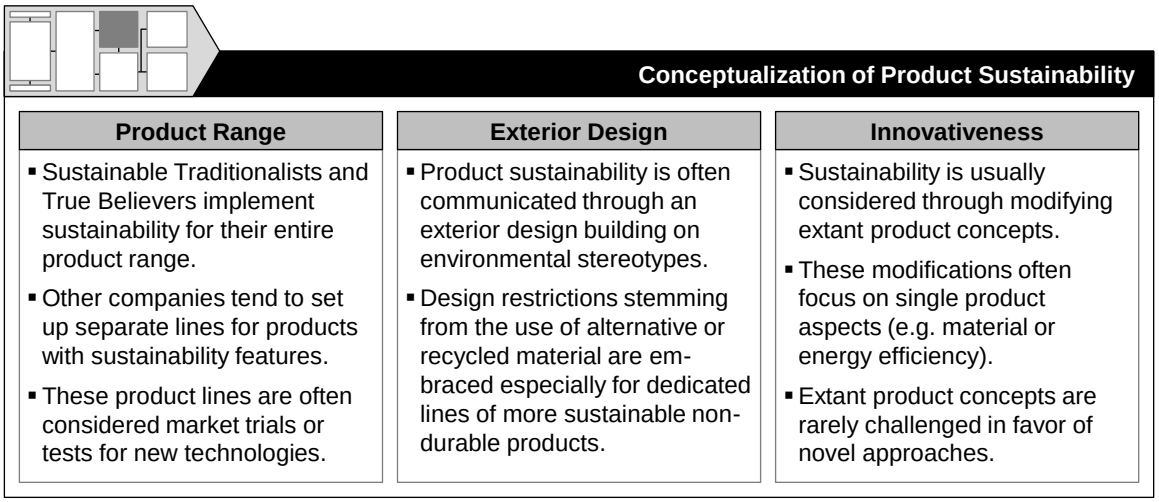

Figure 28: Findings for Category "Conceptualization of Product Sustainability"

The conceptualization of product sustainability is characterized through three aspects. First, the product range pinpoints for which product range sustainability is being considered. Second, exterior design and the question of serving sustainability stereotypes are seen as other relevant decision variables for sustainability conceptualization. Last, the level of innovation defines which kinds of modifications are made to foster product sustainability.

5.6.1 Product Range

With all participants, it was discussed whether sustainability is considered as a base criterion for all products. Two distinct positions that reflect the different sustainability approaches on a company level emerge from the data. First, several interviewees indicate that if they consider sustainability today, they focus their attention on a small number of products developed and promoted as being more sustainable compared to the rest of the companies' product range (this mirrors the approach taken by Test Balloonists but also holds true for most Reactors). This approach is also deemed appropriate for companies with a low sustainability track record as the following quote illustrates. The interviewee works for a Premium Manufacturer and – expecting that sustainability might one day be of importance for her products – plans to start a test balloon to gain experiences:

> *We are lucky in a way because we can fly under the radar to some extent. As a smaller company, we can launch a test product. And if it does not work in the marketplace, we just scrap it and move on.* ***#30, Consumer electronics***

Companies that introduce separate lines of more sustainable products sometimes put considerable effort into the development and production of these products. However, most of them do not plan to extend their sustainability improvements to their other products. One reason for this is higher raw material costs as this interviewee expresses:

> *For this particular line, we chose raw materials costing more than 100 Euros per kilogram. That is something we would never do elsewhere because normally you have prices ranging from two to ten Euros.* ***#3, Household commodities***

Most of the interviewees working for Test Balloonists or Reactors realize that it would be desirable to extend their efforts to other products as well. However, since they also perceive their exercisable leverage regarding sustainability as small, they sometimes resort to a "better than nothing"-mentality:

> *It is still a small share of the collection that actually is made from organic cotton. But at least we are doing something, right?* ***#2, Apparel***

Only some interviewees leverage their limited more sustainable product lines as an opportunity to try out new technologies, raw materials, and product concepts. Through truly challenging their existing products they report having learned a lot about possibilities and limits of sustainability improvements. Some identified options are then rolled out onto the overall product range. This participant, for example, indicates that his test balloon (even though only mediocrely successful from a commercial point of view) offered a valuable starting point for more extensive sustainability improvements:

> *Until now sustainability has been a base criterion only for the eco-line. And through the experience we gained we now say: we want to expand that on other products as well.* ***#13, Stationery***

An entirely different position is advocated by Sustainable Traditionalists and True Believers as they are most likely to consider sustainability for each of their products. Such companies are concerned about credibility and demonstrate their true commitment through their products:

> *We consider sustainability for every single product. Otherwise, we would be asked: why don't you do that for the other products as well?* ***#6, Household commodities***

Even Minimalists try not to appear to be selling special products with an emphasis on sustainability. If they achieve some sustainability improvements that could be promoted, they refrain from actually talking about it. This aspect brings together the attitude of Minimalists and True Believers: both are afraid of tarnishing their credibility through

promoting single products as being superiorly sustainable as opposed to their entire portfolio. However, the consequences they draw from this concern are completely different. True Believers take all products into consideration while Minimalists would not even talk about any improvements:

> *When we improve certain things, we discuss if we want to communicate it or not. And often we say that we do not want to make a fuss about it, and we do not want to highlight one collection. Because then it would look like the other collections have nothing to them.* ***#14, Personal items***

Literature provides ample support for companies' approach to increasingly demonstrate their commitment to sustainability with new brand and product introductions (Luchs et al. 2010, p. 18). Boks & McAloone (2009, p. 433) trace this development back to the 1990s when environmentally friendly niche products were brought to market by start-ups and large corporations responded by adding similar eco-design products to their portfolio. Until today, many of those separate products seem to be "one-off" designs as they are often terminated not long after their introduction (Charter & Clark 2007, p. 15; Diegel et al. 2010, p. 68; Alblas et al. 2014, p. 527). However, Verhulst & Boks (2014, p. 83) point out the importance of such projects for the implementation of sustainability in product development. They consider them being one of two trajectories during the implementation process. Following this trajectory, several projects focusing on specific aspects of product sustainability could lead to formulating a vision and strategy towards more sustainable products (Charter & Clark 2007, p. 36). Nevertheless, observations in practice reveal that this is seldom the case. Based on the empirical findings in conjunction with support from the literature, the following proposition for further research emerges:

Proposition 4:	**Companies starting to get involved with product sustainability often exclusively focus on separate product lines.**

5.6.2 Exterior Design

Communicating sustainability through the exterior design of products emerged as a hot and quite polarizing topic throughout the interviews. Some interviewees are much for satisfying sustainability clichés through muddy colors and earthy materials to signal environmental friendliness. Other participants firmly oppose such an approach. Surprisingly, these positions cannot be clearly assigned to the different types of companies' approaches towards sustainability. However, it becomes apparent that especially interviewees working for Test Balloonists favor an eco-look for their special product lines. This representative from a federal authority concerned with the design of more sustainable products reported the following:

> *We share the perception that there are big corporations out there with some established product lines and that try to somehow introduce an eco-design product as well. Often they tend to add "eco" to the product name and choose green as exterior color so that it becomes very obvious that this product is different from others.* ***#23, Federal authority***

Some interviewees share experiences from their actual products and explain how they decided upon the exterior design. In both cases featured below, the material is not intentionally dyed in earthy colors. Instead, the natural color resulting from using mixed recycled plastics is embraced and used to communicate a higher level of product sustainability. Both interviewees are aware that their products are not as visually attractive as they could be but hope to reach out to conscious consumers:

> *But the coloring itself – some consumers like such a product, i.e. the conscious consumers. They want to have recycled plastics, and the muddier coloring does not bother them.* ***#13, Stationery***

> *Fine feathers make fine birds. If I see a blazing red product next to our eco-line, then the eco-line certainly is a bit unattractive. However, if I care about doing something for the environment, I will buy the eco-line.* ***#10 Household articles***

Several interviewees name products they are aware of or even worked on that were specifically designed to look environmentally friendly. Most of the time these are examples of durable consumer goods developed during the eco-design wave around the turn of the millennium. However, it seems that today this approach is especially common for non-durable consumer goods. Participants attribute this to impulsive and rather uninformed decisions consumers make when purchasing such goods (see Section 2.3.1). Accordingly, the "sustainable" appearance of products or their packaging is mainly used to stick out of the other products and to attract consumers' attention.

> *And then there will be some – well, actually the majority – they do not have much time to deal with sustainability issues. Some of these consumers might buy products having an eco-look and say: Well, instead of doing nothing I'll start here.* ***#19, Leisure and sports equipment***

Some participants compare eco-looking products to private labels. These products – or rather their packaging – also regularly seem to be designed to look unattractive on purpose. Even though there are some exceptions on the market, most products advertised under private brands feature a minimalistic and rather unambitious exterior design. However, in the case of private labels the minimalistic design is not supposed to signal sustainability but to signal low prices (Roßa 2011). Thus, consumers are not distracted by design aspects and are more or less driven to only see the price advantage (Starr 2014).

Literature reports little about product developers' preferences towards stereotyped sustainable exterior design and their intention to signal product sustainability. However,

from a consumer perspective, there is evidence that product developers should be careful when trying to signal sustainability through product design: Luchs et al. (2010, p. 28 f.) demonstrate that a "sustainable" product design can be a liability for some product categories as it might signal low product performance. In a subsequent study, they demonstrate that aesthetic design is especially beneficial in situations where sustainability improvements lead to reduced functional performance (Luchs et al. 2012, p. 913). However, whether earthy colors or natural looking materials contribute to one's aesthetic sensation does not only depend on the individual consumer but also on the product category in question. In general, it is established that especially the product color is a signal of different aspects like product quality or ease of use – whether developers intend to signal such information or not (Creusen 2015, p. 308). Also, material choices are crucial for product communication as consumers are in direct contact with them. Material features like its surface, smell, flexibility, and color contribute significantly to product communication (Gekeler 2012, p. 70). Moreover, it has been demonstrated that the first impression consumers have from the design of a product is hard to counter through more objective information (Hoegg & Alba 2011, p. 356 f.). This underlines the importance of well-thought-out design choices – also beyond the frame of sustainability. Based on the findings from data analysis, the following propositions emerge:

Proposition 5:	**Sustainability of non-durable consumer goods is often signaled through a stereotyped exterior design.**

Proposition 6:	**Sustainability of durable consumer goods is only seldom signaled through a stereotyped exterior design as this could signal lower functional performance.**

5.6.3 Innovativeness

Interviewees report to have two distinct possibilities to improve product sustainability: they can either modify existing products to the extent that enables better sustainability performance or they can develop entirely new products with a special focus on sustainability. The latter option normally aims at replacing existing products that are perceived as being less sustainable as this participant explains:

> *The main focus of our product development is to replace products that are harmful to the environment like aluminum foil or plastics through paper-based products. That is what we are working on at the moment. #**6, Household commodities***

Developing new product concepts results in higher levels of innovativeness and can yield comprehensive sustainability improvements. It is evident that such an approach offers more degrees of freedom to developers than if they stick to long-standing product concepts and

attempt to retrofit their sustainability. However, developing new product concepts for comprehensive sustainability improvement is not standard procedure in industry:

> *What we experience – especially with big companies – is that they always focus on one specific area. This may be materials or an improvement of energy efficiency. They really focus on one area and try to achieve improvements there.* ***#23, Federal authority***

Of course, it is also possible to bring sustainability to a new level through improving existing products. Some sampled companies are quite successful with this approach as they undertake numerous small steps that together represent a significant sustainability improvement. However, most participants working in companies not profoundly committed to sustainability report seeing little opportunity to radically improve product sustainability. Since none or only little time is allotted for identifying and implementing sustainability initiatives, product developers are left with adapting existing product concepts. This leaves no room for experimental runs as this participant explains:

> *We always have to develop new products quickly. That is why we often build on existing products and adapt them. If you truly want to make a product more sustainable, you have to pursue this with more time on your hands and with another approach.* ***#17, Toys***

While it is true that developing more sustainable products should be understood as a "journey" (Aschehoug & Boks 2013, p. 99) and this journey is about finding the "next better thing" rather than the "next new thing" (Esslinger 2011, p. 403), there is a pressing need to achieve higher levels of innovation than are realized today (Charter & Clark 2007, p. 15). Accordingly, literature repeatedly calls for more radical sustainability innovation and also confirms that most sustainability innovations that make it into mass markets are rather incremental (Dangelico & Pujari 2010, p. 477 f.; Gekeler 2012, p. 209). Llerena & Wagner (2008, p. 145) found that this is especially true for larger corporations as they seem to be more constrained in their freedom of action. Also, a lack of time and space within developers' daily working routines are seen as being responsible for incremental sustainability improvements (Charter & Clark 2007, p. 24) as is also observed for other industries (von See & Kalogerakis 2015, p. 4). Taking into account the findings from data analysis and literature, the following proposition is established:

Proposition 7:	**Improving the sustainability performance of extant product concepts often yield in rather incremental changes.**

Another finding from the data analysis concerns the development of product service systems. As was revealed in Section 3.2.2, literature perceives PSS to offer promising opportunities for radical improvements also beyond sustainability (Boks & McAloone 2009,

p. 436; Thompson et al. 2011a, p. 117; Lindemann 2016, p. 871 f.). Some interviewees voice quite idealistic and truly radical ideas how sustainability could be enforced (e.g. by trimming entrepreneurial freedom through simply forbidding specific products or restricting product variety). However, more realistic approaches like combining products with supplementary services are not mentioned as an opportunity to foster sustainability. While this is not surprising for non-durable consumer goods, there actually might be options for durable consumer goods as is already demonstrated by several of today's shareconomy offerings or the example of Xerox. The decision to move from selling copiers to leasing them and offer supplementary document services, for example, lowered energy use and led to a recycling quota of 91 percent (Esty & Simmons 2011, p. 56). Taken together, the following proposition emerges:

Proposition 8:	**Developing product service systems to improve sustainability receives little attention in practice despite the high attention in the literature.**

5.7 Implementation of Product Sustainability

If product developers want to convert their sustainability conceptualization into actual products, they are confronted with an interminable variety of individual sustainability measures. Accordingly, the identification, evaluation, and selection of these measures played an important role throughout the interviews. Figure 29 lists a selection of measures frequently mentioned with respect to the life-cycle phase they impact most.

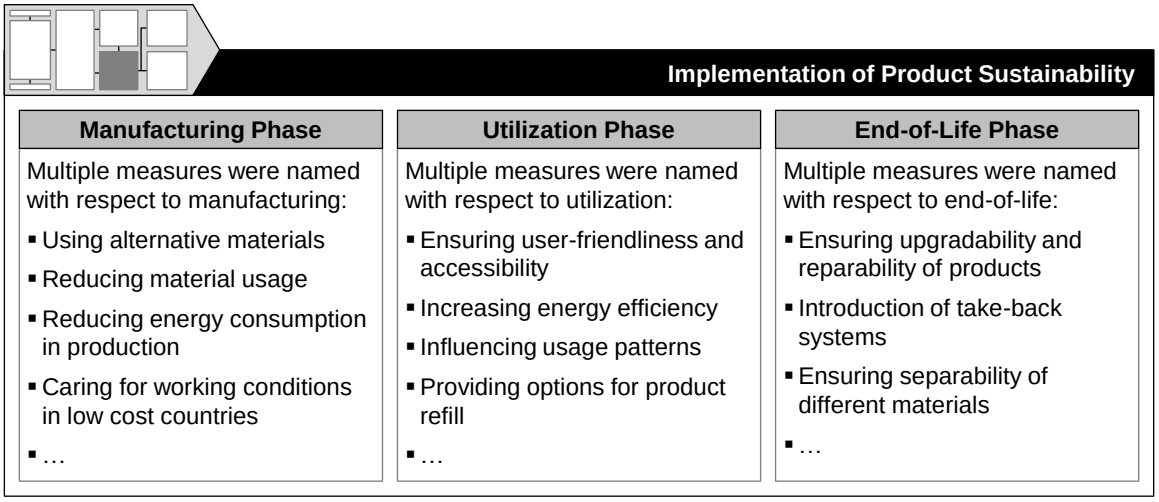

Figure 29: Findings for Category "Implementation of Product Sustainability"

It became apparent that the interviewees are aware of numerous different sustainability measures directly or indirectly impacting the environmental, economic, and social bottom lines of products. However, listing all measures participants come up with is not deemed reasonable since they are product or company specific and often hard to delimit. More

interesting with respect to the implementation of sustainability initiatives are two potentially contradictory findings: First, interviewees are aware that influencing product sustainability should not end at the company boundaries. They often emphasized that the overall product life-cycle and the entire supply network should be taken into account when evaluating and improving product sustainability. However, this attitude does not seem to correspond fully to the interviewees' actual behavior since the second finding is concerned with the importance interviewees attach to different options and different life-cycle phases throughout their daily work. It becomes apparent that most interviewees are truly focused on the manufacturing phase and specifically on material and energy efficiency measures. This emphasis is reflected in the nature of projects that were already accomplished as well as in scheduled projects and in measures interviewees declared to implement if they have enough time and resources on their hands. On the other side, targeting the utilization phase (e.g. by means of influencing consumer behavior) receives little attention. End-of-life aspects (e.g. to facilitate recyclability) are more frequently mentioned especially by participants working on durable consumer goods. However, the following quotes illustrate the participants' predominant focus on improving sustainability through material considerations:

> *For me as a designer, it is actually this material topic. I think that is what matters most. Hence, the question is: how can I further improve things and choose something more environmentally friendly?* ***#30, Consumer electronics***

> *I know about projects with the goal of doing something really environmentally friendly. However, all of these projects got nowhere near far enough from my point of view because they only focused on material issues.* ***#19, Leisure and sports equipment***

> *For now, we are used to saying that our product is sustainable because for us using recycling material ranks first.* ***#1, Household commodities***

As most sampled companies have limited experience in managing product sustainability, it seems that product developers tend to focus on areas familiar and most convenient to them. However, possibilities to make a major difference regarding sustainability might be outside of this focus and thus remain unnoticed.

Literature supports the interviewees' perception that material selection is a critical issue for developing more sustainable products (e.g. Ljungberg 2007, p. 477; Brockhaus et al. 2016a, p. 141). It is suggested to frame product sustainability as a materials problem since material choices also have a decisive impact on the end-of-life of products (Hopkins 2010, p. 76). However, some authors emphasize the importance of considering the utilization phase and more specifically influencing consumer behavior for the sake of sustainability improvements (Pettersen & Boks 2008, p. 287; Phipps et al. 2013, p. 1231 f.; Strömberg et al. 2015, p. 163). For example, Pettersen et al. take laundry as an example to illustrate the

considerable potential product development has to interfere with unsustainable usage patterns (2013, pp. 94–97). Also, some major FMCG companies like Unilever and Kimberly-Clark claim to be working on influencing consumer behavior to achieve major sustainability improvements with respect to the overall product life (Mizera 2013a, p. 187, 2013b, p. 192). However, the interplay between humans and technology is not at the heart of traditional eco-design strategies applied in practice (Pettersen 2015b, p. 210). In this course, it is acknowledged by the literature that the role of product developers as facilitators of product sustainability becomes more complex when trying to make behavior-influencing design decisions (Boks & McAloone 2009, p. 443). Charter & Clark (2007, p. 37) summarize the discussion by suggesting that the biggest impact of many products has to be allocated to the use phase. Accordingly, they call for designers to broaden their understanding of user behavior as this is sometimes contradictory. Based on the findings from data analysis and literature, the following proposition emerges:

Proposition 9:	**For improving product sustainability, developers focus on the manufacturing phase. Influencing consumer behavior or end-of-life aspects receive less attention.**

5.8 Challenges for Product Development

Product developers experience several challenges when setting out to bring the conceptualization to life by means of selecting and implementing different options for sustainability improvements. Figure 30 summarizes three major challenges that emerged from the interview data.

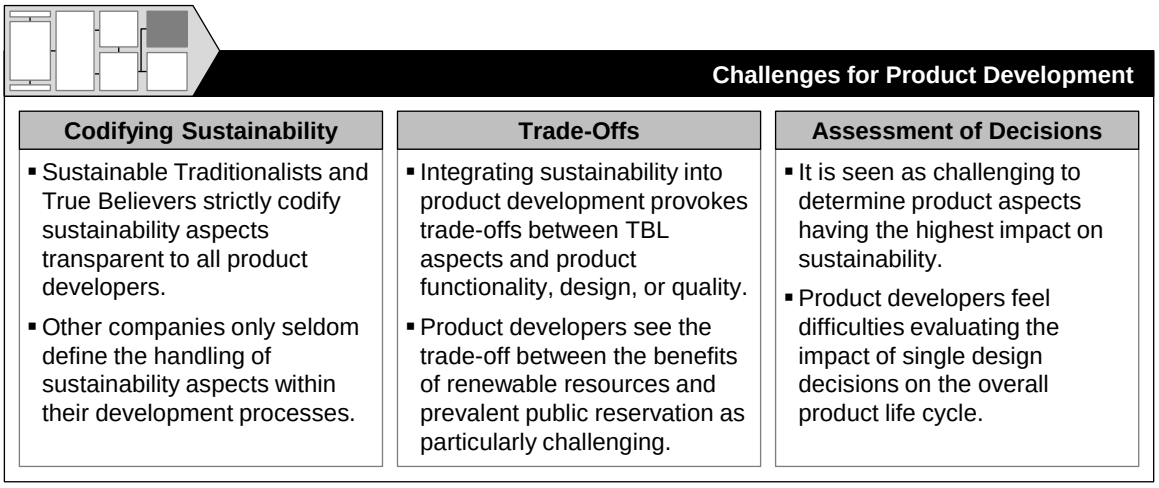

Figure 30: Findings for Category “Challenges for Product Development”

First, the consideration of sustainability is often not codified properly in the development process. This makes it difficult for product developers to set an appropriate scope and choose between different options. Furthermore, improving sustainability often reveals trade-

offs with functionality or other product attributes. Finally, product developers experience difficulties when they try to compare different options from a life-cycle point of view.

5.8.1 Codifying Sustainability

All interviews contained several questions about the nature of the companies' product development process as well as employed tools and methods. Almost all interviewees report following a clearly defined development process. Also, apart from Minimalists, all interviewees claim to consider sustainability up to a certain extent. However, it becomes apparent that despite well-defined processes the consideration of sustainability is handled differently. True Believers and Sustainable Traditionalists usually strictly codify sustainability aspects. Interviewees report having set up clear and measurable internal guidelines for product development. Furthermore, some companies also subject their products to rigorous external certifications like Cradle to Cradle. Through such internal and external guidelines companies aim at achieving transparency for the handling of sustainability aspects within their development departments:

> *For our brand, we set up green and social development guidelines to define and cement this holistic sustainable development. It is like a constitution that we are writing for our brand. Thus, there are rules and standards that the products have to comply with. We are continuously working on codifying sustainability in the DNA of the brand.* ***#12, Household commodities***

Most other interviewees reveal a striking gap between the roles sustainability and functional requirements play in product development. While functional requirements are recorded through product specifications, the desired sustainability level is not. Accordingly, participants claim to consider sustainability if possible, but at the same time it is seldom defined which conditions constitute such a possibility:

> *Sustainability is rather something on a gut level, and it also depends on the product manager or the person in charge of development.* ***#31, Leisure and sports equipment***

> *There is no checklist for sustainability where such things are inquired and where one suddenly could experience decision conflicts.* ***#19, Leisure and sports equipment***

However, interviewees indicate that this lack of codification is not the result of reluctance. Rather, companies experience difficulties committing to a clear sustainability scope for product development in a first step and then defining by which criteria product sustainability should be evaluated:

> *No, sustainability is not specified as some requirement for our development projects. We have not elaborated that in depth yet. In our department, we are still rather concerned with the question which parameters we want to use in the first place.* ***#28, Home and garden commodities***

The extant literature supports the empirical findings. Alblas et al. (2014, p. 533) found that for most of their case companies concrete sustainability targets or a clearly defined scope for sustainability initiatives did not exist. This lack of guidance for product development resulted in large difficulties with managing sustainability. Similarly, Thompson et al. (2011b, p. 5 f.) report that companies employ a number of decision tools to support sustainability considerations. However, apart from lists containing banned substances these tools provided no clear targets or company-specific codes on how to actually deal with sustainability. Petala et al. (2010, p. 178) investigate product briefs at Unilever, which are used to summarize relevant features of new products entering the development stage. While the template for these product briefs contains a section on sustainability aspects, it is found that this section was often not completed. Such discrepancies are summed up by Short proclaiming that sustainability is desired by companies, but the engineers in charge of actually implementing sustainable solutions are "left ignorant as to what it specifically implies for them" (2008, p. 22). Based on the findings from data analysis and literature review, the following propositions emerge:

Proposition 10:	**Product sustainability is often not codified strictly within the development process.**

Proposition 11:	**The lack of codified sustainability criteria can result in sustainability not being considered in a systematic way during product development.**

5.8.2 Trade-Offs

Another major challenge named by most interviewees is to find an appropriate way of dealing with sustainability-related trade-offs. While solving trade-offs between the functional aspects and costs of a product have always been an integral part of product developers' job, incorporating sustainability adds a new layer of trade-off potential and complexity. For example, several participants report trade-offs they experience between maintaining product quality and choosing more sustainable materials. This interviewee shared insights into the effect of material changes they constantly make due to tightened regulations or rather because they suspect some substances to be potentially harmful:

> *You know, in some product aspects the quality we achieve today is lower than it had been years ago. Simply because we are restricted today and, hence, cannot use the materials we used back then.* ***#15, Stationery***

Apart from product functionality, interviewees also refer to other drawbacks caused by sustainability improvements. For example, using recycled materials might interfere with the desired exterior design of the product as this participant indicated:

> *These materials are only available in muted colors. And that, of course, contradicts fashion considerations in many areas.* ***#5, Medical and therapeutic products***

Participants also experience trade-offs between the different aspects of sustainability. These emerge, for example, if a sustainability improvement of one aspect (e.g. using biodegradable plastics) leads to a drawback with respect to another sustainability aspect (e.g. problems for established recycling systems). These intra-sustainability trade-offs sometimes also comprise complementary goods as this interviewee explains by means of a washing machine:

> *The lower energy consumption that is desired leads to a decline in washing temperatures. That is a trend very much supported by the detergent industry because they want to sell more chemicals. You definitely need those chemicals if you wash with lower temperatures. Thus, the isolated focus on energy consumption is not helpful.* ***#22, Domestic appliances***

Today, many of these sustainability-related trade-offs cause inertia with respect to tackling sustainability. For example, interviewees appear to be hesitant to use alternative materials since they are worried about possible quality drawbacks. In fact, some interviewees indicate to have already refrained from promising sustainability initiatives because of potential conflicts with other product aspects. In opposition to this practice, the extant literature calls for accepting unfavorable trade-offs as a necessary effort towards sustainable development rather than "embarking on the eternal quest for win-win solutions" (Hahn et al. 2010, p. 226). However, some authors (e.g. Short 2008, p. 30; Esty & Simmons 2011, p. 190) caution that "green" itself should not be the major selling point of products. They say that sustainability should be a guiding principle for product designers but should not be used as an excuse for poor product quality. The findings from the data analysis concerned with sustainability trade-offs are also directly confirmed by Alblas et al. (2014, p. 526): the question of how one should deal with emerging trade-offs between sustainability aspects was one of the fundamental issues the companies in their case studies were facing. Taken together, the following proposition is established:

Proposition 12:	**Improving the sustainability of existing products often yields trade-offs between sustainability and product performance.**

Throughout the interviews, introducing renewable raw materials and more specifically replacing petroleum-based polymers by bio-based polymers (bioplastics) emerged as a hot topic and source of many trade-offs. Interviewees consider bioplastics in general as a promising option to enhance environmental sustainability. However, only a few of them actually choose to employ bioplastics for some products. On the one hand, this gap can be traced back to higher material costs compared to traditional plastics, as these participants explain:

> *The thing is that in our case the bio-based polymers are way more expensive than conventional polyethylene.* ***#13, Stationery***

> *The material that I can use and that is from corn or potato starch is three to four times more expensive than normal polyethylene. How am I supposed to sell this to the consumers?* ***#1, Household commodities***

Furthermore, interviewees fear that they might not be able to keep their established quality level if they switch to renewable raw materials. This interviewee worked on a project that aimed at using bioplastics. During the development process he indeed encountered various technical problems with respect to production as well as logistics:

> *Bioplastics are often not designed to be exposed to very high temperatures. If you simulate that the products have to withstand 60 or 70 degree Celsius in a container for four weeks, then the products actually deformed and arrived unserviceable in some countries.* ***#17, Toys***

Nevertheless, interviewees are positive that the cost differences will diminish in the long term and that bioplastics will one day meet their quality criteria as material development advances. However, even if these criteria are already met today, participants express their mixed feelings towards using them. One reason are ethical issues related to the cultivation of non-food crops. This interviewee illustrates some of these matters by means of plastics that could be used for his products and that is based on the castor bean:

> *There is a material on the market we could use. However, I find myself in a dilemma here because that is actually a food item, and if I use it, people cannot eat it. Often this comes from countries that are short on food as it is. I cannot justify this from an ethical perspective.* ***#21, Body care products***

Other interviewees articulate their doubt about the environmental merits and the actual biodegradability of bioplastics since often specific conditions have to be met. Furthermore, interviewees do not know about any established recycling system for bioplastics:

> *I can use this biopolymer, and it will be great for production, but you won't find a supplier out there who tells you that they are also up to snuff with respect to recycling. Quite to the contrary actually: They all openly say, they have no idea how to recycle this stuff yet.* ***#19, Leisure and sports equipment***

Most importantly, interviewees worry about possible negative public relations related to the use of bioplastics. The case of Danone was often referred to: In 2011, they introduced a yogurt cup made from renewable sources and got attacked by ecology groups for promoting these cups as being more environmentally friendly (Resch 2011). Danone itself had commissioned an analysis from the ifeu-Institute earlier (Kauertz et al. 2011) that returned some ambiguous results. Danone then abbreviated their "proof" of the enhanced sustainability in a way that may have overridden negative aspects of the new material. When ecology groups started to protest against this rather lax handling of data to back up the

claims, Danone finally had to retreat (Resch 2011). As the following quotes illustrate, participants feel discouraged by such examples:

> *And then there is the Danone case we are all still recovering from. Someone is trying to use bioplastics and then they are scolded from all sides because they did not pay attention to the whole production and recycling process. #**9, Domestic appliances***

> *What made all of us cautious was that Danone case. That was tarnished as greenwashing; they had to pull it from the market. (…) Right now, you are playing with the fire when you introduce something like this to the market at large. #**10, Household commodities***

The perception of bioplastics by product developers has not yet been covered in detail in the extant literature. Also, consumers' perceptions and interests in bioplastics are rarely reported (Kurka 2012, p. 127; Kainz et al. 2013, p. 392). Overall, consumers seem to have a positive attitude towards bioplastics. However, they also reveal a limited understanding of different material types and their environmental effects (Kainz et al. 2013, p. 396). On the other side, literature provides evidence for product developers' mingled feelings towards bioplastics: First of all, some environmental associations and industry federations are critical about the use of bioplastics (Beier 2009, p. 7). Furthermore, a myriad of studies demonstrates that bioplastics do not necessarily entail lower environmental impacts compared to petroleum-based plastics (e.g. Hottle et al. 2013; Yates & Barlow 2013; Rossi et al. 2015). Based on the empirical findings and supported by literature the following proposition is established:

Proposition 13: **Product developers are hesitant to use bio-based polymers because of technical hurdles and the volatile public discourse.**

5.8.3 Assessment of Decisions

Most interviewees report finding the sustainability assessment of their design decisions quite challenging. Especially taking into account the overall life-cycle seems to be a problem. One reason for this stems from limited knowledge about the use phase of a product. This participant states that he encounters problems assessing life-cycle aspects since the power tools he develops are used in different ways by different groups of consumers:

> *For us, it starts with difficulties in defining the life-cycle of our products. If you have a refrigerator, it is easy (…) because it always runs under the same conditions. However, we have ever-changing conditions. And that is the problem, how do you measure that in a way that makes sense? #**27, Home and garden tools***

Even if the focus is specified to one life-cycle aspect, participants indicate that a thorough assessment of decisions is often not possible. Whether a design decision has an overall

positive impact on sustainability, depends on a number of variables that might not be visible at first sight as this interviewee explains by means of supplier selection:

> *Is a supplier who has to drive 500 kilometers actually better than a supplier driving 700 kilometers? It depends on the truck he is using and on the route he takes. And is he coming in our direction anyway or is he driving specifically for us? You cannot make the decision only looking at the distances. #**3, Household commodities***

As was revealed in Section 5.7, product developers tend to primarily consider material changes for improving sustainability because it seems that this is the product aspect they are most familiar with. However, material choices are also surrounded by some question marks. While it is evident that the avoidance of hazardous materials for consumer products is a good thing, interviewees indicated that it gets complicated as soon as they want to proceed further and search for more sustainable alternatives:

> *Well, if I replace a synthetic granulate with a renewable resource, I really have little insight how much good I am actually doing, I doubt it. #**25, Consumer electronics***

> *Try asking a packaging manufacturer – we have done that – what would be more environmentally friendly from their point of view: a plastic bag for wrapping the product, an adhesive foil for protecting the product or a cardboard inlay. They cannot properly answer this question because paper manufacturing is also really energy intensive. And is it true that paper is always better for the planet? #**19, Leisure and sports equipment***

Literature supports the findings presented above. For example, Alblas et al. (2014, p. 526) find measuring environmental impacts of different product designs to be the most important sustainability issue for their case companies. Also, these companies had a hard time working with suppliers towards sustainability improvements in consideration of the entire life-cycle of a product. Clancy et al. (2015, p. 351) find that a lack of information is a major roadblock for considering the overall life-cycle when making design decisions since adequate information is necessary to compute life-cycle analyses as advocated by many authors (e.g. Klöpffer 2003; Bevilacqua et al. 2007; Luthe et al. 2013). Another inhibitor for acquiring a life-cycle view is seen in the increasing geographical separation of design and manufacturing since many product developers simply do not know anymore under which specific conditions the product is manufactured (Charter & Clark 2007, p. 23). Further, some authors neglect the challenge of measurability by saying that it should not be a big problem to never know the total impact of one's decisions as long as developers are making progress (Hopkins 2010, p. 80). However, data analysis has demonstrated that developers often do not even know into which direction they progress as soon as they consider sustainability initiatives more manifold than material reduction or pollution prevention. As a result, especially product developers with only limited experience in managing sustainability often shun more innovative sustainability initiatives since they cannot fully oversee their consequences. Taken together, the following proposition emerges:

Proposition 14: **Product developers experience difficulties to evaluate their development decisions from a life-cycle perspective.**

5.9 Challenges for Commercialization

Already after the initial interviews, it became apparent that the interviewees' focus with respect to sustainable product development was not confined to development practices but incorporates a much wider view on the topic. Accordingly, participants emphasized the challenges of successfully bringing more sustainable products to market. Figure 31 summarizes the three most important challenges that emerged from the data.

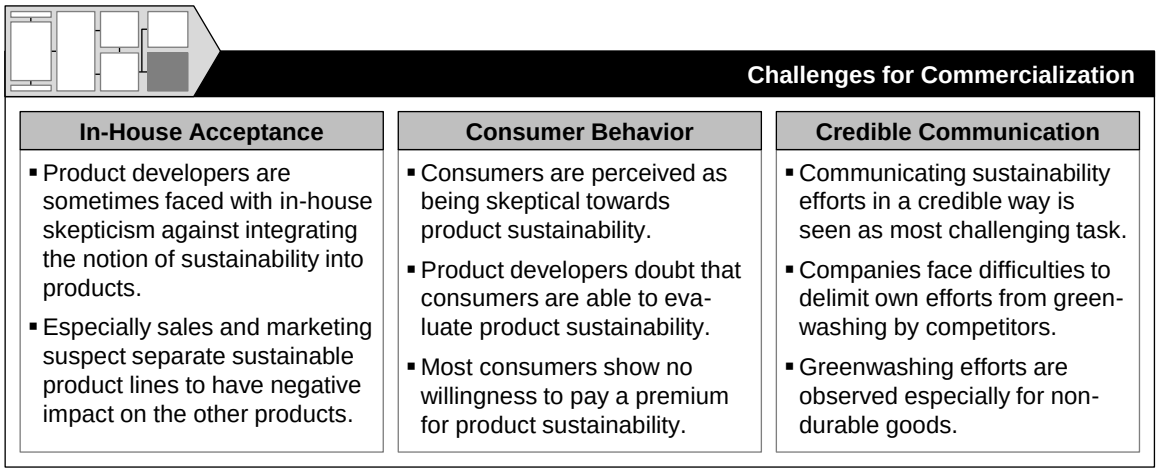

Figure 31: Findings for Category "Challenges for Commercialization"

First, gaining in-house acceptance for sustainability innovations is seen as crucial since product developers themselves are not the ones charged with selling the products. Further, consumer behavior challenges product development since consumers seldom embrace sustainability as companies expect. On a related note, credible communication of sustainability efforts is seen as a challenging task in an environment where greenwashing activities seem to become common marketing measures.

5.9.1 In-House Acceptance

Before the products can be brought to market, product developers are sometimes challenged by in-house resistance. Participants experience such resistance especially in situations where management does not comprehensively support sustainability. This interviewee reports about a self-motivated sustainability project he had been working on for several years, finally resulting in product changes visible to the consumers:

> *And then we had the pundits in our own organization weigh in. I mean you really have to be careful. We have 500 products – all of them are plastics – and then you bring this bioplastics product to market that is more sustainable. Well, and the rest of our products are all garbage now?* ***#17, Toys***

Often, sales and marketing units seem to emerge as roadblocks as they are the ones having to promote and sell more sustainable products regularly conceptualized and pushed through by rather idealistic product developers:

> *I think in marketing and the executive suite they are thinking: 'Oh dear, now she wants to do some of this eco-stuff.' I think sometimes you still have to fight these clichés.* ***#30, Consumer electronics***

However, like with any other issue related to change possibly posing inconvenient consequences for others, project success seems to be the best enabler for in-house acceptance of sustainability. Interviewees report that once sales representatives notice that consumers are aware of the improvements and value them, they quickly cease their resistance and jump on the bandwagon:

> *If you are successful in the end, then people are like: 'Oh, how cool is it that we are doing these things in our company? I was in favor of the project right from the very beginning'.* ***#30, Consumer electronics***

Literature supports the findings from data analysis. Charter & Clark (2007, p. 35) emphasize the importance of selling sustainability projects in the language of different departments to avoid that these projects are "hitting the green wall and move no further." Verhulst & Boks (2012c, p. 153) find that in-house resistance against sustainability projects starts to grow when people are forced to adapt their habits and procedures. This especially holds true for sales representatives considering sustainability as an additional burden. However, they also illustrate that resistance can turn into enthusiasm once the added value of sustainability is understood (Verhulst & Boks 2012c, p. 154). Based on the findings from data analysis and literature, the following proposition emerges:

Proposition 15:	**If sustainability is not part of the companies' strategy, product developers experience difficulties in selling their efforts internally and externally.**

5.9.2 Consumer Behavior

Almost all participants brought up the challenge of selling sustainability to their consumers. While this may sound like a shallow excuse for not embracing sustainability, it becomes apparent that even the sustainability frontrunners of the sample reported similar experiences. In fact, sustainability seems to be of limited relevance for the actual purchasing decision of consumer goods as these interviewees express:

> *I would claim that we could not sell our products under the heading of sustainability.* ***#28, Home and garden commodities***

> *Why is society's demand so small? Although everyone is interested in the topic and everyone is happy if they know that their Starbucks cup is made from recycled paper?*

> *It really focuses on specific areas and leaves out all others. And I really do not understand this gap.* ***#17, Toys***

Interviewees frequently report their experiences concerning the gap between consumers' attitude and behavior towards more sustainable products. While in general many consumers have a positive attitude towards sustainability, only a few are actually willing to change their usual purchasing behavior – especially if this means paying extra for superior sustainable products. This interviewee reports about a line of products that was developed under rigorous consideration of sustainability aspects. A minuscule share of consumers truly embraces these products and demonstrate high commitment. However, most consumers do not:

> *However, certainly 95 percent of the consumers say: 'If it is green and cheaper, I'll take it. Otherwise, I do not care.' And in consumer research, you always have the problem that people you ask on the street do not want to embarrass themselves by saying that they are against the environment. And then you get such big-mouthed promises: I will buy this product even if the price is 20 percent higher. And then they show their true colors in the stores.* ***#15, Stationery***

> *First, everyone says that he wants to have an environmentally friendly product, one that is sustainable and so forth. (…) However, once it is about money and economic aspects, the notion of sustainability disappears for many consumers.* ***#6, Household commodities***

However, interviewees are aware that consumers have a hard time evaluating product sustainability at the retailers' shelf. Sustainability is often not easily understood because it is only seldom transferable into measurable aspects like energy efficiency or water consumption. Since most aspects of product sustainability cannot be observed in the store, consumers have to rely on labels or other claims made by the manufacturers. As was already demonstrated in previous sections, product developers tend to focus their sustainability efforts on aspects related to the manufacturing phase while more or less neglecting the use phase of a product. Considering the market perspective, this approach poses a serious problem as in turn consumers primarily notice sustainability improvements observable during the use phase. Thus, companies wanting to target conscious consumers by improving product sustainability should focus their attention on aspects the consumer can notice more easily. While focusing on material and production issues, especially for non-durable consumer goods interviewees assume that consumers have no idea how much R&D efforts went into the products they buy:

> *I think the more complex products get, the more difficult it is for the consumer to evaluate to what extent the product can be produced environmentally friendly.* ***#4, Leisure and sports equipment***

> *Consumers choose whatever looks interesting on the shelf. They do not think a lot, and we cannot expect that the consumers concern themselves with what we in R&D invest into the product.* ***#15, Stationery***

Accordingly, most interviewees voice the opinion that sustainability cannot be sold to consumers on its own. Sustainability should not be considered as decisive for the purchase decision but as kind of add-on to products sold because of other features:

> *The product has to be perfect for its price. And if it then features sustainability aspects, it is great. Because then people can brag about it.* ***#30, Consumer electronics***

A look into the literature reveals a myriad of studies overbidding themselves with high percentages of consumers claiming to be interested in more sustainable products (e.g. Otto Group 2013, p. 19; Schudak et al. 2014, p. 27; Nielsen 2015, pp. 8–10). However, these studies do not report actual behavior but only inquire consumers' attitude and at the same time often illustrate that the respondents do not know what sustainability means (e.g. Buerke & Gaspar 2014, pp. 25–27; Schudak et al. 2014, p. 19). Overall, literature confirms that consumers' demand for more sustainable products is low and therefore probably not the main driver for product development to "green up" their products (Boks & McAloone 2009, p. 434; Luchs et al. 2010, p. 29; Gmelin & Seuring 2014b, p. 6). Further, it could be demonstrated that sustainability is difficult to explain to consumers. Alblas et al. (2014, p. 527) illustrate that with a characteristic example also brought up by one of the participants from this study: vacuum cleaners are typically bought because of high wattage and not because of their suction. This "the more, the merrier"-perception results in a 2,400 W cleaner selling better than an energy-efficient 1,200 W cleaner even though the eco-product outperforms the other regarding suction. Taken together, the findings from data analysis and literature lead to the following proposition:

Proposition 16:	**Product sustainability is of little importance for most consumers' purchasing decisions.**

Before this background, interviewees indicate that they have a hard time anticipating how consumers react to different sustainability initiatives. Therefore, they see little opportunity to purposefully influence sustainability-related purchasing decisions through constructive measures. This is partly attributed to a lack of suitable standards for comparison consumers could use to evaluate different products:

> *If you take a look at refrigerators, you see these A+ and A++ and A+++ labels. Everyone looks at these labels. However, there it is evident that if you spend more money today, this will pay back in the course of time through lower energy bills. You will not experience such a thing for power tools.* ***#26, Home and garden tools***

Literature provides no immediate support for this finding. However, multiple studies underline the importance of having a close look at consumer behavior. Specifically, it is called for investigating which situational and psychological variables have an impact on the choice of more sustainable products (Sheth et al. 2011, p. 34 f.; de Medeiros et al. 2014, p. 82; Luchs & Kumar 2015, p. 17). Building upon the empirical findings, the following proposition is established:

Proposition 17:	**Product developers do not know how to catalyze sustainability-based purchasing decisions through product development activities.**

5.9.3 Credible Communication

Even though marketing measures are not in their field of responsibility, almost all interviewees express worries that their efforts to enhance sustainability might go unnoticed alongside the phalanx of greenwashing activities by some competitors. Greenwashing seems to be especially popular with non-durable consumer goods since consumers normally make fast and impulsive purchasing decisions. These decisions can be influenced, for example, by sustainability claims, eco-look, or labels. However, since sustainability is a relative concept it is not easy to differentiate actual greenwashing attempts from incremental improvements blown up through marketing measures:

> *You can write many things onto your products. Moreover, if you change 0.2 percent of the product and if you are brazen, then you write down that it is now more sustainable than the other products. You know, Persil got better every year as well...*[24] ***#28, Home and garden commodities***

Several interviewees name competitors that they thought were making a fuss about sustainability without actually reflecting that with their products:

> *Nobody is interested in accusing a competitor of lying. Let's just say that sometimes it can be rather demanding to follow the line of arguments that is put forward.* ***#11, Furniture and lighting***

> *And then there are other manufacturers claiming to be green. But nobody really knows why that is the case. But everyone is trying to work with the term sustainability.* ***#9, Domestic appliances***

As was already indicated, consumers have little interest or at least little knowledge about sustainability. For this reason, product developers especially worry about competitors' claims towards sustainability if they are genuine but misunderstood by consumers:

[24] Persil is Germany's top-selling laundry detergent manufactured by Henkel. Since 1994, it is repeatedly promoted using slogans like "Das beste Persil aller Zeiten" (= Best Persil of all time).

> *Others write on their packaging that it is 100 percent recyclable. We write on it that it is made from 80 percent recycled material. Now I ask you, what do the consumers notice? Do you see how difficult that is? Even though we are way ahead of the curve on this, we have to communicate much more effectively. Otherwise, we would appear in a bad light in the cursory consumer perception. #**12, Household commodities***

Taken together, interviewees from all types of companies report to experience difficulties in communicating information about product sustainability to their consumers in a credible and authentic way. Other examples from practice underline this issue: Unilever, for example, once tried to reduce packaging waste by offering concentrated laundry detergent. However, most consumers thought they were getting less laundry detergent for the same amount of money and refused to buy the product (Esty & Winston 2006b). It is no secret that actual greenwashing attempts frequently happen as sustainability moves into the spotlight of public attention (e.g. Delmas & Burbano 2011, p. 64; Nyilasy et al. 2013, p. 693). For example, a recent study on the Brazilian consumer goods market analyzed 2,300 allegedly "green" products and revealed that only 15 percent of the sustainability-related claims were backed up by trustworthy third-party certificates (Moodie 2015). Moreover, 82 percent of all products under investigation were to blame for at least one of the seven sins[25] of greenwashing. However, literature has not yet examined greenwashing from a product developers' point of view. This is not surprising as promoting sustainability to consumers is typically a marketing task. However, negative effects of greenwashing on product developers' motivation to further improve sustainability appear to be worth looking into. Based on the findings from data analysis, the following proposition emerges:

Proposition 18:	**Product developers experience difficulties distinguishing their efforts from competitors' greenwashing activities in a credible way.**

5.10 Implications of the Qualitative Analysis

After presenting the findings of the qualitative study, their implications are put forward in the following sections. They are differentiated into theoretical implications about the field of research on sustainable product development as well as managerial implications concerned with the strategic alignment of product development in industry. However, it is acknowledged that especially in empirically grounded work like the current study, the implications emerge to be highly intertwined.

[25] The seven sins of greenwashing are (1) the sin of the hidden trade-off, (2) the sin of no proof, (3) the sin of vagueness, (4) the sin of irrelevance, (5) the sin of lesser of two evils, (6) the sin of fibbing, and (7) the sin of worshiping false labels (Terrachoice 2010, p. 10).

5.10.1 Theoretical Implications

The findings of the current analysis have important implications for research and theory. First, research should reshape the focus of most conceptual contributions to match the actual needs of the industry. As has been revealed in Chapter 3, a myriad of methods have been published that are intended to help companies with enhancing product sustainability. Most of them are highly complex and require detailed information about materials and products, and, more importantly, only work if the companies have already set their sustainability goals and priorities. However, the analysis revealed that most companies from the sample (1) are not familiar with any of these methods and (2) would not be able to fulfill the requirements anyway. In fact, they are still rather concerned with exploring what sustainability means in their products' context than with running a detailed environmental analysis of a component's different constructional sketches. Thus, they would truly benefit from a method that helps them learn about their products' sustainability issues and to set achievable, yet ambitious sustainability goals. Research should also factor in that most development departments of consumer goods companies are rather small, as most companies from the sample employ less than ten development engineers. Thus, methods that were developed with multinational companies in mind (e.g. from the automotive industry) are probably not applicable for SME.

Second, the review of the extant literature already demonstrated that while the research dedicated to frameworks and methods can support enhancing product sustainability (if applied), it falls short of tackling behavioral roadblocks. In fact, behavioral aspects of developing more sustainable products are largely neglected. Only a small amount of studies cover human factors like resistance against sustainability (see Section 3.3). The relevance of working on this research opportunity was especially emphasized throughout the analysis through the example of bioplastics. The analysis illustrates the importance of outside factors, public perception, and "feelings" for decision-making in product development. It was found that behavioral issues impede the diffusion of novel materials like bioplastics, as product developers report a lack of perceived behavioral control. Also, they struggle with doubts about the environmental benefits and trade-offs of bio-based materials in terms of their TBL performance. As a result, they often refrain from advancing mere concepts to a state of market readiness due to doubts about consumer receptiveness and fears of greenwashing allegations. Only if the behavioral roadblocks product developers face around bioplastics can be overcome, more successful bioplastics consumer products will become mainstream. Therefore, research is called to look into the environment product developers find themselves in when trying to increase product sustainability, also beyond just bioplastics.

Third, the analysis underlines that it would be beneficial to consider the market perspective in research on sustainable product development. Participants repeatedly brought to the table the problems they experience in that respect since sustainability is relatively new to most development departments, and many uncertainties exist regarding consumers' expectations and behavior. Especially in SME, product developers experience high exposure to market aspects since companies are simply not big enough for a silo mentality to emerge. In fact, many participants also bear responsibility for some marketing or product management tasks. Thus, they gain firsthand feedback on their attempts to enhance product sustainability. Most publications reviewed in Chapter 3 implicitly assume that consumers will go out and buy a product as long as the sustainability level is high enough. However, as marketing research has highlighted over and over again, and as this study's interviewees repeatedly noted, that is not how consumers behave nowadays. Thus, combining the perspectives of product development and marketing for both conceptual and empirical studies might help to establish a link between tangible development practices and related consumer responses. Summing up, the following theoretical implications are derived from the qualitative data analysis:

- **[T1] Match conceptual work to companies' needs:** Research should focus on providing methods that help product developers to get started with sustainability. This includes educating them about the sustainability issues of their products and providing support for setting appropriate sustainability targets.
- **[T2] Zoom in on human factors:** Even though they are proven to have a crucial influence on the outcome of a development project, human factors with respect to sustainability is a largely neglected area of research. Thus, research should focus on the role of developers' behavior with respect to decision-making for more sustainable products.
- **[T3] Consider the market perspective:** Especially in SME, product development activities and marketing tasks are highly intertwined. Developers get direct (and often negative) feedback on their sustainability initiatives. Research should acknowledge that by looking into consumers' responses to concrete development practices.

5.10.2 Managerial Implications

Besides their theoretical implications, the findings of the current analysis also have several important implications for the management of product development in practice. First, the analysis has demonstrated the importance of aligning the corporate sustainability approach with the product portfolio management. For example, if a company considers itself as being truly dedicated to sustainability, it should refrain from introducing a separate "green" product line into the market, as this does not appear credible. Product developers should instead extend their sustainability initiatives to the entire product range. If a company is not known for any sustainability efforts, a line of "green" products is also not credible. However, some participants reported about such test balloons, which were started to fit the spirit of the time

instead of being part of a serious corporate push for enhanced product sustainability. Since such a product strategy is not credible in the eye of the consumer, these products commonly face a lack of market demand and tend to remain short-lived experiments. If, for example, a company offers a range of cheap plastics products and suddenly introduces a more sustainable product from bioplastics, retailers have problems promoting it under the traditional brand name because (1) consumers that care about sustainability do not look for such products with that brand and (2) the company's traditional consumers do not care about sustainability. Only in rare cases did participants declare their test balloons as being test beds, and thus being part of an overall strategy to stepwise improve the sustainability of the entire product range.

Second, the analysis underlines that significantly increasing product sustainability is not something many companies can realize alone. In fact, it requires the effective alignment of the entire backend of the supply chain to achieve success. Especially SME depend on resources outside the firm to improve product sustainability, and most interviewees from the sample were acutely aware of their dependence. However, there is a lack of collaborative behavior both up- and downstream the supply chain. Big retailers, in particular, try to leverage power over their suppliers to "bully" them into improving sustainability without equal sharing of costs and benefits, rather than working as partners. Moreover, participants from SME indicated feeling stuck between "a rock and a hard place" because big material suppliers are only seldom interested in working with them on specific solutions, as their order quantities are usually below the suppliers' attention thresholds. In fact, a recent study reveals that compared to most other industries, consumer goods companies are unlikely to collaborate around sustainability (Kiron et al. 2015). This behavior impedes more successful joint sustainability efforts and harms progress in product sustainability. The analysis illustrated that currently, only existing, long-term, and trusted relationships are broadened to include sustainability considerations. This is illustrated by some examples of Sustainable Traditionalists or True Believers that are collaborating closely with their suppliers: they educate their suppliers, for example, about sustainability potentials they see for their existing products, and in return get educated about new materials, process technology, or other more unconventional ways to improve product sustainability. Some Test Balloonists and Reactors, on the other hand, are trying to walk the talk on their own without being aware that they sometimes try to reinvent the wheel. Close collaboration with old and especially new partners like material start-ups or consulting engineers could act as a catalyst to improved product sustainability.

Third, companies should not halt their efforts after having made sustainability one of their strategic business objectives. For actually gearing a company towards sustainability,

corporate claims have to be translated into clear guidelines for the operational reality. For product development, this implies that sustainability has to be introduced into development projects through mandatory, product-specific, and quantified requirements. Only then can the sustainability of a product be increased step by step. One Sustainable Traditionalist from the sample follows this route, and recently implemented an internal sustainability scoring model for its products. For each of the pillars of the TBL and for each life-cycle phase, they defined a number of quantifiable measures that are consolidated into one scale. The current product generation was then evaluated as a benchmark. Each of the following generations is expected to improve on all three pillars by a specified order of magnitude. However, such a system cannot be developed overnight. In fact, the interviewee indicated that they had to dedicate considerable workforce for a thorough analysis of all sustainability-related aspects throughout the product's life-cycle before deciding about any of the measures. Most companies from the sample could benefit from such an approach because it creates transparency about their products' sustainability performance and forces them to clearly define their product sustainability roadmap.

Finally, the analysis recommends that companies should create opportunities for product developers to freely experiment with more sustainable solutions. For example, several interviewees shared that they believe bioplastics deserve more attention and their companies should allocate resources for exploring the use of such novel materials. Many of these projects might have long lead times, but if provided with the opportunity, product developers can arrive at innovative and possibly transformative solutions. The example of Google supports this notion. Until changing its strategy in 2013, Google allowed its engineers to use up to 20 percent of their working time for developing individual projects (Walker 2011, p. 369 f.). Even though most of these projects were not successful, today a handful of them (e.g. Google Maps, Gmail, Google News, and AdSense) make up a large share of Google's profit. Also, other companies known for their innovativeness like 3M have comparable programs in place (Peter & Frey 2016, p. 1021). One of the sampled companies follows a similar route by allocating around 10 percent of their developers' time to issues that are not yet linked to a specific development project. Since this company combines clearly codified sustainability goals with sufficient room for experiments, it is not surprising that they are sustainability frontrunners in their product category. Other interviewees shared positive experiences about their executives providing them with resources and trust to explore innovative solutions. More companies should take this route. Most interviewees, however, expose a desire and willingness to experiment with new materials or innovative product concepts, but they also feel they find only little to no time for such topics within their

daily working routine. Summing up, the findings of the qualitative data analysis lead to the following managerial implications:

- **[M1] Establish a credible corporate sustainability approach:** Companies wanting to get engaged in fostering product sustainability first need to establish a suitable corporate approach to sustainability since the success of a more sustainable product in the marketplace eventually depends on the credibility of the company's efforts. This also means refraining from halfheartedly introducing separate "green" product lines to fit the spirit of the time.
- **[M2] Collaborate with supply chain partners:** Product sustainability is something most companies cannot improve on their own since a product's entire supply chain has to be considered. Thus, companies should collaborate more closely to benefit from external resources.
- **[M3] Set clear goals:** The corporate approach to sustainability has to be codified into clear and measurable objectives for product development. Product developers need to be offered guidance on how far they have to, or rather are allowed to, push product sustainability.
- **[M4] Allow for experiments:** Companies should provide their product developers with resources for experimenting to find more sustainable solutions that question established product concepts, and thereby also might pose opportunities to gain competitive advantage.

To facilitate their consideration in practice, the managerial implications derived above are matched with the phases of the product development process and the departments involved (see Figure 32). While the establishment of a credible corporate sustainability approach is clearly a task that involves all departments before or during the planning phase of development projects, collaborating with supply chain partners is an advice product development managers should consider during all phases of the development process. Further, setting clear goals for sustainability efforts of developers is a task product development and marketing should jointly work on during planning and concept development. Finally, product development managers should allow for experiments their development teams might want to pursue until the detail design phase.

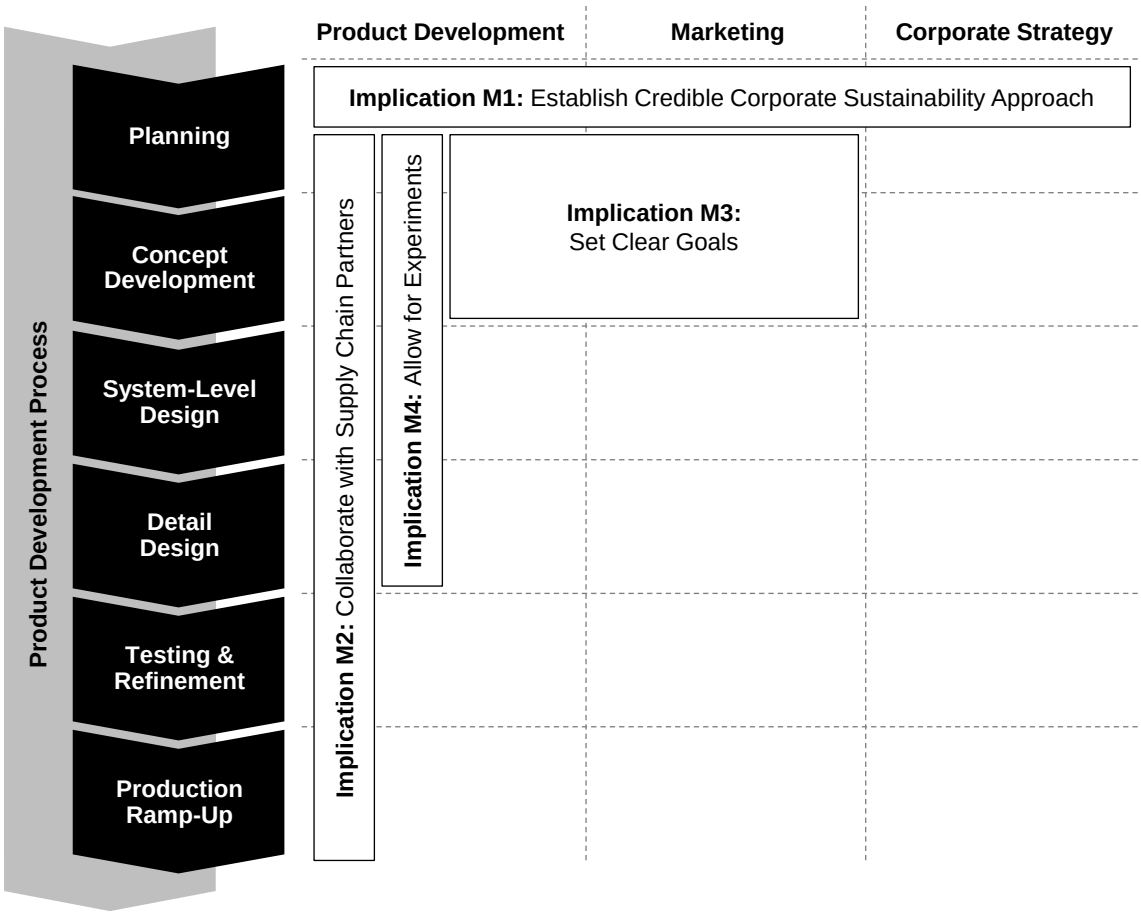

Figure 32: Matching of Managerial Implications, Departments, and Development Process Phases

5.11 Limitations of the Qualitative Analysis

The Grounded Theory approach employed has proven to provide comprehensive insights into how product development of consumer goods companies deals with sustainability issues. The analysis revealed some distinct approaches companies follow for setting a corporate sustainability scope and breaking it down into specific development guidelines. Moreover, several challenges emerging during the development process as well as for successfully bringing more sustainable products onto the market were pointed out and related to the corporate sustainability approaches. However, Grounded Theory possesses some methodological limitations with respect to the research process and the findings that have to be taken into account.

Since Grounded Theory is a research approach building on the collection and analysis of qualitative data, its goal is to uncover relationships between theoretical concepts instead of empirically testing them (Suddaby 2006, p. 636). Even though the emerging relationships were challenged over and over again through constantly comparing them with new data, no statistically valid correlations can be derived from the study due to the limited sample size. Also, the sample was intentionally limited to product development managers as they are

responsible for implementing sustainability into products and also have a suitable overview of the entire supply chain. However, the possibility that other departments like purchasing or marketing might also have a substantial influence on product development decisions is by no means to be ignored.

Further, the interview sample was composed through theoretical sampling to provide meaningful insights into the research questions. Accordingly, the sample is not meant to be representative of the underlying population that was intentionally limited to the non-food consumer goods industry of German-speaking countries. Thus, the current findings should not be generalized without further ado for companies outside of the sample. Further, consumer goods companies act within their unique business environment (as was explained in Sections 2.3 and 5.1). Thus, it is likely that the same research might yield similar but divergent findings in other industries.

Moreover, the nature of the findings of a Grounded Theory study depends on the interpretations the researchers make. Even though this researcher bias was accounted for through a number of measures, it is possible that the data would allow for divergent interpretations. An additional group of limitations pertains to using interviews as the primary source of data. First, it is possible that interviewees purposely withhold information that might be relevant to the construction of theory. Second, the information they do share is reported as the interviewees observed and interpreted it and does not necessarily have to be concordant with the perception of other persons involved. Third, the course of an interview is at risk being unintentionally skewed by the researcher's agenda.

Finally, another limitation is concerned with the temporal stability of the findings since sustainability is a rapidly evolving issue influenced by different stakeholders. Innovation cycles in the consumer goods industry are also rather short, thus, it is likely that some sampled companies already adapted their strategy towards sustainability.

5.12 Opportunities for Further Research

The Grounded Theory study was intended to provide an overall picture of how sustainability is being considered during the development of consumer goods. The findings were distilled into 18 propositions summed up in Table 9. All warrant more focused and in-depth follow-up investigations. Thus, several suggestions for further work are made.

Table 9: Propositions Resulting from the Qualitative Research Phase

Proposition #	Content
Proposition 1	Product developers' understanding of product sustainability appears largely unaffected by the academic discourse and instead refers to the type of products they are in charge of.
Proposition 2	Product developers share the vague belief that product sustainability is to gain importance by means of changing consumer behavior and tightened regulations.
Proposition 3	Product developers believe to have little exercisable leverage to enhance product sustainability in their routine development tasks.
Proposition 4	Companies starting to get involved with product sustainability often exclusively focus on separate product lines.
Proposition 5	Sustainability of non-durable consumer goods is often signaled through a stereotyped exterior design.
Proposition 6	Sustainability of durable consumer goods is only seldom signaled through a stereotyped exterior design as this could signal lower functional performance.
Proposition 7	Improving the sustainability performance of extant product concepts often yield in rather incremental changes.
Proposition 8	Developing product service systems to improve sustainability receives little attention in practice despite the high attention in the literature.
Proposition 9	For improving product sustainability, developers focus on the manufacturing phase. Influencing consumer behavior or end-of-life aspects receive less attention.
Proposition 10	Product sustainability is often not codified strictly within the development process.
Proposition 11	The lack of codified sustainability criteria can result in sustainability not being considered in a systematic way during product development.
Proposition 12	Improving the sustainability of existing products often yields trade-offs between sustainability and product performance.
Proposition 13	Product developers are hesitant to use bio-based polymers because of technical hurdles and the volatile public discourse.
Proposition 14	Product developers experience difficulties to evaluate their development decisions from a life-cycle perspective.
Proposition 15	If sustainability is not part of the companies' strategy, product developers experience difficulties in selling their efforts internally and externally.
Proposition 16	Product sustainability is of little importance for most consumers' purchasing decisions.
Proposition 17	Product developers do not know how to catalyze sustainability-based purchasing decisions through product development activities.
Proposition 18	Product developers experience difficulties distinguishing their efforts from competitors' greenwashing activities in a credible way.

Propositions 1, 2, and *3* are suited as a starting point for a large scale quantitative study across different industries and also across different countries. The field of sustainable product development could truly benefit from a conclusive picture of what developers make out of sustainability as well as which crucial drivers and roadblocks exist in different industries. Such a comparative study could also facilitate transferring best practices among remote industry sectors and contribute to an improved understanding of the sustainability challenge.

Propositions 4, 5, and *6* pertain to characteristic approaches consumer goods companies employ on their journey towards more sustainable products. However, developers admit

that they often do not know how consumers perceive these approaches. Therefore, the three propositions should be the focus of more in-depth research from the consumers' point of view. It would be beneficial for companies to learn how consumers consciously or unconsciously evaluate their development efforts. Especially regarding Propositions 5 and 6, different products could be compared to each other to elaborate further on the work of Luchs et al. (2010, 2011, 2012, 2015). They investigate how consumers behave when faced with trade-offs between sustainability and other product aspects like functional performance and aesthetic appearance. However, sustainability is most of the time operationalized as a clearly measurable variable even though sustainability in practice cannot be communicated through an unambiguous number but through the result of all decisions product developers make. Thus, it appears valuable to extend such consumer studies into the sphere of issues product developers are in control of.

Propositions 7, 8, and *9* can be used as a starting point for investigating how more radical sustainability improvements could be incorporated into consumer goods. Specifically, case studies from other industries could provide insights on how truly questioning extant product concepts or exploring the possibilities of product service systems could foster sustainable development.

Propositions 10, 11, and *12* call for further research on clearly codifying sustainability issues in product development processes. Since the current study revealed that some companies are advanced in this respect, it seems valuable to conduct thorough case analyses to expose successful approaches that could be transferred to other companies. From a conceptual point of view, these approaches could then be used for developing situation-specific methods helping companies to overcome the challenge of codifying their take on sustainability.

In case of *Proposition 13*, further research should focus on the behavioral aspects that keep developers from breaking new ground. For example, the Theory of Planned Behavior (Ajzen 1985, 1991) could be employed to explore which major roadblocks exist and how product developers' ambivalence towards renewable raw materials can be overcome.

Proposition 14 calls for further conceptual research to support the decision-making in sustainable product development. Since the participants indicated to encounter problems in assessing even the cursory impact of some development decisions, tools providing an overview of major interdependencies between sustainability metrics and different types of development decisions would be a meaningful support. Such tools could also help to effectively communicate sustainability improvements to internal and external stakeholders (*Proposition 15*).

Finally, *Propositions 16, 17,* and *18* warrant further quantitative research to investigate how consumers' purchasing decisions can be influenced through product development measures without running the risk of being accused of greenwashing.

Apart from elaborating on the current study's propositions, further research could focus on the *typology of company approaches* towards sustainability. It appears promising to investigate the different trajectories companies follow while evolving their approaches, e.g. through growing from a Minimalist to a Test Balloonist. Also, as the consumer goods industry features some specific characteristics, it would be interesting to explore the applicability of the typology for other industries.

The findings and implications of the qualitative study presented in this chapter shed light on the research questions of this dissertation as they deal with the approaches consumer goods companies employ to develop more sustainable products (research question 1) and with the challenges that have to be met when striving for higher product sustainability (research question 2). Also, the managerial implications put forward in Section 5.10.2 yield some recommendations for the practice of developing more sustainable products (research question 3). To derive further practical recommendations that trigger specific problems participants reported to encounter, a subsequent quantitative study was conducted. It is laid out in the following chapter.

6 Investigating How Product Developers Can Influence Consumers Towards Purchasing More Sustainable Products

Several of the findings from the qualitative research phase spark the need for quantitative follow-up studies. Especially the question of how product developers can use their ways and means to influence consumers towards buying more sustainable products warrants further investigation as it is a timely and relevant topic in the light of currently unsustainable consumption practices. Figure 33 provides an overview of the individual studies of the quantitative research phase and, thus, also the structure of this chapter.

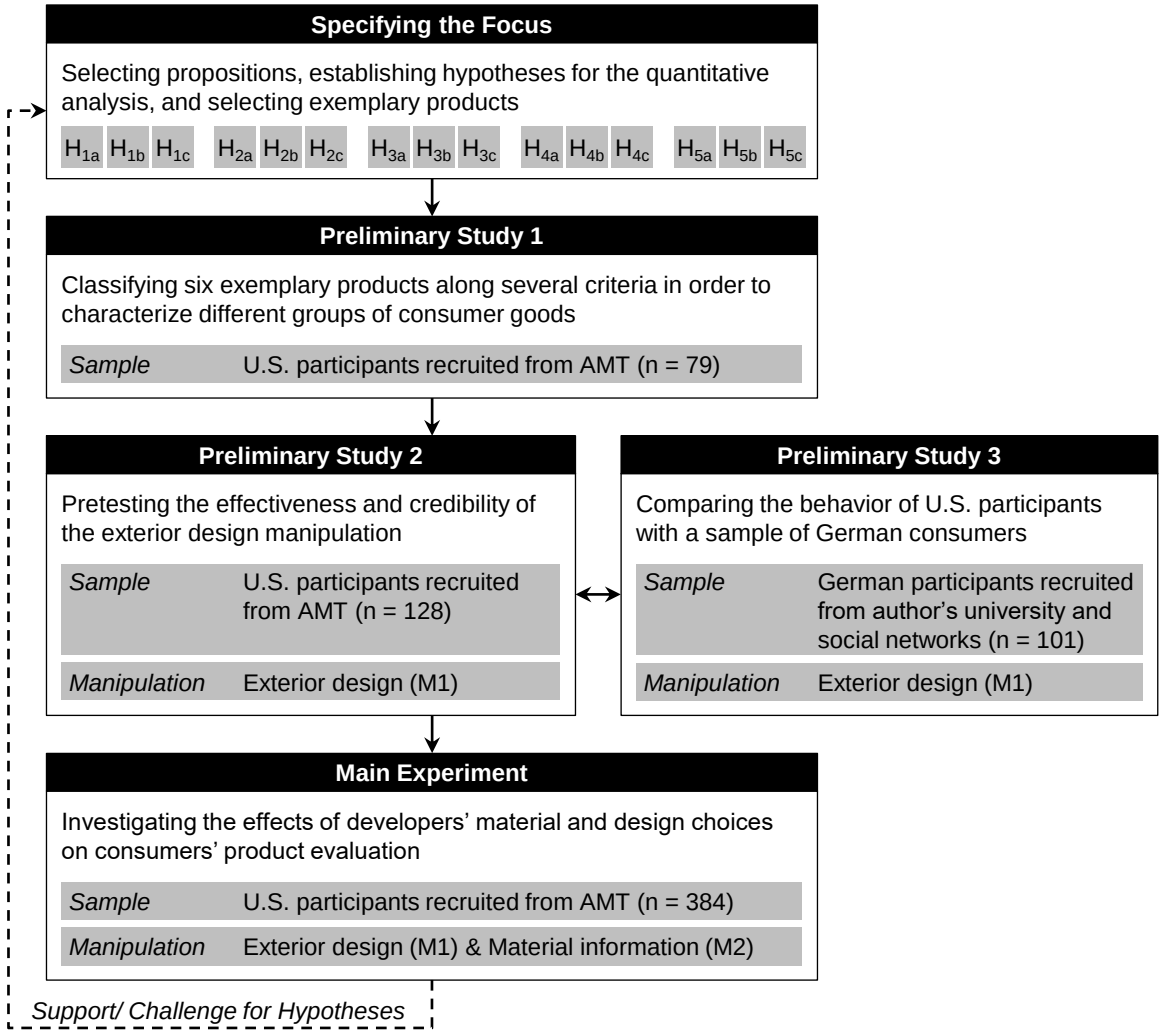

Figure 33: Overview of Individual Studies Conducted for the Quantitative Analysis

First, the focus is specified through selecting suitable propositions from the Grounded Theory study and establishing hypotheses to be tested. Afterward, a first preliminary study is conducted to make six exemplary consumer goods more distinguishable for the further analysis. In the second preliminary study, the first manipulation and the scales used are pretested for each of the six exemplary products with a sample of U.S. consumers. The

third preliminary study investigates if these findings also relate to a sample of German consumers. Finally, the main experiment looks into the effects of different material options and different options for communicating sustainability improvements on consumers' product evaluation. The chapter concludes with detailing the research's implication for theory and management as well as limitations and further research opportunities. Parts of the experimental design and data analysis of the quantitative studies were supported by Dr. Sebastian Brockhaus from Weber State University (Ogden, UT, USA).

6.1 Specifying the Focus of the Quantitative Analysis

Qualitative studies have a much wider focus than most quantitative studies – especially in the case of explorative, theory-constructing research like the Grounded Theory study presented in the previous chapter. Quantitative studies, on the contrary, are usually delimited to a specific, measurable phenomenon that is investigated in more depth. Hence, this implies that not all 18 propositions resulting from the qualitative research phase can be subjected to additional quantitative research efforts as part of the current dissertation. Instead, the focus of the quantitative analysis has to be limited considerably to yield meaningful findings and implications for theory and practice.

For cutting out a relevant piece of the findings for further analysis, the purpose of the quantitative research phase is revisited: recommendations for the practice of developing more sustainable products are to be derived. The qualitative analysis yielded two major areas of challenges product developers face. First, they encounter technical and organizational challenges within the development process, i.e. sustainability improvements might provoke trade-offs, sustainability is hard to assess from a life-cycle perspective, and the consideration of sustainability is only seldom codified properly. Second, they also stumble upon roadblocks on the market side – especially ambivalent consumer behavior and the problem of selling sustainability initiatives in a credible way are deemed challenging. While meaningful conceptual research could tackle the first cluster of challenges, the problems product developers encounter on the market side (i.e. they have only limited insight into how their consumers think about sustainability) warrant subsequent quantitative studies. Extant research also supports this notion. Dangelico & Pujari (2010, p. 483) as well as Driessen et al. (2013, p. 324) find that severe challenges for successfully developing more sustainable products have to be attributed to the market phase. Esty & Simmons (2011, p. 272) report about a study surveying companies' sustainability strategies. Even though most respondents declared sustainability to be a way of generating new sources of revenue, only a minority indicated to have a prime knowledge of their customers' attitude towards sustainability. Also beyond sustainability, product developers and designers often

declare to be lacking helpful information about their customers' needs (Creusen 2011, p. 406). However, to successfully bring more sustainable products to market, companies have to know what and how their potential customers think about sustainability and how that attitude translates into purchasing behavior (Esty & Simmons 2011, p. 274). Thus, research is called to help establish a better understanding of consumers' take on product sustainability (Sheth et al. 2011, p. 34 f.; Luchs & Kumar 2015, p. 17).

To support product developers with their efforts of developing products that are equally more sustainable and successful in the marketplace, a shift of perspective is undertaken for the quantitative analysis. Thus, more sustainable products are not viewed through the eyes of product developers anymore but through the eyes of potential consumers. Observing how consumers react to different measures product development has for improving product sustainability poses an opportunity for providing meaningful recommendations for practice (de Medeiros et al. 2014, p. 83). Such a market-oriented approach also answers the calls for a more cross-functional perception of product development (Krishnan & Ulrich 2001, p. 12 f.) and sustainability issues (Esty & Simmons 2011, p. 192).

6.1.1 Deriving Hypotheses for Theory Validation

The challenges product developers face on the market side are summed up by Proposition 17 put forward in Section 5.9.2: they do not know how to support sustainability-based purchasing decisions through product development activities. However, as has been observed throughout the qualitative study, they still try to bring more sustainable products to the market. For this purpose, product developers from the sample primarily focus their attention on improving sustainability through exchanging material inputs (Proposition 9). Especially traditional fossil fuel-based plastics are often replaced by recycled plastics from post-consumer or industrial waste. Other participants more open to experimentation reported about their efforts to include renewable resources (e.g. in the form of bio-based plastics) in their products. Regardless which kind of more sustainable material is chosen, these products' sustainability features are often communicated through their exterior design (Propositions 5 and 6): earthy colors are especially common with companies that create a new line of more sustainable products separate from the rest of their product portfolio. Also beyond the limited sample of the current analysis, improving product sustainability through more sustainable materials and then communicating these improvements through a stereotyped "green" exterior design is common. The German consumer goods market holds numerous examples of such products from screw anchors (Greenline by fischer) to adhesive tapes (Eco & Clear by tesa), children's books (100% Naturbuch by Beltz & Gelberg), vacuum cleaners (AUFGREEN by AEG), or dishes (Bamboo Fiber by Kesper). All stem from long-standing, established brands that eventually added a line of more

sustainable products to their traditional product portfolio. They are made (at least in part) from recycled or renewable resources and sometimes also hold other sustainability-related features like lower energy consumption or the abstinence of solvents. Also, the exterior of these products has been designed following "green" product stereotypes like muted earthy colors or natural fibers. Often, also the packaging follows the lead and is made from flat cardboard or similar natural-looking materials.

Companies that employ such a strategy are doing so for a good reason: they try to address conscious consumers (Nielsen 2015, p. 8 f.) through their products' form (i.e. color, haptics, and shape). In fact, it is established by research that a product's form can be used to draw attention in a retail environment (Creusen 2015, p. 304). Also, it can influence consumers' perception of a product's functional performance (Krishna & Morrin 2008, p. 816 f.). Especially the color of a product can have decisive influence of consumers' impression of product quality, ease of use, and their aesthetic evaluation (Creusen 2015, p. 308). This influence dominates even after more objective information about the product's features becomes available (Hoegg & Alba 2011, p. 356 f.). Finally, the form of a product can provide consumers with symbolic value as it might help to express their personality (Creusen & Schoormans 2005, p. 66).

While there are several examples of failed efforts to promote products through "green" stereotypes – e.g. Nike's "Considered" product line (Rice 2013) – recent research suggests that companies might actually have some options open to successfully implementing a differentiated design approach in the context of sustainability (Luchs & Kumar 2015, p. 17). However, consumers' interactions with product design in the context of sustainability is still a largely neglected area of research (Luchs & Swan 2011, p. 328). It is therefore called on research to support companies wanting to successfully bring more sustainable products to market (Luchs et al. 2012, p. 915). Thus, the subsequent quantitative analyses look into the effects of employing more sustainable materials and communicating this through a "green" exterior design on consumers' impressions of *product quality* and *product sustainability*, on their *purchase intention* as well as their *willingness to pay*, and on their *aesthetic evaluation*. Post-consumer recycled plastics and bio-based plastics will be used as more sustainable alternatives to fossil fuel-based plastics. Fifteen hypotheses are put forward; they are displayed in Table 10.

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Table 10: Hypotheses for Quantitative Analyses

Issue	Hypotheses	
Product Quality	H_{1a}	Product developers can influence consumers' perception of product quality through a stereotyped "green" exterior design.
	H_{1b}	Product developers can influence consumers' perception of product quality through choosing recycled materials.
	H_{1c}	Product developers can influence consumers' perception of product quality through choosing bio-based materials.
Product Sustainability	H_{2a}	Product developers can influence consumers' perception of product sustainability through a stereotyped "green" exterior design.
	H_{2b}	Product developers can influence consumers' perception of product sustainability through choosing recycled materials.
	H_{2c}	Product developers can influence consumers' perception of product sustainability through choosing bio-based materials.
Purchase Intention	H_{3a}	Product developers can influence consumers' purchase intention through a stereotyped "green" exterior design.
	H_{3b}	Product developers can influence consumers' purchase intention through choosing recycled materials.
	H_{3c}	Product developers can influence consumers' purchase intention through choosing bio-based materials.
Willingness to Pay	H_{4a}	Product developers can influence consumers' willingness to pay through a stereotyped "green" exterior design.
	H_{4b}	Product developers can influence consumers' willingness to pay through choosing recycled materials.
	H_{4c}	Product developers can influence consumers' willingness to pay through choosing bio-based materials.
Aesthetics	H_{5a}	Product developers can influence consumers' aesthetic evaluation through a stereotyped "green" exterior design.
	H_{5b}	Product developers can influence consumers' aesthetic evaluation through choosing recycled materials.
	H_{5c}	Product developers can influence consumers' aesthetic evaluation through choosing bio-based materials.

The fifteen hypotheses put forward are subjected to quantitative inquiry throughout the next sections. However, it is important to note that, in fact, the corresponding null hypotheses will be tested empirically (stating the opposites of the so-called alternative hypotheses displayed in Table 10). If the analysis allows for rejecting a null hypothesis, this provides support for the corresponding alternative hypothesis (Field 2009, p. 27; Blumberg et al. 2011, p. 546 f.). Also, each hypothesis will be tested separately for different exemplary products. However, no interaction effects between the different products will be considered.

6.1.2 Selecting Exemplary Products

As was established in Section 2.3.2, consumer goods can be distinguished into several product categories that comprise products sharing some distinct features. Throughout the qualitative study, it became apparent that the nature of product sustainability and also the kind of extant opportunities for sustainability improvements much depend on these product

specifics. For example, a refrigerator's sustainability level is to a large degree determined by the way consumers use it. Therefore, product developers can bring high leverage to bear on sustainability through improving the energy efficiency or the life expectancy of a refrigerator. The sustainability level of baking paper, on the other hand, is rather depending on the process technology used for manufacturing and the way it is disposed of after its one-time use. Thus, product developers should focus their attention on the manufacturing phase and recyclability if they want to foster product sustainability.

Also from a consumers' perspective, the perception and appreciation of improved sustainability depend on the product category (Luchs et al. 2010, p. 28). For the purpose of deriving recommendations for practice, neither ignoring such differences nor focusing on one specific product would be a constructive approach for the current dissertation. Therefore, exemplary products were selected as representatives of different groups of consumer goods. Requirements were set up that had to be fulfilled by the product sample: (1) all products should contain parts made from plastics to be able to compare material issues, (2) durable and non-durable goods should be included, (3) the products should cover a wide variety of consumer goods categories, and (4) all products should be widely-used and easy to understand. For selecting suitable products, a workshop with five doctoral students from TUHH's[26] Institute of Business Logistics and General Management was held. The final product sample consists of six products: headphones, stapler, picnic dishes, garbage bags, hair blower, and toothbrush (see Figure 34).

Figure 34: Pictures of the Exemplary Products

[26] TUHH = Hamburg University of Technology.

For each of the six products, representative pictures were acquired through a stock photo agency.[27] Care was taken to avoid any product pictures that contain brand names or remind the viewer of a specific brand. Again, a workshop was held to select the most suitable picture for each product. Figure 34 displays the final selection. It is used to illustrate the products throughout the preliminary studies and the main experiment.

6.1.3 Designing the Manipulations

Two aspects will be manipulated throughout the following studies: the material the products are made of as well as their exterior design. The *material information manipulation* will be implemented through a written note as this is the only practical way to disclose any explicit information about a product's material in an online survey. Thus, the product pictures presented in Figure 34 will be supplemented by a reference to the product's main material. Three treatments are defined: "Made from fossil fuel-based plastics", "Made from post-consumer recycled plastics", and "Made from bio-based plastics". Granted, it heavily depends on the specific material, on its processing, and on the weighting of different environmental and social impacts how sustainable both material alternatives to fossil fuel-based plastics are (Hallstedt 2008, p. 13 f.). However, both alternatives are known to consumers, generally understood to be more sustainable, and also are made use of for actual more sustainable products.

The *exterior design manipulation* is implemented through producing stereotyped "green" versions of the six exemplary products. Using the raster graphics editor Adobe Photoshop, a professional picture editor recolored the products in earthy tones and applied textures that can be found on actual products made from bioplastics. Care was taken to ensure the products look realistic. For this purpose, different versions of the edited photos were evaluated by a group of graduate and doctoral students. The final versions of the edited photos are displayed in Figure 35.

[27] See Appendix II for sources of the product pictures.

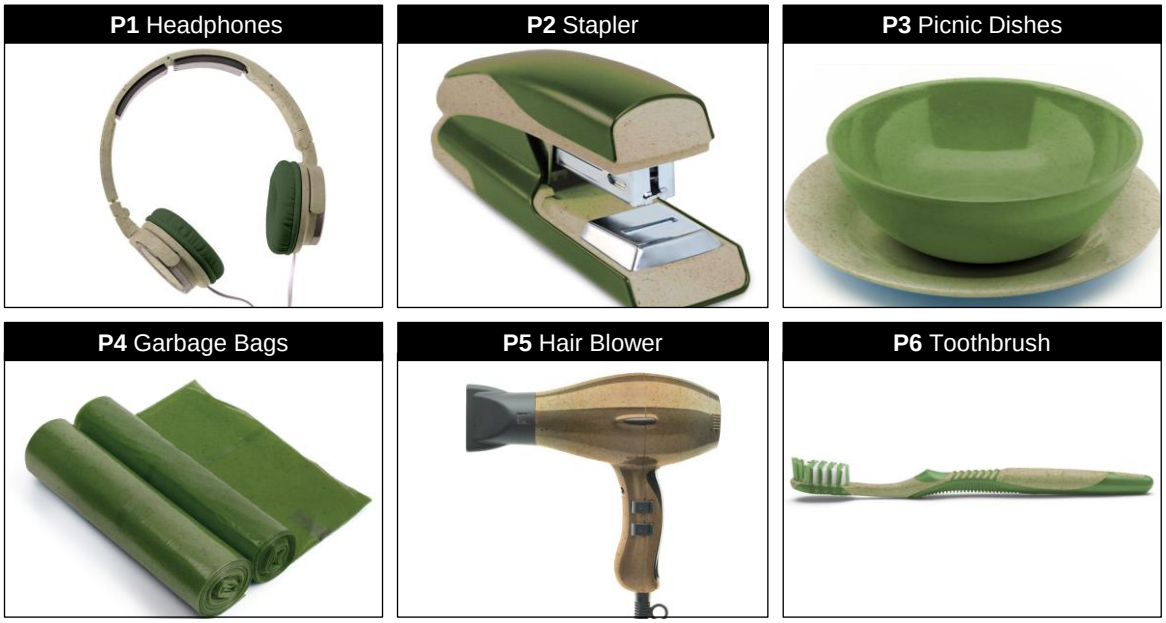


Figure 35: Edited "Green" Versions of the Exemplary Products

6.2 Preliminary Study 1: Classifying the Exemplary Products

As has already been addressed in Section 2.3.1, consumer goods are seldom clearly classifiable as either being durable or non-durable goods. Thus, the different criteria introduced (e.g. involvement or product value) cannot be understood as binary variables but rather as continuums. To be able to classify the six exemplary products along these continuums, a first preliminary study was conducted. Its findings are intended to help transfer the main experiment's findings onto other products that are not included in the sample of exemplary products. In the next sections, the setup, demographics, data preparation, and findings of the first preliminary study are reported. Since this study is not about testing the effect of different treatments, no manipulation is used.

6.2.1 Setup

The study was implemented as a web-based questionnaire using the software tool Limesurvey. First, participants were provided with the original pictures of the six exemplary products (see Figure 34) to establish a common understanding. Second, participants were asked to indicate for each product how much they agree with a number of statements. For measuring their agreement, 9 point Likert scales were used. The first group of statements covered the seven criteria for classifying consumer goods as either durable or non-durable goods (see Section 2.3.1). The statements were phrased in a way that low agreement resembles the characteristics of non-durable consumer goods. They were supplemented by statements covering the impact of friends' recommendations and fashion trends on purchase decisions. Also, a statement about the potential to express one's personality through the product was included. Finally, two statements covered the perceived effect of

one's product choices regarding environmental and social sustainability. In addition to these statements, participants were asked to indicate which of the six products they possess. Also, they were asked which price they typically expect to pay for the products. Concluding, demographic characteristics were collected, and the participants were invited to comment on the survey. An excerpt from the first preliminary study survey is displayed in Figure 36.

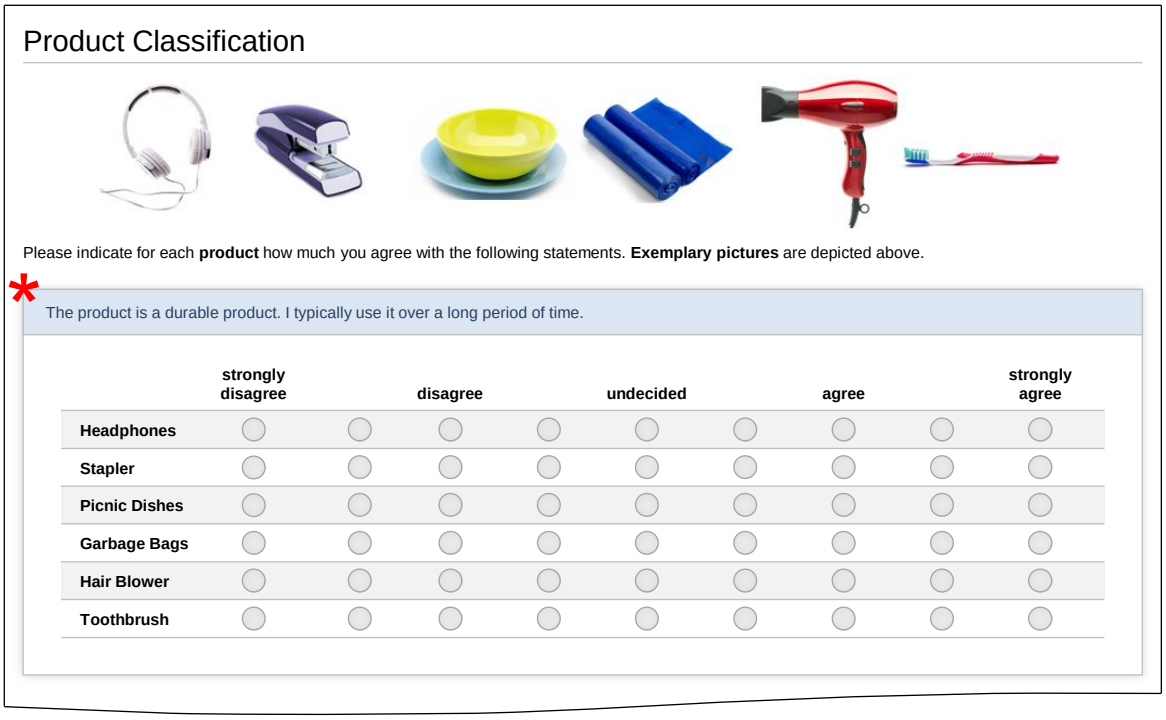


Figure 36: Excerpt from Preliminary Study 1

A pretest was conducted with a small AMT sample (n = 10) and a group of doctoral students from TUHH's Institute of Business Logistics and General Management (n = 5) to test the clarity of the instructions and the suitability of the scales. As a result, several statements were rendered more precisely. The final version of the questionnaire can be found in Appendix VII. Supplementary, Appendix VI contains a list of scales used for all four quantitative studies.

6.2.2 Demographics

A sample of 79 participants providing valid responses was recruited from AMT (see Figure 37).[28] Participants had to qualify for taking the survey through possessing an overall HIT-approval rate beyond 95 percent and already having completed more than 100 HITs. Also, it was mandatory for the participants to be U.S. residents. This was controlled for through the participants' IP-addresses. All participants were compensated monetarily for taking the

[28] The necessary sample size was estimated a priori using the software G*Power (Faul et al. 2009, p. 1149).

survey: the HIT was rewarded with \$0.50 per worker yielding an average hourly wage of \$5.42 ($M_{Duration}$ = 5.54 min, $SD_{Duration}$ = 2.18 min). The data was collected in July 2015.

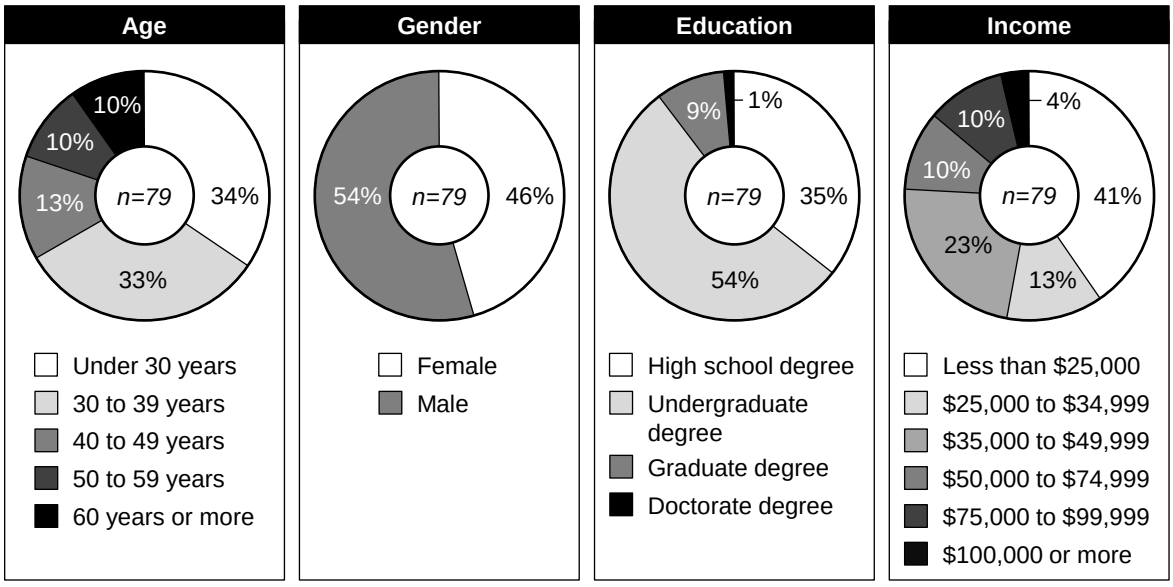


Figure 37: Demographics of the Sample from Preliminary Study 1

The age of the participants spans from 19 years to 83 years (M_{Age} = 37.1 years, SD_{Age} = 13.6 years). 46 percent of the participants are female. With respect to their highest educational achievement, most participants indicate to have completed a high school degree (35 percent) or an undergraduate degree (54 percent). Only a tenth of the sample either possesses a graduate or doctorate degree. This distribution is reflected in the participants' personal income as the major share (41 percent) earns less than \$25,000 per year. Only 25 percent of the participants indicate to have an annual income of more than \$50,000. Overall, the demographics of this sample are comparable to demographics of studies previously conducted on AMT (Mason & Suri 2012, p. 4 f.).

6.2.3 Data Preparation

Before the data was analyzed using the software package "IBM SPSS Statistics 22" to learn about each product's characteristic properties, several steps to clean and transform the data as suggested by Hair et al. (2009, pp. 33–89) were undertaken. This examination of the data is critical for performing sound statistical analyses as meeting the requirements of statistical tests and thus avoiding systematic mistakes can be ensured. Also, especially for anonymous internet surveys, thoroughly examining the data is advised as an appropriate way to identify careless responses (Meade & Craig 2012, p. 437 f.). Thus, before analysis, the data was examined with respect to missing values, outliers, false answers, as well as normality and homoscedasticity of the dependent variables.

Following the guidelines established by Hair et al. (2009, pp. 33–89), the data was first examined regarding *missing values*. This is necessary since especially nonrandom missing data could bias any statistical result (Hair et al. 2009, p. 42). However, since it has been mandatory to answer every question for completing the survey, the data contained no missing values. As the second step, the dependent variables were examined for *outliers* and *false answers*. None of the Likert-scaled variables featured unusually high or low values that might cause problems for the subsequent analysis. The values of the numerical variables (i.e. the prices participants normally pay for the products) were examined for outliers through box-plots. In this course, seven unusually high values for the price of manual toothbrushes were unveiled. Through inspecting the corresponding comment fields at the end of the questionnaire, it was found that seven participants indicated to use electric toothbrushes rather than manual ones. Since these participants pointed out to have answered all questions with an electric toothbrush in mind, all corresponding values were excluded from the analysis. Furthermore, some distinct outliers were found for other price variables. Only two participants provided all these values, and most of them were simply implausible (e.g. $80 for a roll of garbage bags). A close examination of all other answers provided by these participants revealed clear patterns. Also, both participants were unusually fast in answering all questions. It has to be concluded that they just clicked through the questionnaire without even reading the questions and answer options. Thus, both data sets were excluded from the analysis.

The data was further analyzed for normality and homoscedasticity of the variables as these are important assumptions for parametric data analysis (Field 2009, p. 132 f.). *Normality* checks were performed through the Kolmogorov-Smirnov-Test and the Shapiro-Wilk-Test as suggested by Hair et al. (2009, p. 73) and Sarstedt & Mooi (2014a, p. 149). The results of both computational tests indicated that the distributions of the values are significantly differing from the normal distribution. However, it is acknowledged in the literature that the computational tests might be too strict under specific circumstances (Field 2009, p. 144). Moreover, violations of normality should be assessed through multiple approaches (Hair et al. 2009, p. 74). Accordingly, the distributions were also examined graphically through normal probability plots and through their descriptive measures kurtosis (referring to the distribution's peakedness) and skewness (referring to the distribution's shift to the left or the right). According to Schumacker & Lomax (2010, p. 62), distributions are considered close enough to normality if the absolute values for kurtosis and skewness are ≤ 1.5 and ≤ 1 respectively. Since the distributions of all variables met these criteria and more importantly the normal probability plots indicated close approximations of the normal distribution, transforming most of the variables was not deemed necessary. Only the variable for the

price participants usually pay for the products differed significantly from the normal distribution and was transformed to allow for parametric data analysis (Sarstedt & Mooi 2014a, p. 109). Next, Levene's test for equality of variances was performed to verify the assumption of *homoscedasticity* (Hair et al. 2009, p. 75). The results demonstrate that all but two variables featured unequal variances and thus cannot be considered homoscedastic. All efforts to transform the data turned out to be unsuccessful. However, heteroscedastic data was accounted for during data analysis (through a one-way ANOVA) by employing the adjusted F-statistic from the Welch-test computed by SPSS (Sarstedt & Mooi 2014a, p. 168). Thus, the data was considered appropriate for data analysis.

6.2.4 Findings and Discussion

An overview of the first preliminary study's findings is provided in Figure 38 through displaying the participants' mean agreement to each statement and for each product. To investigate whether the mean differences between the six products are statistically significant, a one-way ANOVA was calculated according to the guidelines by Burns & Burns (2008, pp. 287–296). It was found that for all independent variables the means differ significantly from each other. The results of the ANOVA along with the mean values of each variable and their standard deviations can be found in Appendix VIII. To further investigate which of the pairs of values differ significantly from each other (i.e. which pairs of products feature a significant mean difference), a post hoc test has to be performed. Since most variables are heteroscedastic, the Games-Howell test was chosen (Sarstedt & Mooi 2014a, p. 174). The findings of the test are displayed in Appendix IX.

With respect to the seven statements about the consumer goods classification criteria introduced in Section 2.3.1 (1A–1G), four products (i.e. garbage bags, picnic dishes, toothbrush, and stapler) more or less correspond to the non-durable consumer good profile. Out of these four products, the garbage bags are the closest representation of a clear non-durable consumer good. Both electronics products on the other hand (i.e. headphones and hair blower) are rather correlating with the durable consumer goods profile with the headphones closest to being a clear durable consumer good. However, some distinct differences underline that a definite classification is not possible. Regarding *durability*, the stapler is considered being used for the longest period (M_{P2} = 7.76). Surprisingly, the participants evaluated headphones as being only somewhat more durable than a toothbrush (M_{P1} = 6.30 vs. M_{P6} = 5.43). Regarding *purchasing frequency*, the stapler (M_{P2} = 7.90) and the picnic dishes (M_{P3} = 6.63) are close to the durable consumer goods profile. The garbage bags and the toothbrush are bought with higher frequencies. For *involvement, information search, alternative evaluation*, and *purchasing advice* the profiles of the garbage bags, the picnic dishes, and the stapler are similar to each other. The

participants indicate to buy these products without thinking much about their choices. In comparison, the toothbrush is considered a little bit “less non-durable”. On the other side of the spectrum, the headphones are clearly “more durable” than the hair blower as participants more consciously evaluate alternatives (M_{P1} = 7.34 vs. M_{P5} = 5.51) and use purchasing advice more frequently (M_{P1} = 6.99 vs. M_{P5} = 5.15).

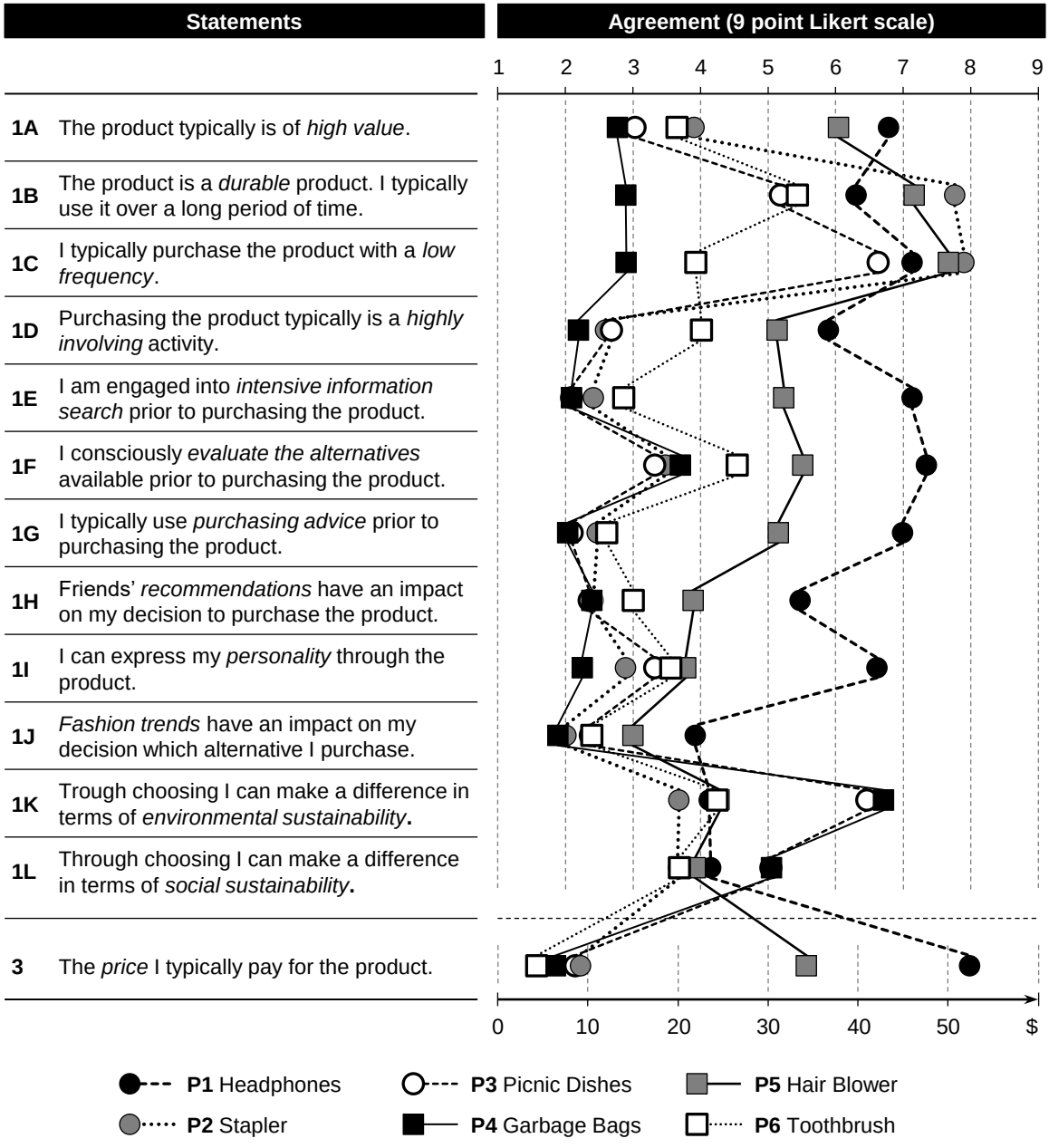


Figure 38: Findings of Preliminary Study 1

Looking at the additional statements, the headphones are considered the only product which purchase is impacted by friends’ *recommendations* (M_{P1} = 5.47). Also, the headphones are by far the only product that is considered helping to express the *personality* of the owner (M_{P1} = 6.61). Surprisingly, participants claim that *fashion trends* have almost no impact on their purchasing decisions of any of the products. When it comes to

environmental sustainability, the garbage bags (M_{P4} = 6.71) and the picnic dishes (M_{P3} = 6.46) are considered allowing for a noteworthy effect through choosing between product alternatives while all other products feature comparably low values (e.g. headphones M_{P1} = 4.13). This also holds true for *social sustainability* even though the effect of the garbage bags and the picnic dishes is considered smaller. Nevertheless, participants estimate that the garbage bags and the picnic dishes offer higher potential for improving social sustainability than all other products. Finally, the distribution of the *prices* participants stated to be paying for the products positively correlates with the first statement's evaluation of the products' value.

Overall, the findings of the first preliminary study underline that consumer goods should not be classified as being either durable or non-durable. In fact, most products feature properties of both consumer goods classes. Thus, the individual product profiles resulting from this study clearly differ from each other. Of particular importance for the main experiments is the impact on sustainability participants think their choices can make. For environmental sustainability, participants indicate that choosing between different alternatives of the relatively simple products garbage bags and picnic dishes has the largest effect. On the other hand, choosing between product alternatives of more sophisticated products like stapler, hair blowers, or even headphones does not pose an opportunity for impacting environmental sustainability to the participants. The same holds true for social sustainability, even though the difference between the groups of products is smaller. This finding is surprising as the garbage bags and the picnic dishes have in common that they are simple products of low value that trigger low involvement and that are bought unaffected of purchasing advice, recommendations, or fashion trends. Moreover, participants state to buy these products without an actual evaluation of product alternatives. Taken together, these products seem to be of little interest for the participants. However, they also state that the environment could benefit from their choices if they just were to evaluate existing product alternatives. Furthermore, participants do not believe being able to make a difference through products they do evaluate consciously before purchasing (i.e. headphones and hair blower).

Summing up, the first preliminary study illustrates that the garbage bags and the headphones are the opposite ends of the consumer goods spectrum under investigation. However, limiting the focus of the subsequent studies to these two products is not deemed appropriate. Especially the sustainability issues expose differences among all six exemplary products. Thus, these differences will be used to set the findings of the subsequent studies into perspective. Overall, the following key findings are put forward:

Key Findings from Preliminary Study 1

- It is supported that the six products should not be handled as being either non-durable or durable consumer goods. They feature a variety of distinct differences that have to be taken into account for the subsequent studies.
- Products that are considered to offer notable opportunities for improving sustainability are simple, inexpensive, and the least interesting for the participants.
- Consumers do not consider more complex products that trigger high involvement and demand a thorough evaluation of alternatives to offer noteworthy potential for sustainability improvement.

6.3 Preliminary Study 2: Pilot-testing the Exterior Design Manipulation

To pilot-test the effectiveness of the exterior design manipulation, the setup of the experimental study, and the suitability of the six exemplary products, a second preliminary study was designed and conducted. In the next sections, setup, demographics, data preparation, and the findings are reported.

6.3.1 Setup

For carrying out the second preliminary study, a dynamic web-based questionnaire was implemented using the software tool Limesurvey. The final structure of the study is depicted in Figure 39. After providing the participants with a short vignette containing the introduction and instructions, the survey started with displaying the six products for evaluation in random order. Either the original product design or the “green” product design was shown to the participants. Apart from the pictures, no further information was provided. Participants were asked to answer 24 questions for each product. These questions were kept constant over the conditions and covered product quality, environmental and social sustainability, purchase intention, willingness to pay, and aesthetics.

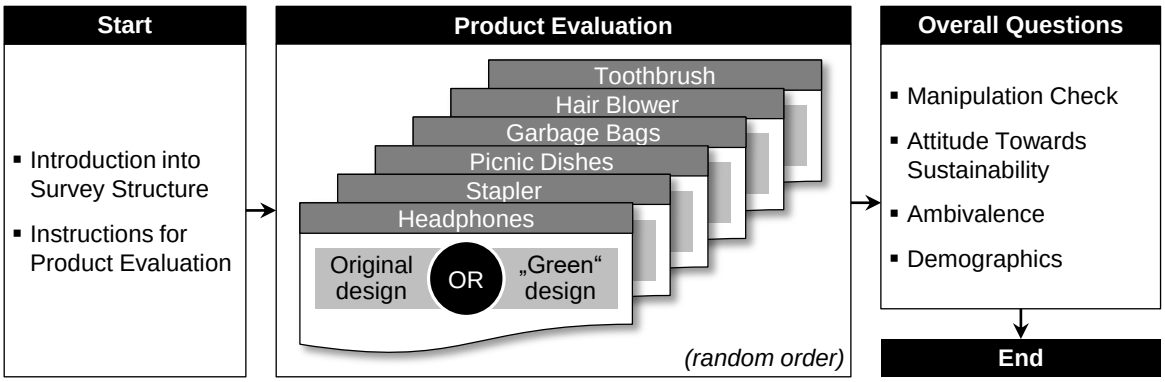


Figure 39: Structure of Preliminary Study 2

Whenever possible, established scales were used to measure the dependent variables. To quantify the perceived *product quality*, a scale developed by Dodds et al. (1991, p. 318)

was adapted. It is composed of four 7 point Likert items covering expectations about the product's reliability and workmanship. Sustainability was split up to differentiate environmental from social issues. Since prior research by Luchs & Miller (2015, p. 258 f.) has demonstrated that consumers link product sustainability issues to different life-cycle phases, the perceived *environmental sustainability* of the product was measured through three 7 point Likert items each covering one stage of the product life-cycle. The perceived *social sustainability* was measured respectively. For quantifying *purchase intention*, a scale composed of four 7 point Likert items put forward by Baker & Churchill (1977, p. 544) was adapted. *Willingness to pay* was measured by asking how much participants would pay for the product providing that they would need one. Finally, to measure the *aesthetics* of the products, a scale developed by Bell et al. (1991, p. 256) for measuring visual attractiveness was used. It contains six 7 point semantic differentials. An excerpt from the product evaluation part of the questionnaire is displayed in Figure 40.

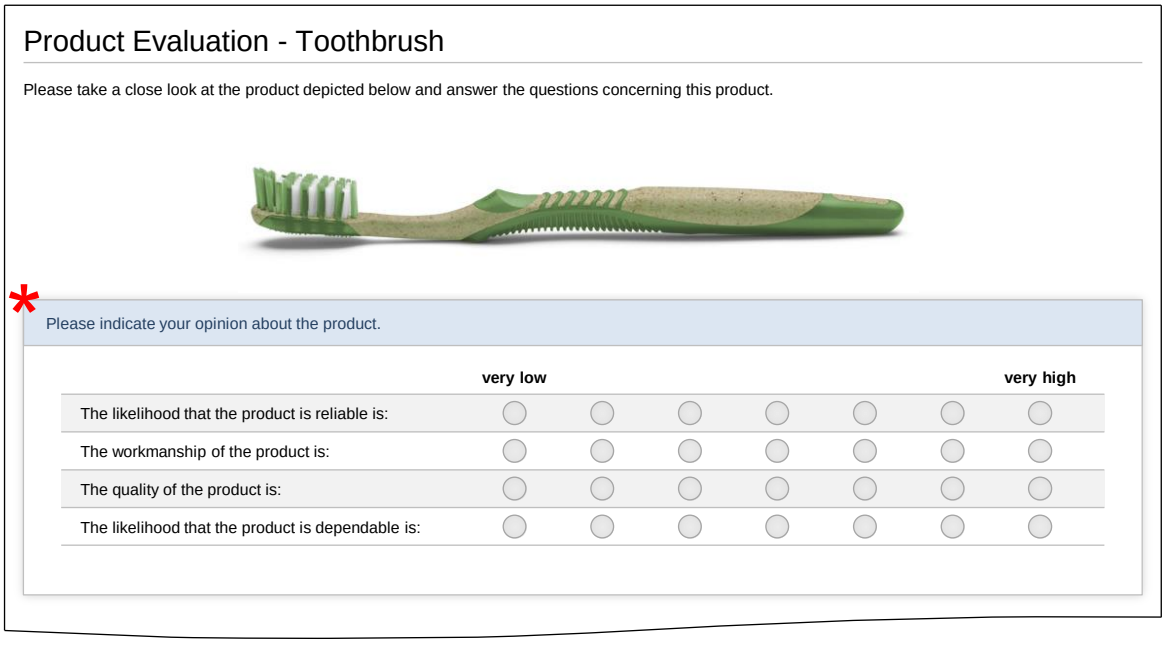


Figure 40: Excerpt from Preliminary Study 2

Subsequently, the second preliminary study contained some questions concerning all six products. First, as a manipulation check, participants were asked to indicate the main color of each product they just evaluated. Furthermore, the participants' individual attitude towards sustainable consumption was surveyed through a green consumption scale developed by Haws et al. (2014, p. 339) and items taken from a scale measuring sustainable consumption (Balderjahn et al. 2013, p. 189). Finally, a scale put forward by Priester & Petty (1996, p. 437) and refined by Nowlis et al. (2010, p. 324) was used to explore how conflicted the participants felt in evaluating the six products. Following the product-related questions, the demographics of the participants were inquired.

Before executing the study, a pretest was carried out using a sample of AMT workers (n = 20) and doctoral students from TUHH's Institute of Business Logistics and General Management (n = 5). The pretest was intended to verify the clarity of instructions, the logic of the procedures, and the suitability of the scales. As a result, several wordings were specified, and small changes to the survey structure were implemented. The questionnaire of the second preliminary study is stated in Appendix X.

6.3.2 Demographics

A sample of 128 participants providing valid responses was recruited through AMT (see Figure 41).[29] Again, participants had to qualify for taking the survey through being U.S. residents, possessing a minimum HIT-approval rate of 95 percent, and having completed more than 100 HITs. The participants were compensated monetarily for taking the survey: the HIT was rewarded with $1.50 per worker yielding an average hourly wage of $8.78 ($M_{Duration}$ = 10.25 min, $SD_{Duration}$ = 6.35 min). The data was collected in July 2015.

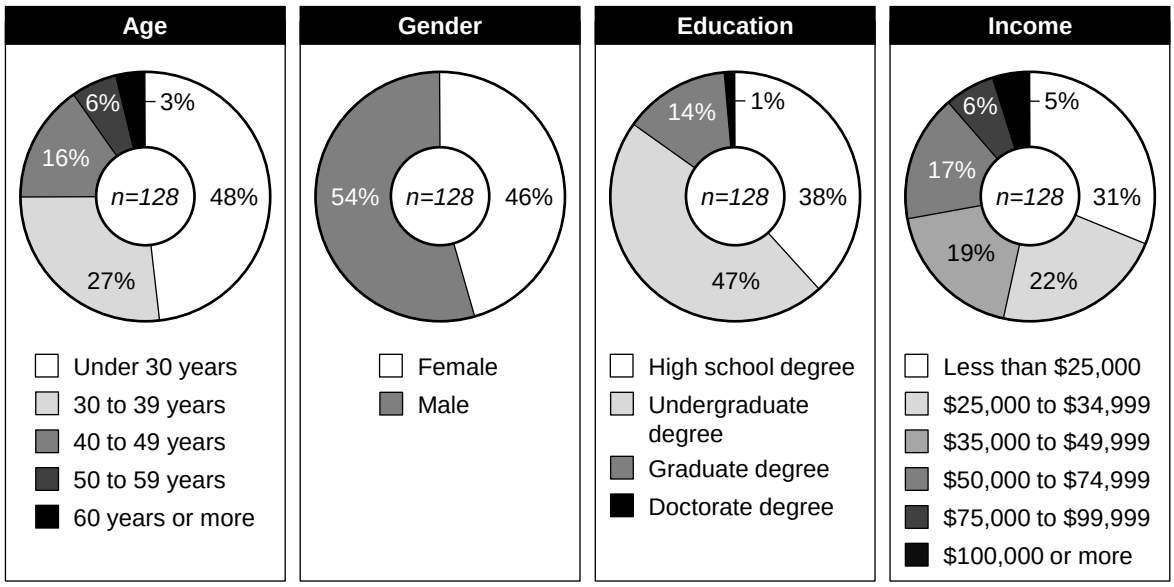


Figure 41: Demographics of the Sample from Preliminary Study 2

A look at the demographics reveals a sample similar to the sample of the first preliminary study. The age of the participants spans from 18 to 66 years with an average age of M_{Age} = 33.2 years (SD_{Age} = 10.4 years). 46 percent of the participants are female. A high school (38 percent) or undergraduate degree (47 percent) is the highest educational achievements of the sample's majority. Only 15 percent of the participants either possess a graduate or a doctorate degree. With respect to their income, more than half of the sample indicates to earn less than $35,000 per year. About a fourth of the participants earns more

[29] The necessary sample size was estimated a priori using the software G*Power (Faul et al. 2009, p. 1149).

than $50,000 annually. Again, the demographics are comparable to previous studies conducted on AMT.

6.3.3 Data Preparation

The data was cleaned, transformed, and inspected for careless responses following the principles introduced in Section 6.2.3. Accordingly, before analysis, the data was examined with respect to missing values, outliers, false answers, as well as normality and homoscedasticity of the dependent variables. Since answering all questions of the survey was mandatory, no *missing values* were found. For detecting *outliers* and *false answers* through box-plots, two data sets were found to contain several values that made no sense. A closer inspection of all answers provided by these participants revealed clear patterns. Also, these participants were among the fastest in the sample. It was concluded that they just clicked through the questionnaire without actually reading the questions. Both data sets were excluded from the analysis. Subsequently, the results of the manipulation check were inspected to filter out any more careless responses. It was found that participants only sporadically did not remember the correct colors. Thus, no measures had to be taken. As the next step, the values for the compound scales were calculated. Also, Cronbach's α was calculated for all scales (1951).[30] Since the lowest value was $\alpha = .91$, all multiple-item measures used feature high internal consistency. The data was then analyzed for *normality* and *homoscedasticity* of the variables. Normality checks were performed through graphical and analytical tests. Variables failing to fulfill the requirement of normality were transformed (most of them were price variables). Also, some variables featured unequal variances, thus being heteroscedastic. As all efforts to transform these variables failed, this was accounted for through the values of the t-statistics computed by SPSS for heteroscedastic data.

6.3.4 Findings and Discussion

To analyze the study's data, mean values and t-tests were calculated following the guidelines established by Sarstedt & Mooi (2014a, pp. 160–163). Also, effect sizes were calculated using Cohen's effect size index *d* (1988, p. 20 f.).[31] The results of the statistical analyses are displayed in Appendix XI. Figure 42 displays a graphical overview of the findings through illustrating each product's mean values and significance levels. Since the purpose of this study is limited to pilot-testing the exterior design manipulation and testing

[30] Cronbach's α (1951) is an estimation of the internal consistency of a multiple-item measure. Even though there is no universal level of acceptable values (Schmitt 1996, p. 353), $\alpha > .8$ is commonly perceived signaling good and $\alpha > .9$ signaling excellent internal consistency.

[31] Cohen's *d* (1988, p. 20 f.) is an estimation of the size of an effect. It enables to evaluate the relevance of a mean difference beyond the significance level. Cohen considers effect sizes of $.2 \leq d < .5$ being small, $.5 \leq d < .8$ being medium-sized and $d \geq .8$ being large (1988, p. 40). However, these are mere guidelines that should not be applied out of context (Grissom & Kim 2012, p. 128). Hattie (2009, p. 17), for example, concluded from an extensive meta analysis of methods for improving learning in schools that an effect size should be larger than .4 to produce real-world differences.

the credibility of the edited product pictures, no detailed interpretation of the findings will be presented. This will be made up for in the main experiment when the effect of both manipulations will be examined and interpreted in detail.

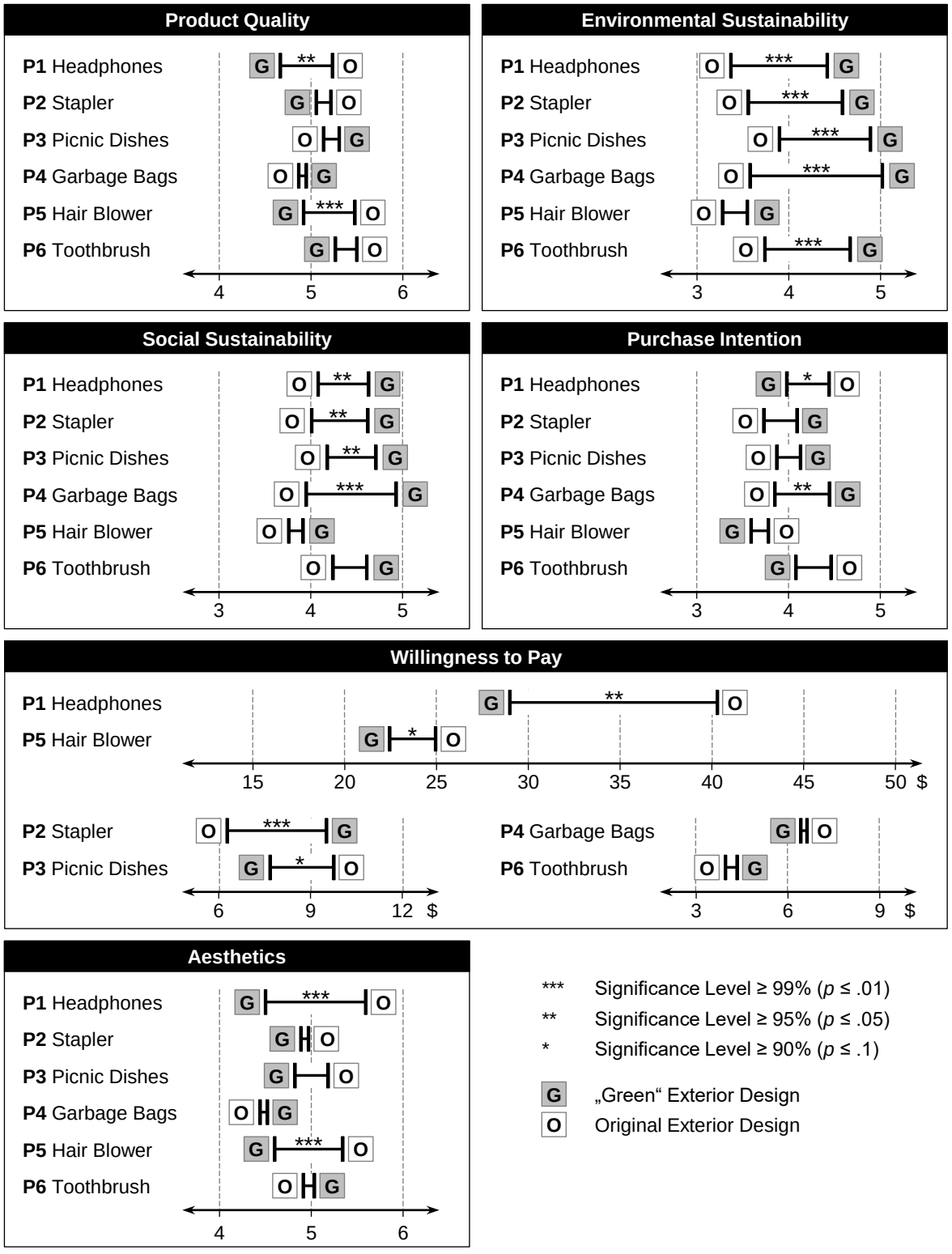


Figure 42: Main Effects of the Second Preliminary Study's Exterior Design Manipulation

Perhaps the most prominent finding is the participants' perception of superior environmental sustainability for the "green" exterior design of nearly all products. Thus, the visual manipulation successfully influences how participants think of the product. This is also illustrated by some participants' comments at the end of the survey: "*Using earthen tones as the color for the products really illustrates that they are environmentally friendly.*" Another participant stated: "*Made me really want to know if the products were environmentally friendly in particular.*" As can be seen from the visual presentation of the findings in Figure 42, the manipulation also influences the participants' perception of product quality and aesthetics as well as their reported purchase intention and willingness to pay. However, large differences between the different products can be observed.

As next step of the analysis, ANCOVAs[32] (Field 2009, pp. 396–408) were calculated to assess if the participants' attitude towards sustainable consumption or their demographic details explain their evaluation of the products' environmental and social sustainability as this might confound the findings of the study. It was found that none of the covariates has a significant influence on the dependent variable. Thus, participants indicating to care much about sustainability when purchasing consumer goods evaluated the products the same way than participants not interested in sustainability at all. Thus, the effectiveness of the manipulation is not impacted by the participants' personal attitude towards sustainability or their self-reported consumption behavior.

Finally, the credibility of the edited photos was assessed. This was done through inspecting the comments at the end of the survey. Apparently, most participants were thinking that they were evaluating actual products within a market research study, like this participant stated: "*Some of the products were very novel looking and interesting to see!*" Some participants even wanted to buy the products, like the following participant indicated: "*I think these products are amazing and would like to see more products like this if possible. And also, if possible, I would like to be emailed when these products become available for purchase.*" However, especially the hair blower produced mixed reactions. Some participants found the "green" version to be not credible: "*The hair-dryer seems not believable. Is it an actual product?*" This notion is also supported by the findings of the manipulation check. Particularly for the "green" version of the hair blower but also of the toothbrush, participants were often not able to indicate which color it had. Their answers ranged from "orange" to "chrome" or "gray". Thus, the manipulation does not seem to be particularly effective for these two products. Summing up, the following key findings are put forward:

[32] ANCOVA = Analysis of Covariance.

Key Findings of Preliminary Study 2

- The exterior design manipulation is robust enough to influence the participants' perception of product features and their purchase intention. The "green" versions are perceived being more sustainable. However, the evaluation of other product features depends on the product type.
- The participants' evaluation of superior sustainability for the "green" versions is not a result of their general attitude towards sustainable consumption. The exterior design manipulation is not significantly affected by confounding variables.
- The edited versions of the product pictures, in general, seemed believable to the participants. Only the hair blower and the toothbrush raised some doubts.

6.4 Preliminary Study 3: Comparing the Behavior of U.S. and German Consumers

The Grounded Theory study presented in Section 4.3.4 used expert interviews as primary source of data. All experts work for companies located in the DACH region. Whenever they shared their experiences about selling sustainability to consumers, they did that with consumers from these countries in mind. However, the first two preliminary studies were conducted using a sample of AMT workers residing in the U.S. While research points out that – if viewed from a global perspective – German and U.S. consumers behave in a similar way in the context of sustainability (Hayward et al. 2014, pp. 9–14), the second preliminary study was replicated using a sample of German consumers to find out if there are distinct differences between both samples.

6.4.1 Setup

The setup developed for the second preliminary study was kept constant. Only the text elements were translated to German.

6.4.2 Demographics

Since German workers are rare on AMT, a sample was composed of current and former graduate and doctoral students of TUHH and through snowballing on Facebook. Overall, 101 participants were recruited in July and August 2015. Other than the participants from the previous study, they were not compensated monetarily for taking the survey. The demographics of the sample are summed up in Figure 43. In summary, the participants are a little younger (M_{Age} = 31.9 years, SD_{Age} = 9.4 years) and better educated (60 percent possess at least a graduate degree) than the AMT workers from the first two preliminary studies. While different purchasing powers and fluctuating exchange rates impede the comparison of the participants' income, it is fair to say that the distribution of income classes throughout the German sample is comparable to the AMT sample. Taken together, the

differences between the samples are limited, however, should be observed carefully when comparing the results.

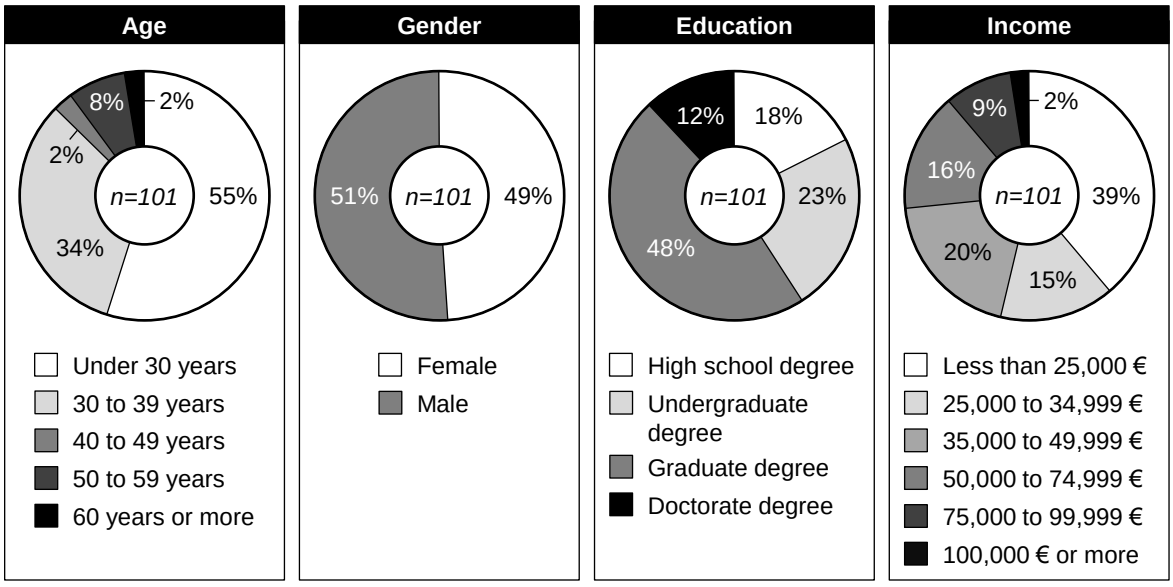


Figure 43: Demographics of the Sample from Preliminary Study 3

6.4.3 Data Preparation

The data was cleaned, transformed, and inspected for careless responses adhering to the procedure introduced in Section 6.2.3. No values were found to be missing, and no data sets had to be eliminated. Only one value for the willingness to pay was removed since its amount made no sense and probably resulted from a typo. Also, the compounds of the multi-item measures as well as the corresponding Cronbach's α were calculated. Since the lowest value was α = .779, internal consistency of all measures is assured. Several variables (mostly price variables) had to be transformed to achieve normality. Mean differences, t-tests, and Cohen's *d* were calculated for analyzing the influence of the manipulation. The complete findings of the statistical analysis can be found in Appendix XII.

6.4.4 Findings and Discussion

The findings of both studies were then compared to each other. In summary, they are similar since almost all significant effects from preliminary study 2 are also found to be existing and significant in preliminary study 3. Moreover, most of the effects and mean differences are of similar size in both studies. This especially holds true for the effects of the manipulation on the perceived environmental and social sustainability. However, some distinct differences between the samples have to be noted. In the case of the garbage bags, no effect of the manipulation on the purchase decision can be found in the German sample. For the hair blower, there is a significant effect on the purchase decision as German participants indicate to prefer the original design over its "green" counterpart. This effect

does not exist for the U.S. sample and is probably the result of the significantly better aesthetic evaluation of the original design. Finally, for the toothbrush the manipulation's effect on the perceived social sustainability is larger and moreover also significant for the German sample. Figure 44 provides a visual comparison of the findings from the two preliminary studies. The size of the differences between both design treatments is indicated by the size of the bubbles, and the bubbles' color indicates the direction of these differences. Thus, the bubbles contain the exact information that is displayed through the spread between the treatments in Figure 42. For each product, the findings of both studies are presented side by side. It can easily be seen that the results from both preliminary studies are similar.

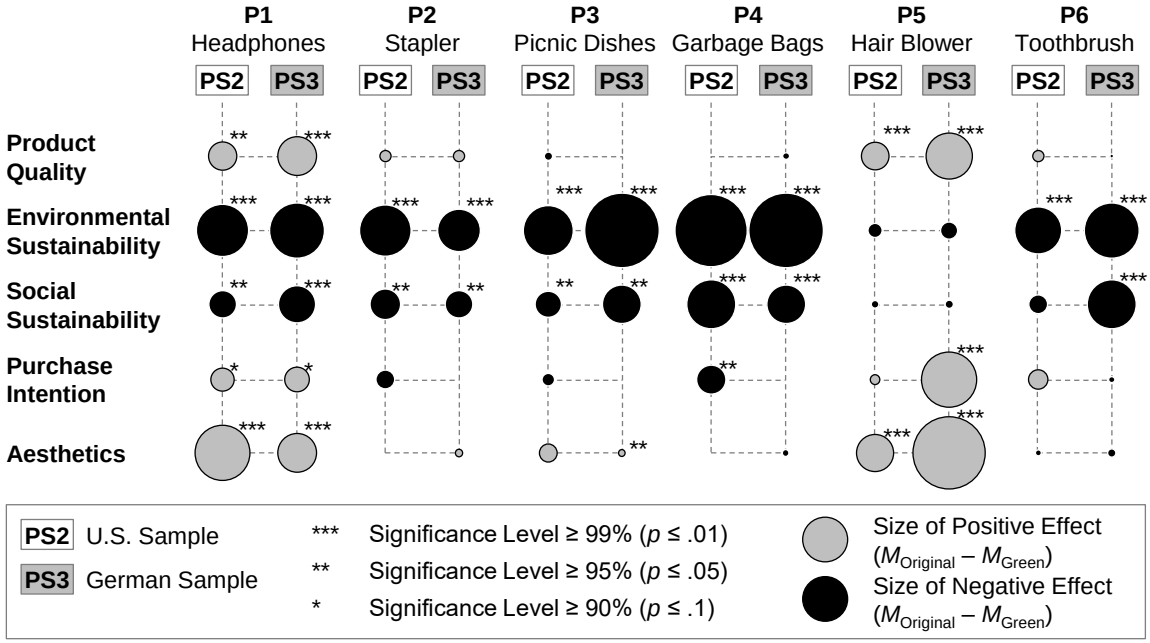


Figure 44: Comparison of the Effects of Preliminary Studies 2 and 3

The analysis presented above compares the sizes and the directions of the mean differences as well as the levels of significance for both samples. However, it does not compare the mean values themselves and therefore ignores the position of the effects. To analyze the mean differences for each variable across the samples, both data tables were combined, and t-tests were calculated. The complete results are presented in Appendix XIII. A graphical illustration of the results is depicted in Figure 45. The size of each bubble illustrates the size of the mean difference for a variable. If this difference is significant, the significance level is also stated. For example, it can be seen that the German participants on average gave lower quality ratings for the original design of the headphones than the U.S. participants. However, the difference is small and also not significant.

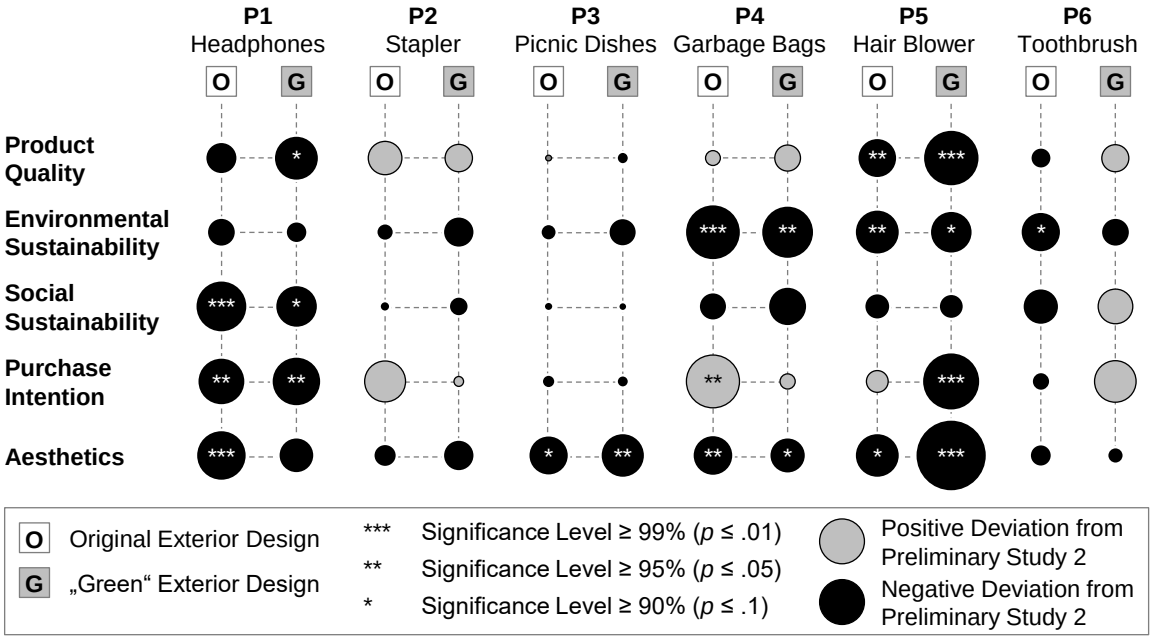


Figure 45: Comparison of the Mean Differences of Preliminary Studies 2 and 3

Significant mean differences are found for a number of variables. It seems that the German sample, in general, was more critical and gave significantly lower ratings especially for the environmental sustainability and aesthetics of most products. However, in almost all cases these mean differences do exist for both the original and the "green" treatment. Most of them are of comparable size and more importantly have the same direction. This results in comparable effect sizes and directions as is illustrated in Figure 45. In a nutshell, the German sample yields comparable effects of the manipulation with some distinct differences regarding the hair blower and toothbrush while overall participants tend to provide lower ratings for the environmental sustainability and aesthetics evaluation of both treatments. This illustrates that the exterior design manipulation also influences the perceptions of the German participants even though the sample's demographics do differ regarding education and also some cultural differences may exist in the context of sustainability. It is also supported by the participants' comments at the end of the survey. Most of them directly drew conclusions from the exterior of the products: *"I think it is interesting to see that one can read the product's environmentally friendliness from its color. Designers should more often signal sustainability through such a product design."* Some were seemingly aware, that "green" designs like the ones mimicked for this study are often mere marketing ploys but admitted to being influenced by it: "*I know very well that you cannot tell from the color and design of the product how sustainable the product is manufactured. However, I am definitely allured by it.*"

As a next step, the findings from the concluding questions about the participants' attitude towards green and social consumption as well as their ambivalence ratings were compared.

For the green consumption scale, a small (M_{1A} = 4.52 vs. M_{1B} = 4.82, d = .22) but slightly significant difference was found (t(229) = -1.67, p = .097). The difference in the social consumption scale also yields a small (M_{1A} = 4.23 vs. M_{1B} = 3.91, d = .19) but insignificant mean difference (t(229) = 1.45, p = .148). Thus, participants from both samples reported being equally concerned about sustainable consumption. As calculating a series of ANCOVAs reveals, the German participants' attitude towards sustainable consumption does not interfere with the effects of the exterior design manipulation. A highly significant mean difference is found for the ambivalence scale (t(229) = -5.944, p < .001). German participants indicate that they were much more conflicted when evaluating the products than U.S. participants (M_{1A} = 2.98 vs. M_{1B} = 4.12, d = .79). This is likely to be attributed to the routine most AMT workers already gained through participating in similar studies.

Regarding the credibility of the edited product pictured, the German sample is also in line with the U.S. sample. While most products appeared to be actual products to the participants, as stated before, the hair blower and the toothbrush raised some doubts. Also, the participants had difficulties recalling the correct color of the "green" hair blower. Taken together, AMT samples behave similarly to German consumers in the context of sustainable consumption choices. Thus, it seems eligible to also use an AMT sample for this dissertation's main experiment. Summing up the comparison of both preliminary studies, the following key findings are put forward:

Key Findings of Preliminary Study 3

- The major effects of the exterior design manipulation were replicated for the German sample. In general, German participants were more critical regarding their sustainability ratings. However, signaling superior product sustainability through a "green" exterior design does also work with the German sample.
- Also to the German sample, the edited versions of the product pictures seemed believable. However, again the hair blower and the toothbrush raised some doubts.
- AMT samples like the one used in preliminary study 1 and 2 are considered to behave similarly to a sample of German consumers in the context of the current dissertation. Thus, the main experiment's participants will also be sampled from AMT.

6.5 Main Experiment: Investigating the Effects of Material and Design Choices on Product Evaluation

To empirically validate the fifteen hypotheses put forward in Section 6.1.1 individually for each of the four products, an experiment was designed and conducted building on the findings from the three preliminary studies. The aim was to analyze the main effects of product developers' material and design choices as well as possible interaction effects on

consumers' impressions of a product. In the next sections, the setup, demographics, data preparation, and the findings of the main experiment are reported.

6.5.1 Setup

The setup and questionnaire from the preliminary studies 2 and 3 were adapted to accommodate the additional material manipulation. Thus, the product pictures were supplemented with a reference to the products' material (see Figure 46). Since it was intended to reuse the data gathered in preliminary study 2 (where no information about the material was disclosed) as reference values, both manipulations resulted in a 2x4 between-subjects experimental design. Also, since the "green" versions of the hair blower and the toothbrush produced mixed responses with both the German and the AMT sample and moreover also yielded divergent findings, the opportunity was taken to limit the complexity of the main experiment: both products were excluded from the experimental setup. Finally, the manipulation check was adapted also to find out if the participants realized the different types of plastics the products are allegedly made of. Apart from that, the structure of the survey and the questions themselves were kept as already introduced in Figure 39 and Appendix X.

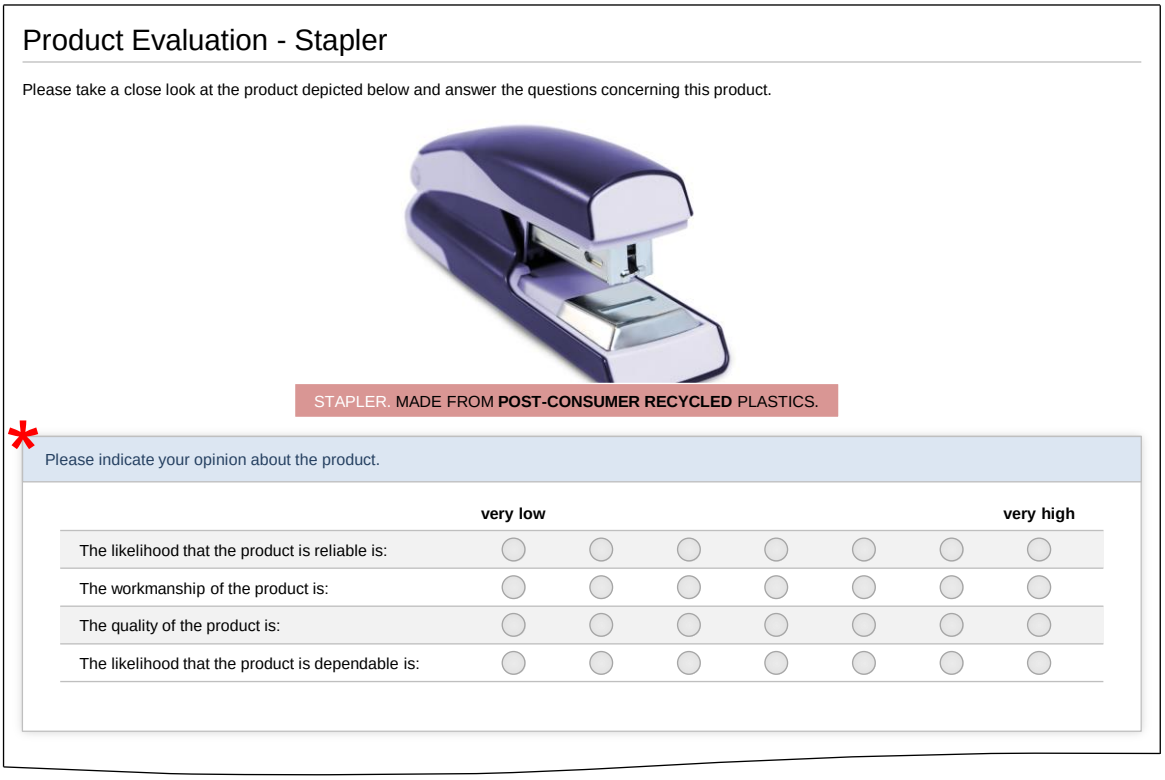


Figure 46: Excerpt from the Product Evaluation of the Main Experiment

Again, the experiment was implemented as a dynamic web-based questionnaire through the software tool Limesurvey. A pretest with a sample of AMT workers (n = 20) produced

no mistakes or inconsistencies. Before executing the experiment, care was taken to exclude participants of preliminary study 2 from taking the (very similar) survey.

6.5.2 Demographics

A sample of 384 participants providing valid responses was recruited through AMT (see Figure 47).[33] Participants being U.S. residents, possessing a minimum HIT-approval rate of 95 percent, and having completed more than 100 HITs qualified for taking the survey. They were compensated monetarily for participating in the study: the HIT was rewarded with \$1.00 per worker yielding an average hourly wage of \$6.35 ($M_{Duration}$ = 9.45 min, $SD_{Duration}$ = 5.10 min). The data was collected between October and December 2015.

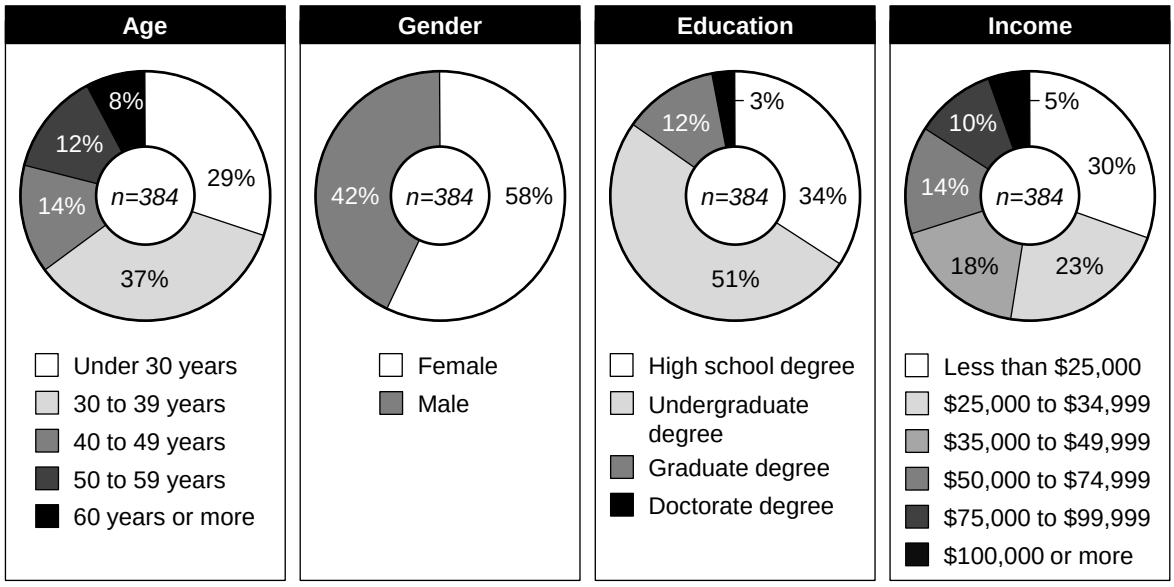


Figure 47: Demographics of the Main Experiment's Sample

The demographics indicate that this experiment's sample is a little older than the previous samples. The age of the participants spans from 18 to 86 years with an average age of M_{Age} = 37.6 years (SD_{Age} = 12.4 years). 58 percent of the participants are female. The educational and income level of the sample is similar to the previous samples of this dissertation: Two-thirds of the participants at least possess an undergraduate degree. While more than half of the participants indicate to earn less than \$35,000, more than a quarter of the sample has an annual income of more than \$50,000. Like for preliminary studies 1 and 2, the main experiment's sample is typical for AMT studies.

6.5.3 Data Preparation

The data was cleaned, transformed, and inspected for careless responses following the principles introduced in Section 6.2.3. Since it was mandatory to answer every question of

[33] The necessary sample size was estimated a priori using the software G*Power (Faul et al. 2009, p. 1149).

the survey, no *missing values* had to be treated. Several participants failed to pass the material information manipulation check (i.e. they were not able to remember any of the materials correctly). Most of these participants were also unusually fast in answering all questions and in some cases their data exhibited clear patterns or numerical values that made no sense. Altogether, 18 data sets had to be excluded from the analysis since it became evident that these participants just clicked through the survey as fast as they could without actually reading the questions or thinking about any answer. All other participants only sporadically did not remember the correct material. Thus, no measures had to be taken. In terms of detecting *outliers* and *false answers* through box-plots, it became apparent that seven participants deviated from the imputation standard for the numerical values. After their answers had been transformed to fit the standard, no further severe outliers were discovered.

Then, the current data was merged with the data gathered for the second preliminary study. Subsequently, the compound values and the corresponding α were calculated. Since the lowest value for α was .93, again all multiple-item measures used feature high internal consistency. The data was then analyzed for *normality* of the dependent variables. All price variables had to be transformed to meet the assumption of normality. Moreover, about half of the variables were found to feature unequal variances across the groups and thus did not meet the assumption of *homoscedasticity*. Unfortunately, SPSS does not provide adjusted F-statistics for a two-way ANOVA like it does for a one-way ANOVA. However, it is established in the literature that one can still analyze heteroscedastic data in a two-way ANOVA if one is more conservative when interpreting the significance levels (Sarstedt & Mooi 2014b, p. 1).[34] Thus, no measures had to be taken, and the data was considered appropriate for data analysis.

6.5.4 Findings

To analyze the data, two-way ANOVAs were calculated following the guidelines established by Sarstedt & Mooi (2014b, pp. 1–4) and Field (2009, pp. 430–446). The ANOVAs' findings for both the main effects and the interaction effects are displayed in Appendix XIV, the descriptive statistics along with the effect sizes (Cohen's *d*) can be found in Appendix XV. Since the material manipulation contains four treatments, a post-hoc test (Games-Howell) had to be calculated. Appendix XVI displays the resulting significance values. Like for the preliminary studies 2 and 3, ANCOVAs (Field 2009, pp. 396–408) were calculated to

[34] Throughout the visual presentation of the findings in Figure 488 and Figure 499, heteroscedastic data is signaled through parenthesizing the significance level.

examine whether any covariates significantly affect the dependent variables; none were found.

The findings of the main experiment are laid out in the following. First, the main effects of the exterior design manipulation are revealed. After that, the findings of the material information manipulation and the interaction effects between both manipulations are presented. For the sake of reader-friendliness, no numbers will be included in the description. Instead, a highly detailed summary of the data analyses' findings can be found in the Appendix as introduced above.

Main Effects of Exterior Design Manipulation

An overview of the findings is illustrated in Figure 48. Overall, they are similar to the findings of the exterior design manipulation from the second preliminary study (see Figure 42). In the following, the essential findings are described sorted by the six measures used for product evaluation.

Product Quality. The analysis reveals a significant effect of the manipulation on the perceived product quality for the headphones and the picnic dishes. While for the headphones the participants expect the original exterior design treatment to be of higher quality than its green counterpart, the opposite is true for the picnic dishes. In the case of the stapler, there is virtually no difference between the treatments. Also, the garbage bags yield no significant mean difference.

Environmental Sustainability. A highly significant and substantial effect of the manipulation on the perceived environmental sustainability of all products is revealed. For all, participants expect the "green" treatment to be more environmentally friendly than the original exterior design treatment. This effect is particularly strong for the garbage bags. However, also for the headphones, the stapler, and the picnic dishes the size of the effect is considerable.

Social Sustainability. The evaluation of the products' social sustainability reveals a pattern similar to those of environmental sustainability. The "green" treatment of all products is perceived to be more socially sustainable than the original exterior design treatment. Again, the effect is particularly strong for the garbage bags.

Purchase Intention. Only the stapler and the garbage bags feature a significant effect of the manipulation on the participants' self-reported purchase intention. In both cases, participants indicate to be more likely to buy the "green" version than the original version of the products. For the two other products, the mean differences are rather small and more importantly not significant.

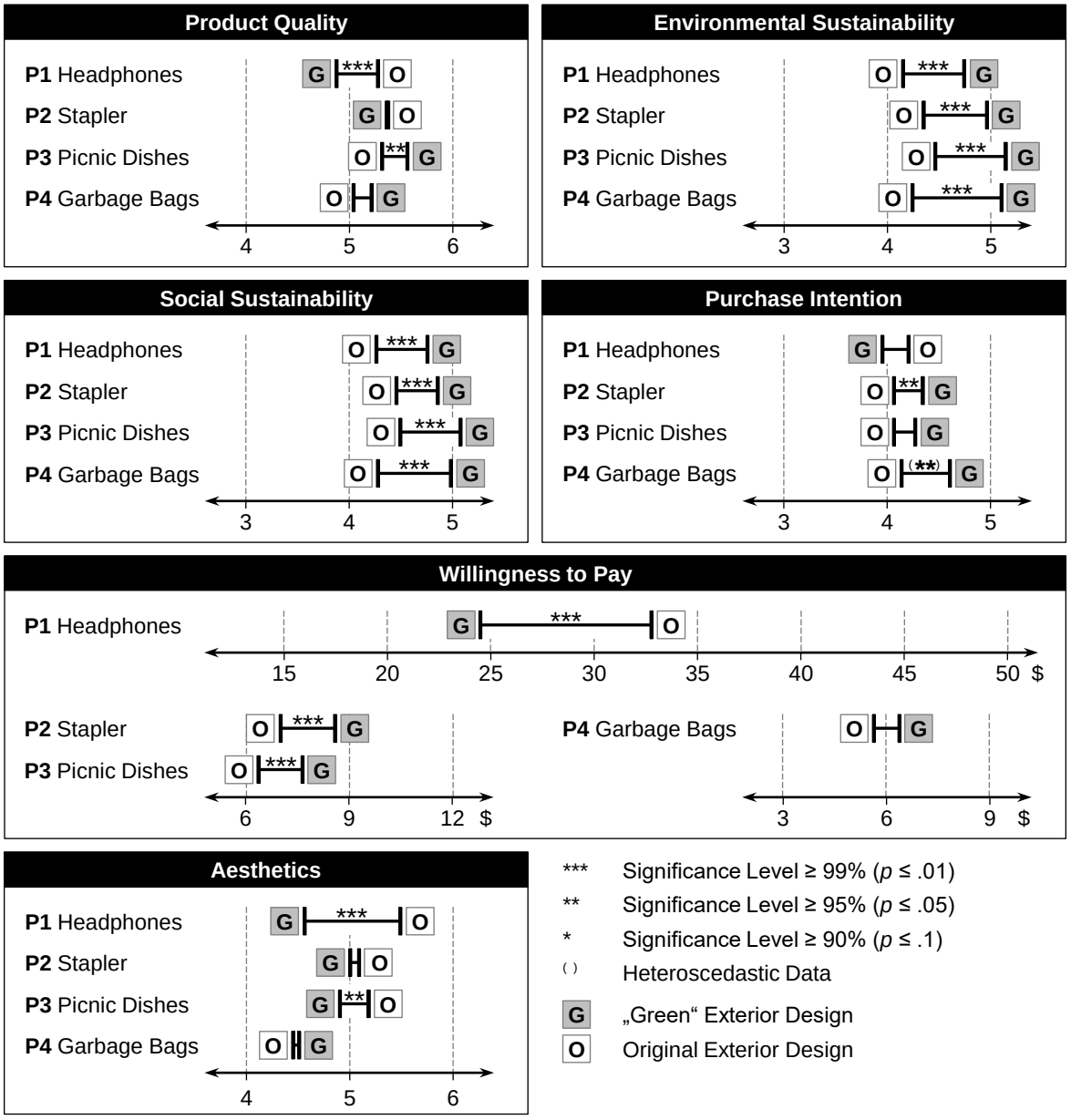


Figure 48: Main Effects of the Main Experiment's Exterior Design Manipulation

Willingness to Pay. For three products, the analysis reveals significant effects of the manipulation on the participants' willingness to pay. In the case of the headphones, participants indicate to be willing to pay less for the "green" treatment. For the stapler and the picnic dishes, opposing effects are revealed as participants are willing to pay considerably more for the "green" treatment. Both effects are highly significant. In the case of the garbage bags, the analysis reveals no significant effect of the manipulation.

Aesthetics. The manipulation also has a significant effect on the aesthetic evaluation of the headphones and the picnic dishes. In the case of the headphones, the participants are clearly more attracted to the original exterior design. Also, the original version of the picnic dishes is evaluated being more attractive than the "green" version. For the garbage bags

and the stapler, the mean differences between the treatments and the effect sizes are almost zero. Thus, the participants found both treatments to be equally attractive.

In general, possibly due to the increased sample size, several mean differences feature a higher significance level compared to the findings of preliminary study 2. Also, some mean differences that were not significant in the second preliminary study are significant in the main experiment. At the same time, several mean differences and also their respective effect sizes *d* are smaller in the two-factorial design. It can be concluded that the presence of a second manipulation weakened the strength of the exterior design manipulation. However, almost all effects were reproduced.

Main Effects of Material Manipulation

Figure 49 provides an overview of the findings of the material manipulation through displaying the mean values (see Appendix XVI for complete results) and the significance levels from the Games-Howell test (see Appendix XVII for complete results) for all four products. Only the most prominent findings concerning the four treatments FB (fossil fuel-based plastics), PC (post-consumer recycled plastics), BB (bio-based plastics), and NI (no material information) will be presented in the following.

Product Quality. The analysis reveals some significant but rather small effects of the manipulation on the perceived product quality of some products. For the garbage bags, participants perceive both more sustainable material treatments (PC and BB) as being of higher quality than the FB and NI treatment. Moreover, PC is evaluated as exceeding BB regarding product quality, while there is no significant difference between FB and NI. The headphones, on the other hand, exhibit no significant mean difference between any of the treatments. In fact, the mean values are almost equal. For the stapler, only one small but significant mean difference is found as the information that the product is made from recycled plastics (PC) induces a higher quality perception than for the treatment without any material information (NI). Also for the picnic dishes, knowing that the products are made from more sustainable materials (PC and BB) yield a significantly higher quality perception as if no material information was provided.

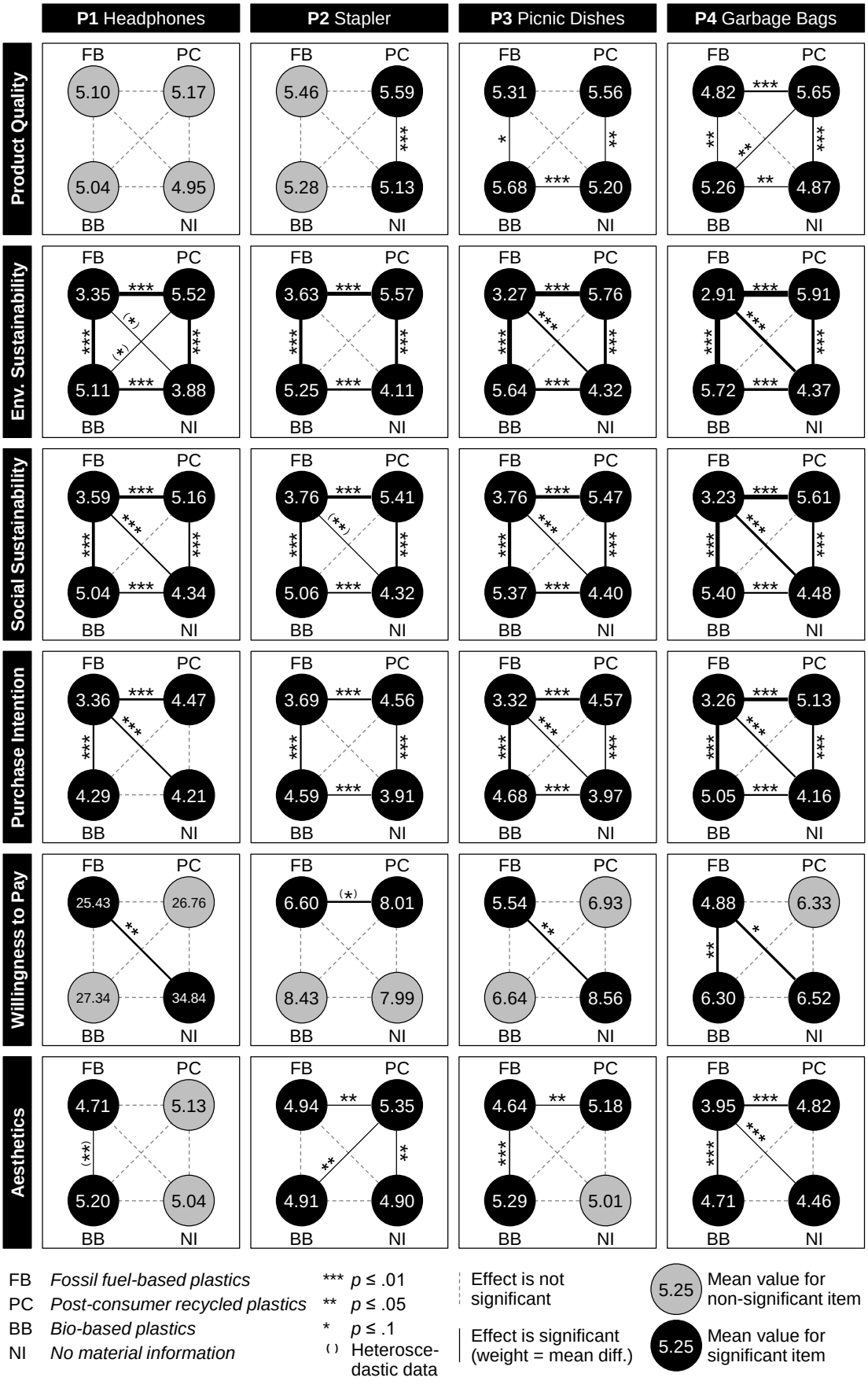


Figure 49: Main Effects of the Main Experiment's Material Manipulation

Environmental Sustainability. Regarding environmental sustainability, the effects of the manipulation are similar for each of the four products. First of all, the more sustainable materials treatments (PC and BB) are always perceived being more environmentally sustainable than the FB and NI treatments. All these mean differences are significant at a one percent level. The effects are especially large for the garbage bags. Also, it does not make a significant difference which more sustainable material the products are allegedly made of. Finally, the FB treatment of all products is perceived being less environmentally sustainable than the NI treatment. However, the resulting mean differences are only significant in the case of the picnic dishes and the garbage bags.

Social Sustainability. As was already found for the main effects of the exterior design manipulation, the evaluation of social sustainability follows the pattern of environmental sustainability. However, all mean differences are smaller. Thus, the PC and BB treatments are perceived being more socially sustainable than the FB and NI treatments while the type of more sustainable material (PC or BB) makes no significant difference. Again, the largest effects are found for the garbage bags. Also, except the stapler, knowing nothing about the material (NI) is significantly better for the evaluation of social sustainability than knowing that the product is made from fossil fuel-based plastics (FB).

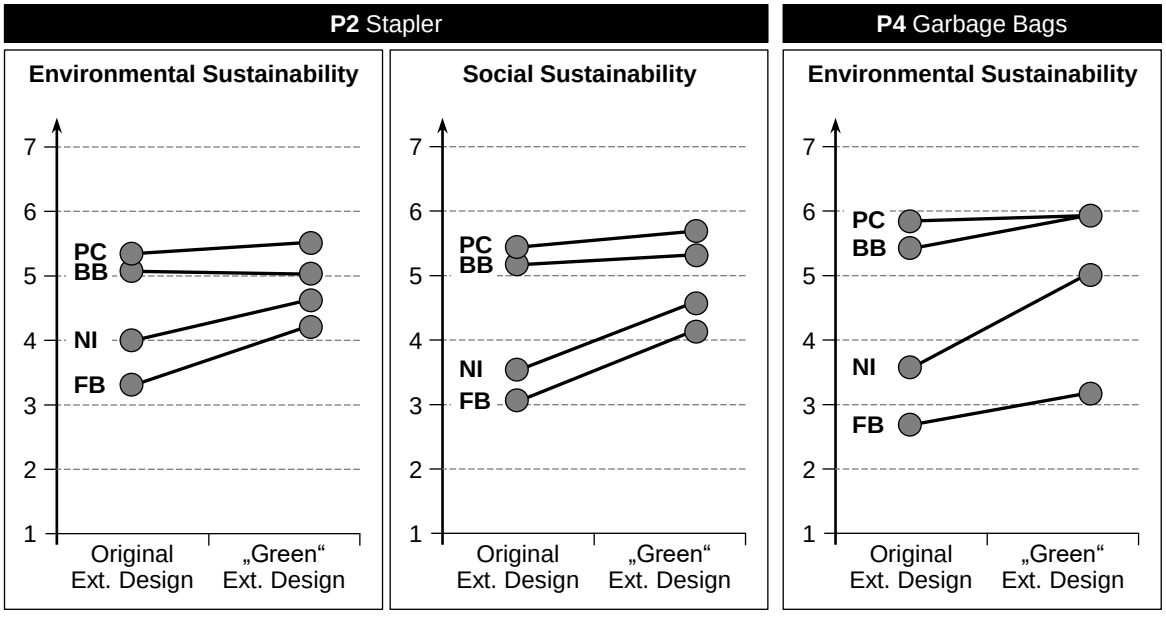
Purchase Intention. For all products, more sustainable materials (PC and BB) are significantly improving purchase intention in comparison to fossil fuel-based plastics (FB). Like before, these effects are largest for the garbage bags even though they are not as big as for the sustainability perceptions. However, also for purchase intention it does not make a difference which more sustainable material the product is made of. Except the headphones, the purchase intention for PC and BB is also significantly higher than for the control group without material information (NI). Except the stapler, participants indicate to have a significantly higher purchase intention for the NI than for the FB treatment.

Willingness to Pay. For the headphones, participants indicate to be willing to pay significantly more for the NI treatment than for the FB treatment. All other differences are not significant. However, the mean values for PC and BB are close to those of FB. Again, information about a product's material reduces the self-reported willingness to pay. For the stapler, the willingness to pay for the PC, BB, and NI treatments is almost equal to each other and clearly higher than for the FB treatment. However, none of the mean differences is significant. In the case of the picnic dishes, the NI treatment holds a significantly higher willingness to pay than the FB treatment. For the garbage bags, participants are willing to pay significantly more for the BB treatment than for the FB treatment.

Aesthetics. While the participants' evaluations of the first four measures are more or less homogeneous across the four products, distinct differences are found regarding aesthetics. First, there are no significant effects of the manipulation on the headphones' evaluation. For the stapler, the PC treatment is evaluated being significantly more visually attractive than the other three treatments. FB, BB, and NI feature about the same mean values and thus there is no significant mean difference to be found. In the case of the picnic dishes, knowing that the product is made from more sustainable materials yields a significantly higher aesthetics rating than the FB treatment. Again, it does not matter which more sustainable material is used since no significant difference between PC and BB exists. For the garbage bags, the FB treatment gets significantly lower aesthetics ratings than the other three treatments. However, there is no significant difference between any pair of the PC, BB, and NI treatments.

Interaction Effects

Between the two manipulations, only three significant interaction effects were identified. They pertain to the environmental and social sustainability of the stapler as well as the environmental sustainability of the garbage bags. Figure 50 illustrates them.



FB *Fossil fuel-based plastics* | **PC** *Post-consumer recycled plastics*
BB *Bio-based plastics* | **NI** *No material information*

Figure 50: Interaction Effects Between the Main Experiment's Main Effects

Even though the absolute mean values and significance levels differ, all three significant interaction effects are, in fact, similar. The graphs indicate that for the original exterior design of all three cases both more sustainable material treatments (PC and BB) are evaluated being clearly more environmentally or socially sustainable than the NI and FB

treatments. With one exception, the evaluation of PC and BB slightly improves if looking at the “green” exterior design treatment. The evaluations of NI and FB, on the other hand, improve much more (except FB in the third interaction effect). Thus, a “green” exterior design does not equally contribute to the participants’ perception of superior sustainability for all four material treatments. For example, in the case of the garbage bags, a “green” exterior design yields only little improvements in the participants’ evaluation of the environmental sustainability of any of the three materials stated (FB, PC, and BB). However, if no information about the material is provided (NI), the “green” exterior design has a much more positive impact on participants’ evaluation. Taken together, the interaction effects demonstrate that the different signals of sustainability can interfere with each other and, thus, should be evaluated side by side.

6.5.5 Discussion

For the discussion of the findings, first, some general observations are put forward. Then both main effects are jointly discussed for each of the four products, also taking into account the significant interaction effects.

First of all, it was demonstrated that the *exterior manipulation* has a considerable effect on the perceived environmental sustainability of all four products as the “green” treatments are evaluated as being much more environmentally sustainable than the original design treatments. Thus, the findings from the preliminary studies 2 and 3 are supported even though the effects are found to be smaller in the main experiment. Designing products in earthy colors leads consumers to believe that they are more environmentally sustainable than their original exterior design counterparts. It is surprising though that the same effect seems to be at work regarding social sustainability, especially because no information whatsoever was provided about the social implications of any of these products. Even though the effect sizes are smaller, participants still assume that most of the “green” treatments also hold a superior social sustainability. This might be the result of some spillover effect as the participants might consider social aspects as being interrelated with environmental sustainability. Related research by Luchs & Mooradian (2011, p. 140 f.) yields comparable findings. They conclude that the effect of environmental and social issues on consumer behavior can be similar as both issues function as signals of a more (or less) ethical consumption alternative.

For the *material manipulation,* it was demonstrated that post-consumer recycled plastics and bio-based plastics are perceived as being superior environmentally sustainable in the case of all four products. This comes as no surprise since studies have illustrated that – despite having limited knowledge about the specifics of the materials – consumers have

positive sentiments about them and relate recycled and especially bio-based materials to sustainability issues (Kainz et al. 2013, p. 393 f.). However, there are no significant differences between the two materials to be found for any product. Products from fossil fuel-based plastics, on the other hand, are across the board perceived as less environmentally sustainable. When compared with the no material information treatment, it becomes clear that this is the result of two effects reinforcing each other. First, knowing that the products are made from recycled or bio-based plastics – instead of knowing nothing about the material – leads consumers to believe that the entire product is more environmentally sustainable. Second, knowing that the product is made from fossil fuel-based plastics (which most plastics products available in the stores, in fact, are made of) induces a lower environmental sustainability rating compared to possessing no information about the material. Thus, a higher level of information both works as a "penalty" in the case of fossil fuel-based plastics and as a "promotion" in the case of recycled or bio-based plastics. Comparable to the "green" design treatment, the sustainable material treatments have the same effects on the perceived social sustainability even though there appears to be no immediate relation between environmentally friendly materials and social considerations. Thus, participants again seem to understand social and environmental issues as interrelated features of a more (or less) ethical consumption alternative.

Looking at the products one by one and starting with the *headphones*, both manipulations have a significant effect on the perceived sustainability of the product. The combination of the "green" treatment and the post-consumer recycled plastics is perceived being most sustainable while the original design made from fossil fuel-based plastics is evaluated worst. Regarding product quality, the material information manipulation has no effect, while the "green" exterior design is perceived to be of significantly lower quality than the original design. Thus, the color of the product influences participants' quality perception while its material has no effect at all. This is a surprising finding since in reality a product's material is a highly decisive determinant of its quality. Regarding aesthetics, the material has no significant influence while the color dominates participants' evaluation as can be expected. As was demonstrated in the first preliminary study, headphones are technical products that are only bought after extensive research on available alternatives. Moreover, for some consumers, headphones have become highly visible status symbols that are used to communicate the individual style and taste (Moore 2016, pp. 169–172). Thus, participants dislike the "greenish" version. However, this is not reflected in the participants' purchasing intention as the material is the decisive factor (PC and BB receive significantly higher ratings) while the exterior design holds no significant effect. Regarding willingness to pay it is the other way round: the product design leads participants to be willing to pay about a

third less for the “green” design than for the original counterpart. The material has no decisive influence on the willingness to pay. Taken together, the participants’ perception of the headphones’ quality and aesthetics is dominated by the developers’ design decisions. The purchase intention, however, is only affected by their material choices. In general, the original design made from post-consumer recycled plastics would most likely be bought. This treatment also holds the best evaluations of quality and aesthetics and a comparably high sustainability evaluation.

The perception of the *stapler’s* sustainability is also affected by both manipulations; the “green” design from post-consumer recycled plastics is evaluated being most sustainable. However, significant interaction effects have to be observed. They reveal that the reference to more sustainable materials already produces strong sustainability ratings even for the original exterior design. A change to a “green” exterior design would yield only small changes. Thus, if product developers want to signal product sustainability, they should rely on material information instead of an overt “green” design that might severely limit the target audience. Regarding the FB and NI treatment, on the other hand, switching to a “green” exterior design has a considerable positive impact on the product’s sustainability evaluation. Even though the combination of fossil fuel-based plastics and a flecked, “greenish” exterior design should be quite non-credible, it gets a much better sustainability rating compared to the original design. Regarding quality, both manipulations have almost no influence on participants’ perception. Looking at the aesthetics, the puzzling finding emerges that the design choices do not influence the aesthetics rating. However, the material choices do. Thus, knowing that the stapler is made from post-consumer recycled plastics produces small but significantly better aesthetics ratings compared to the other three treatments. Regarding purchase intention, both manipulations influence the participants. Both the “green” design and the sustainable material treatments would be preferred. However, if looking at the willingness to pay, only the exterior design makes a significant difference as the “green” design produces higher values. Taken together, like already found with the headphones, consumers’ perceptions of a product are not typically shaped through the product aspect that should be decisive. While it seems possible that two different designs are rated equally aesthetic, it is surprising that additional information about the product’s material can change this rating.

Looking at the *picnic dishes*, the perceived sustainability level is again positively affected by a “green” design and more sustainable materials. The bio-based “green” product alternative is evaluated as being most sustainable while the original design from fossil fuel-based plastics is rated worst. Regarding quality perception, the design is found to be much more decisive than the material. Just like for the headphones, participants’ perception is

rather shaped through a factor that has no impact on product quality than through a factor that can at least theoretically have an influence. However, other than for the headphones, for the picnic dishes the "green" design is perceived being of higher quality. The aesthetics evaluation is dominated through the design manipulation as the original design is perceived as being significantly more attractive than the "green" version. However, the design has no influence on the purchase intention as it is driven by the material choices. Surprisingly, the willingness to pay is not affected by the material choices but only by the design choices as the "green" design triggers the highest willingness to pay. Taken together, like with the two other products, consumers' perceptions are not typically shaped through the product aspect that one would expect to be decisive.

The perception of the *garbage bags'* sustainability performance is affected by both manipulations. The "green" treatment from post-consumer recycled plastics is considered best regarding sustainability. Again, an interaction effect has to be observed for environmental sustainability. Like already observed for the stapler, switching to a "green" exterior design hardly affects the sustainability rating of the sustainable materials treatments. The NI treatment, however, profits from the "green" design while the FB treatment generates a much smaller effect. Thus, coloring garbage bags made from fossil fuel-based plastics in green is not helping much to move the needle on the participants' sustainability evaluation. When comparing all four products, both manipulations have the highest sustainability-related effect on the garbage bags. This coincides with the findings from the first preliminary study. There, participants believed to have the highest leverage to bear on sustainability through choosing between different product alternatives of the garbage bags. Regarding product quality – other than for the headphones and picnic dishes – the perception of garbage bags is not affected by the design but by the material choices as expected. However, the more sustainable materials are perceived to offer higher product quality. This is surprising as most developers from the qualitative study's sample expect consumers to associate recycled plastics and bio-based materials with lower product quality. Now, since garbage bags are such a simple product from only one material, quality should be assessable quite straightforward. Thus, even though the effect sizes are not large, this example illustrates that consumers think differently about more sustainable materials than most product developers seem to expect. However, when looking at the aesthetics evaluation, it gets complicated again. As already observed in the case of the stapler, surprisingly the design manipulation has no effect on the perceived attractiveness while the material manipulation has a decisive influence. The purchase intention is affected by both manipulations: participants declare to have the highest purchase intention for the "green" garbage bags made from post-consumer recycled plastics. The manipulations do

not significantly influence the willingness to pay. Summing up, the following key findings of the experiment are put forward:

Key Findings of the Experiment

- Signaling superior sustainability through a stereotyped "green" exterior design works for all four products. It allows for communicating both higher environmental and social sustainability. However, it depends on product specifics if the "green" exterior design also positively impacts the perception of other product aspects. Especially for aesthetics and willingness to pay it often does not.
- Participants find all products from bio-based and post-consumer recycled plastics to be more environmentally and socially sustainable. However, they seldom make a difference as both options are perceived as equally more sustainable. Also for most other product aspects, no significant difference is found. In general, more sustainable materials positively impact the evaluation of almost all product aspects included in the study.
- In some cases, the participants' evaluation of product features is affected by manipulations that should not have an impact. For example, the aesthetic evaluation is sometimes a result of the material manipulation and not the design manipulation. The perception of product quality, on the other hand, is sometimes influenced by the design instead of the material.

Finally, after presenting and discussing the findings of the experiment, they are related to the hypotheses put forward in Section 6.1.1 in the following. An overview of the support for the individual hypotheses is offered in Table 11. As stated before, each hypothesis was tested separately for the four products as if, in fact, sixty different hypotheses were tested. For this reason interaction effects between the four products were not considered during the analysis.

Table 11: Overview of the Support for Hypotheses from the Main Experiment

Hypotheses	P1 **Head-phones**	P2 **Stapler**	P3 **Picnic Dishes**	P4 **Garbage Bags**
H_{1a} Product developers can influence consumers' perception of *product quality* through a stereotyped *"green" exterior design*.	×	×	✓	×
H_{1b} Product developers can influence consumers' perception of *product quality* through choosing *recycled materials*.	×	×	×	✓
H_{1c} Product developers can influence consumers' perception of *product quality* through choosing *bio-based materials*.	×	×	✓	✓
H_{2a} Product developers can influence consumers' perception of *product sustainability* through a stereotyped *"green" exterior design*.	✓	✓*	✓	✓*
H_{2b} Product developers can influence consumers' perception of *product sustainability* through choosing *recycled materials*.	✓	✓*	✓	✓*
H_{2c} Product developers can influence consumers' perception of *product sustainability* through choosing *bio-based materials*.	✓	✓*	✓	✓*

Hypotheses	P1 **Head-phones**	P2 **Stapler**	P3 **Picnic Dishes**	P4 **Garbage Bags**
H_{3a} Product developers can influence consumers' *purchase intention* through a stereotyped *"green" exterior design*.	×	✓	×	✓
H_{3b} Product developers can influence consumers' *purchase intention* through choosing *recycled materials*.	✓	✓	✓	✓
H_{3c} Product developers can influence consumers' *purchase intention* through choosing *bio-based materials*.	✓	✓	✓	✓
H_{4a} Product developers can influence consumers' *willingness to pay* through a stereotyped *"green" exterior design*.	×	✓	✓	×
H_{4b} Product developers can influence consumers' *willingness to pay* through choosing *recycled materials*.	×	×	×	×
H_{4c} Product developers can influence consumers' *willingness to pay* through choosing *bio-based materials*.	×	×	×	✓
H_{5a} Product developers can influence consumers' *aesthetic evaluation* through a stereotyped *"green" exterior design*.	×	×	×	×
H_{5b} Product developers can influence consumers' *aesthetic evaluation* through choosing *recycled materials*.	×	✓	✓	✓
H_{5c} Product developers can influence consumers' *aesthetic evaluation* through choosing *bio-based materials*.	×	×	✓	✓

✓ = hypothesis is supported × = hypothesis is challenged * = significant interaction effect

Since product sustainability was constructed from an item measuring environmental sustainability and an item measuring social sustainability, the corresponding hypotheses are only supported, if the manipulation had a significant effect on both items. In the case of the post-consumer recycled plastics (PC) and bio-based plastics (BB) treatments, the corresponding hypotheses are only supported if the participants' evaluation were significantly better compared to both the fossil fuel-based plastics (FB) and the no material information (NI) treatments.

Taken together, Table 11 clarifies that only seven out of fifteen hypotheses are consistently supported or challenged for all four products: a "green" exterior design and both more sustainable materials positively influenced consumers' evaluation of product sustainability, the purchase intention was raised by using bio-based or recycled materials, the willingness to pay was never positively influenced by using recycled materials, and "green" designs were never beneficial for consumers' aesthetics evaluation. Support or challenge for the other eight hypotheses depends on the kind of product under investigation.

6.6 Implications of the Quantitative Analysis

After presenting the findings of the quantitative study, their implications are put forward in the following sections. Just like for the qualitative research phase, they are differentiated into theoretical and managerial implications even though it is acknowledged that they emerge to be highly intertwined.

6.6.1 Theoretical Implications

The findings of the quantitative research phase hold some important implications for theory and research. First, the current analysis emphasizes the importance of product design as a field of inquiry, as the exterior of a product shapes consumers' perceptions about all product properties. Certain features like the exterior design, as well as information about the material, can induce a halo effect that influences the perceptions of the product on a larger scale. Specifically, it was demonstrated that manipulating the exterior of a product can have both obvious (e.g. "greening" of a product might improve sustainability evaluation) and rather surprising findings (e.g. "greening" of a product might improve quality evaluation). Also, the findings are distinctive for different product types. In general, some product properties are easy to grasp and compare for consumers after experiencing the first impression of product design, and they start to engage with the product – e.g. the quality level of garbage bags can be observed once they are filled, and the functional performance of headphones can be observed when consumers use them and listen to music. Sustainability, however, only seldom becomes truly visible to consumers, as it emerges to be more abstract and fuzzy. The way garbage bags or headphones are produced or disposed and the associated social and environmental consequences cannot be experienced through using them. Thus, consumers' sustainability evaluations are entirely based on their (first) impression about the product and information provided by the consumer goods companies through claims or labels. Until today, empirical studies on the effects of different product designs are rare. The current analysis exclusively focused on manipulating the product color and texture, which already produced a cornucopia of sometimes contradictory findings. However, product design is also determined by other factors like the shape and size as well as haptics – a factor that cannot be manipulated in an online survey and warrants laboratory experiments. The current trends with respect to more affordable and readily available additive manufacturing technologies could be a decisive facilitator for more laboratory studies in the field of product design. Thus, research should further focus its attention on the role product design can play in influencing consumer behavior – especially in the context of more sustainable products.

As a second implication, research should focus on consumers' perceptions of different materials. The current analysis has demonstrated that consumers seem to have a highly positive opinion of more sustainable materials like post-consumer recycled plastics and bioplastics. They typically evaluated these materials more favorably than the other treatments for all product aspects included in the study – e.g. switching to bioplastics makes garbage bags look more attractive and picnic dishes appear to be of higher quality. However, previously the qualitative study has revealed that product developers often refrain

from using these materials. Besides technical challenges, one important reason for this is the ambiguity of consumer responses to more sustainable materials – at least, product developers expect consumers to behave this way. Specifically, they expect consumers to doubt the durability of bio-based materials or to demand lower prices for products made from recycled materials, as these might be understood as made of waste. The quantitative follow-up study questions these preconceived notions and suggests consumers have much more nuanced perceptions. Therefore, product developers should consider pairing their efforts to move towards more sustainable material choices with effective signaling of these enhanced properties (such as materials labels). Granted, in the current study, consumers did not react to experiencing the true look and feel of more sustainable materials, but to claims made during an online survey. Also, the small amount of extant research on this topic does not go beyond this more theoretical stage. Thus, more in-depth research on consumer responses in a laboratory environment is warranted to comprehensively grasp consumers' expectations, apprehensions, and reactions as well as to support the widespread adoption of more sustainable materials in the industry.

The third implication is a need for more multidisciplinary research in the field of sustainable product development – both in the sense of jointly examining multiple departments and working in multidisciplinary research teams. As the qualitative study has illustrated, the activities of product development and marketing are highly intertwined with respect to bringing a new concept to a state of market readiness. While product developers are certainly more concerned with the technical aspects of this process, their cognition does not end at organizational borders. Thus, product developers appeared to be highly concerned with market reactions to their products and their ways of influencing them. While silo mentality seems to be at least partly overcome in such industry environments, it still dominates research on sustainable product development (see Chapter 3). Most studies focus on highly specific issues, and only some authors aspire to get the bigger picture of developing more sustainable products within the dynamics of a company or an entire supply network. However, as the current analysis has illustrated, it can yield meaningful findings if the scope of the study is extended beyond the area of responsibility of a single department: the current quantitative analysis took a product developer's perspective to address a problem from marketing through more or less building on established market research techniques. It also seems promising to spotlight problems encountered in product development from the marketing, production, or even supply chain perspective. Also, as the process of sustainable product development requires multiple departments, it appears valuable to conduct more research in this area in multidisciplinary research teams. Thus, researchers from diverse domains like social sciences, engineering, industrial design, and

life sciences should join forces to advance the field further. Summing up, the findings of the quantitative research phase lead to the following implications for theory and research:

- **[T4] Focus on consumers' perception of product design:** Product design has a decisive influence on consumers' first impression of a product. While the perception of most product properties like quality or functionality can be corrected when consumers engage with the product, sustainability most often cannot. Thus, more research – also including other aspects of product design – is warranted.
- **[T5] Focus on consumers' perception of more sustainable materials:** In the current study, consumers exposed a positive opinion about more sustainable materials. Further, the signals introduced with more sustainable materials can induce halo effects that influence consumer perceptions far beyond the first impression. Product developers should leverage these subtle ways of influencing consumer reaction. In contrast, product developers from the qualitative study named unpredictable consumer behavior as a major roadblock for the adoption of bio-based materials in particular. Thus, laboratory research on consumers' reactions to actual products is needed to support a widespread use of more sustainable materials.
- **[T6] Intensify multidisciplinary research on sustainability issues:** Most extant research on sustainable product development focuses on domain-specific issues without addressing the bigger picture. However, multidisciplinary research – both regarding multiple departments and multiple academic disciplines – would help to establish a better understanding of the true needs of and obstacles to the practice of more sustainable product development.

6.6.2 Managerial Implications

The findings of the current quantitative analysis also hold important implications for management. The underlying question of the current analysis was concerned with the benefits of communicating sustainability improvements through a stereotyped "green" exterior design. Thus, the question emerges: is it beneficial for companies to follow this path? The answer to this question is not as straightforward as would be expected since the benefits much depend on the product type. Even though there are a several findings consistent for all products under study (as displayed in Section 6.5.5), most findings are individual to the product in question. For example, it has been demonstrated that signaling superior sustainability through a "green" design or more sustainable materials works for all four products. However, making consumers believe in superior product sustainability is only part of the equation since it does not seem to automatically translate into an actual purchasing intention. In fact, the current analysis has demonstrated that it seldom does. "Green" headphones, for example, will not be bought by many consumers since most of them tie sustainability to lower quality and also dislike the "green" design. Related research suggests that consumers believe that there is an inherent trade-off between product sustainability and performance. This trade-off can in part be overcome by a superior aesthetic product design (Luchs et al. 2012, pp. 913–915). Granted, the evaluation of aesthetics is a highly subjective task. However, as the main experiment has revealed, the

"green" product design in nearly all cases received lower ratings than the original design. Thus, an overt "green" design is probably not appropriate for products that consumers care about (i.e. they are looking for high performance and quality).

It further has to be kept in mind that all findings were generated in a constructed and controlled research setup, and are not the result of observing consumer choices in a retail environment. While it is established that the first visual impression shapes consumers' attitudes towards products, in reality, numerous other factors also determine if a consumer would leave the store with a standard or a "green" product in hand. For example, the product's packaging as well as its presentation at the point of sale can also be decisive. Some of the "green" products from the German consumer goods market introduced in Section 6.1.1 are sitting on the shelves just like any other product while others are advertised through custom-made point of sale displays or on end caps. However, despite the constricted experimental setup, some surprising observations can lead to insightful conclusions. For example, consumers' aesthetic evaluations were significantly affected by the material information, while, in fact, the product's exterior design in the picture was held constant. In reality, in the light of the high number of possible influences on consumers' product perceptions, there might be numerous other side-effects that product developers do not consider while deciding on a "green" product design. Even though it might seem tempting to trigger consumers' social and environmental consciousness through design stereotypes, companies should not make it too easy on themselves.

Apart from this, companies should be careful about launching a more sustainable product as a test balloon for another reason: the qualitative analysis has revealed that the consequences of a market failure often go far beyond the immediate financial losses. A "crashed" test balloon can act as a severe and long-lasting internal roadblock to hamper further activities regarding more sustainable products. Once a company experiences the unavoidable "crash landing" with a rather halfhearted test balloon, it is likely to abandon any product sustainability initiatives for the time to come, as pundits will feel vindicated: "We tested it, and the consumers did not like it." Summing up, the findings of the quantitative data analysis lead to the following managerial implications:

- **[M5] Develop a consistent design strategy:** The analysis has demonstrated that a "green" design indeed signals superior sustainability. However, companies should choose their design strategy wisely, as a "green" design often has a negative impact on the purchase intention of consumers. Thus, simply trying to establish a more sustainable product line by coloring it green does not work. Sustainability stereotypes may lower consumers' confidence about sufficient quality and functionality for some product categories. A consistent strategy that considers the halo effect of "green" design and material choices seems to be the most promising way to avoid sending mixed signals.

- **[M6] Consider undesired side effects:** Consumers' purchase decisions are affected by a high number of influencing factors. Developers should be aware that their design choices in the context of more sustainable products also might have undesired side effects, due to unusual interdependencies with product aspects that do not comply with the rational thinking of engineers.

In analogy to the presentation of the qualitative study's findings, this study's managerial implications are matched to the relevant departments and phases of the product development process in Figure 51. As became clear during the entire study, both developing a consistent design strategy and considering undesired side effects are issues product development and marketing should jointly discuss during system-level design and detail design. Even though both tasks should ultimately be the responsibility of product development, developers would be well advised to systematically include marketing's knowledge of consumer behavior and expectations also during these later phases of the development process.

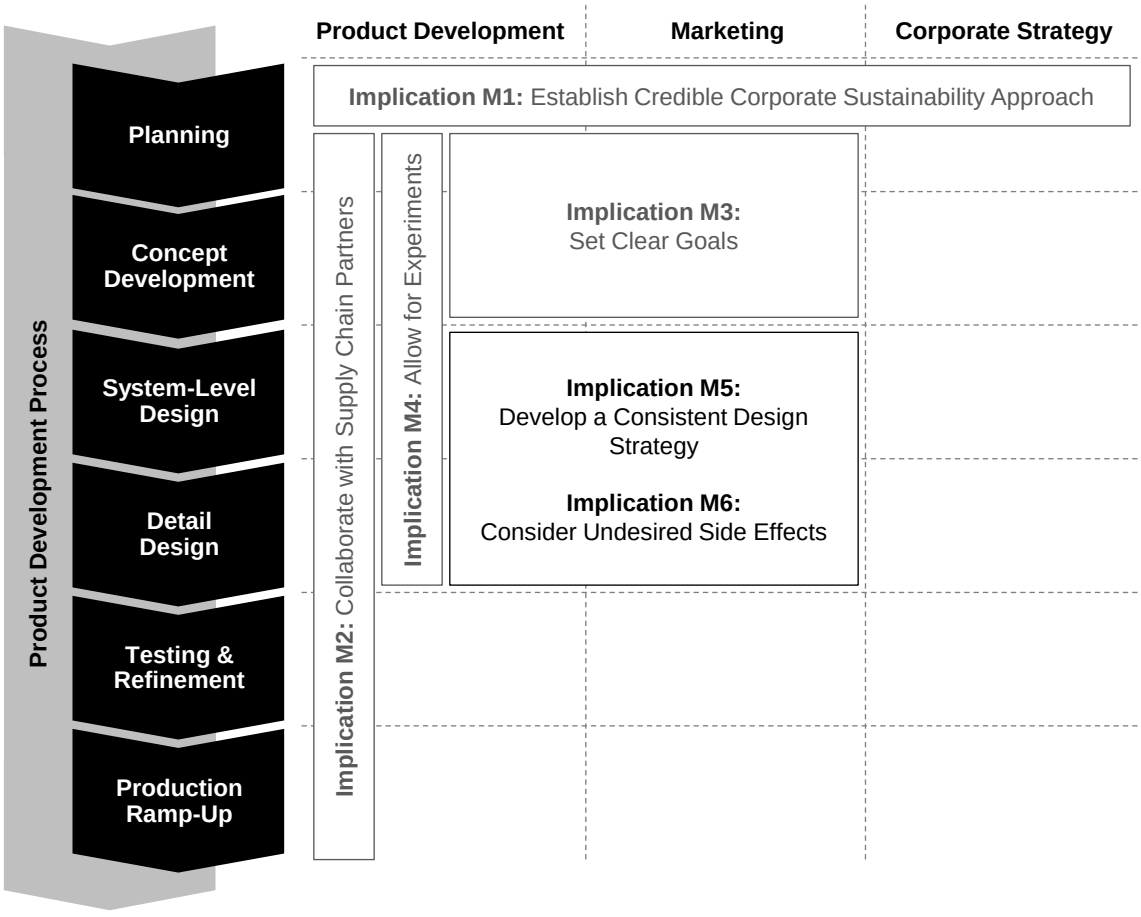


Figure 51: Matching of Managerial Implications, Departments, and Development Process Phases

6.7 Research Validity and Limitations of the Quantitative Analysis

Several measures were taken that address the quality criteria for quantitative studies introduced in Section 4.3.2. Table 12 provides an overview to support the trustworthiness of the research process and its findings.

Table 12: Measures Taken to Ensure Validity of Research Process and Findings

Criteria	Measures
Objectivity	▪ Researcher triangulation was performed for parts of the data collection and analysis. ▪ No experimenter bias; all participants received identical, textual instructions because the research was conducted online.
Reliability	▪ Setup, execution, data analysis, and findings of the experiments are documented in detail within this dissertation; including details on samples' demographics. ▪ Sampling from large, relatively stable, and easily accessible subject pool.
Internal Validity	▪ Manipulation checks were included to ensure that the effects are caused by the different treatments. ▪ Sequence of exemplary products and assignment of treatments were randomized. ▪ Implementation as an experiment conducted in a controlled environment allowed for comprehensively eliminating interfering variables.
External Validity	▪ Actual products from the consumer goods market were used. ▪ Extensive pretests were conducted to assure that exemplary products are understandable and represent a wide range of consumer goods. ▪ Participants assumed their natural role as a consumer; no extensive vignettes had to be crafted due to intuitive evaluation task.

Even though behavioral experiments are proven to offer a useful way for investigating consumer responses to sustainability issues, they hold some limitations that have to be considered when interpreting their findings. First, the samples of the studies are probably not truly representative of the underlying populations of consumers from Germany and the U.S. This might affect the external validity and especially pertains to the German sample of the third preliminary study: it clearly contains an above-average number of young university graduates. Also, the AMT samples differ from their underlying population since internet users, in general, are younger and better educated (Paolacci & Chandler 2014, p. 185). However, the AMT samples contain participants from all age groups and educational levels with varying purchasing power and individual attitudes towards sustainability. They are therefore considered suitable to yield important insights that are also of value for sustainability considerations regarding the overall population.

Another important limitation pertains to possible social desirability bias that might have impacted the findings. For example, it is imaginable that the self-reported higher purchase intention for products that are perceived being superior sustainable is more a result of societal values than of the actual participants' feelings towards the product. However, first of all, between-subjects experimental designs are proven to be a suitable way of limiting the effect of social desirability bias in sustainability research (e.g. Luchs et al. 2010). More

importantly, the analysis of the covariates (environmentally and socially sustainable consumption) demonstrated that effects like a higher purchase intention for the “green” products occurred both for participants that were not interested in sustainability in any way and for participants considering themselves as sustainability frontrunners. This is a strong indication that social desirability bias did not systematically impact the experiment’s findings.

Finally, the experimental research investigates specific issues and therefore purposefully constructs simplified behavioral situations that might be much more complex in real life. For example, in real life, the perception of product quality is not only driven by the product’s appearance but also through its haptics, its packaging, and its retail price among a myriad of other factors. Thus, when interpreting the findings, one has to be aware that these experiments do not provide a blueprint for successfully developing and marketing more sustainable products. They are rather one small but helpful piece of the overall sustainable consumption puzzle.

6.8 Opportunities for Further Research

The findings of the experiments yield interesting opportunities for further research. First of all, the current dissertation builds on data collection from a single, discrete period. However, sustainable consumption is a topic constantly evolving as it is defined by slowly changing consumer behavior as new more sustainable products are brought to market. Elaborating the research by adding data from other time periods for a longitudinal study might yield meaningful insights. Also, it appears worthwhile to include other products that are not necessarily made from plastics. For example, comparing products that already have a sustainable image (e.g. fabric bags or bicycles) with other products perceived as rather “bad” from a sustainability point of view (e.g. chemical cleaning supplies or disposable lighters) might yield meaningful insights. The experiments could then also be extended to the products’ packaging, as the sales packaging has a decisive influence on consumers’ purchasing decisions (Luchs & Swan 2011, p. 342).

Moreover, it appears valuable to also replicate the main experiment with a European (for example German) sample to investigate their take on more sustainable materials and compare it to the findings from the U.S. sample. In 1991, the world’s first dual system for nationwide collection and recycling of used sales packaging was implemented in Germany. Thus, German consumers have a long history of separating their household waste. Today, most households at least theoretically sort their waste into five different trash cans.[35] It

[35] Paper waste, packaging waste, organic waste, glass waste, and residual waste.

would be interesting to find out how the German emphasis on waste separation would be reflected in the participants' evaluation of products made from post-consumer recycled plastics. Also, German consumers (as most Europeans) are much more skeptical towards cultivating genetically modified plants than American consumers are (Song et al. 2011, p. 316). However, today some bio-based plastics are made from such resources (Álvarez-Chávez et al. 2012, p. 53). Thus, it would also be interesting to see if and how these reservations would be reflected in German participants' verdict on products made from bio-based plastics if they would know about genetic modifications.

Another opportunity for continuative studies is the integration of sustainability labels or claims often used by consumer goods companies into the experiment. Previous research has revealed that once consumers have made up their mind about a product based on their first impression, it is hard to counter this impression through additional, more objective information (Hoegg & Alba 2011, p. 356 f.). Thus, it appears valuable to extend this research into the sphere of sustainability to shed light on the role of labels and claims on consumers' first impression of a product. Social judgment theory (Sherif & Hovland 1961) might provide a suitable starting point for subsequent investigations as it looks into how individuals subconsciously evaluate every piece of new information and match it with their current attitude. Such an analysis might be especially interesting because consumers often suffer from "labelitis diffusa" (Gekeler 2012, p. 166) – the sheer endless amount of different sustainability labels and claims printed on products today often leads to severe confusion and wrong conclusions about their informational value (Buerke & Gaspar 2014, p. 25 f.). Specifically, consumers often have a hard time distinguishing unsubstantiated corporate claims from reliable third party labels.

Finally, it appears valuable to expand the current dissertations' experiments from the internet to the field, thus, sacrificing internal validity for the sake of increasing external validity. For example, the willingness to pay and the purchase intention were self-reported by the participants. Even though care was taken to control for social desirability bias, the findings do not necessarily have to correspond to real-world behavior. Thus, it would be interesting to analyze participants' willingness to pay in an actual retail environment. Also, it would be beneficial to investigate the interplay of exterior design, materials, sustainability assessment, and experienced functionality of a product. For example, it would be highly interesting to analyze if the experienced sound quality of headphones is impacted by their exterior design. Also, it might produce insightful results to investigating whether an allegedly sustainable toothbrush allows for brushing one's teeth as thoroughly as a traditional toothbrush does.

7 Conclusions and Outlook

Current consumption practices are a serious threat to the economic, environmental, and social well-being of the planet. One solution to tackle issues caused by global consumption practices is to develop products that are more sustainable. Companies have high traction in this respect since product development to a great extent predetermines a product's sustainability performance over its entire life-cycle. However, due to its multi-dimensional nature, it is not easy to define what constitutes a more sustainable product. Also, little is known about the practical implications of the rather fuzzy notion of sustainability on established development processes in industry. Nevertheless, companies more and more often strive to consider sustainability aspects for their products.

In the light of the above, the current dissertation's objective was **to gain a better understanding of how product sustainability is accounted for in product development and to contribute to the further adoption of sustainability principles through identifying best practice examples.** Three research questions were put forward and tackled through a mixed-methods research design. First, an inductive, qualitative study was performed through conducting and analyzing 32 interviews with product development managers from the consumer goods industry. These interviews, along with secondary data, provided a rich context for highlighting prevalent development practices and producing a number of research propositions. Some acted as impetus for a subsequent deductive, quantitative study that looked into consumers' responses to prevalent development practices through a series of behavioral experiments.

Research Question 1:	**Which approaches are taken by companies for the development of more sustainable products?**

The first research question is addressed through the findings and implications of the qualitative study. Two interrelated aspects are found to determine the way companies deal with developing more sustainable products. First, six types of approaches towards sustainability on a corporate level were identified, ranging from Minimalists (i.e. companies only marginally considering sustainability) all the way to True Believers (i.e. companies founded with the premise of sustainability in mind). Second, on the product development level, three variables for conceptualizing sustainability are identified: the range of products considered for sustainability initiatives, the way these sustainability initiatives are communicated through the exterior design of the product, and the initiative's level of innovativeness. This conceptualization on the product development level reflects the corporate approach. For example, Test Balloonists (e.g. companies starting to engage with sustainability in a specific area) tend to set up separate lines of more sustainable products

holding only incremental improvements but communicating this approach through a stereotyped “green” exterior design. True Believers, on the other hand, consider sustainability for all products, often through challenging established product concepts. Also, they do not attempt to signal sustainability using design stereotypes.

Research Question 2:	**Which challenges do product developers have to meet in the context of developing more sustainable products?**

The second research question is also addressed through the findings and implications of the qualitative study. Product developers face a number of challenges throughout the development process. First of all, the handling of sustainability issues is only seldom properly codified as opposed to, for example, quality requirements. Thus, developing more sustainable products is often subjected to uncertainties about sustainability requirements to be fulfilled and more importantly degrees of freedom that developers are allowed to use in the pursuit of higher sustainability. Second, integrating sustainability into products introduces trade-offs with classic development objectives like functionality, cost, and quality. These trade-offs are hard to solve since third, product developers have difficulties assessing their sustainability-related decisions from a life-cycle perspective. Besides these challenges emerging during early development phases, developers from the sample also reported the severe obstacles they face when bringing the new products to market. For example, they sometimes have to overcome in-house skepticism since especially sales and marketing might fear that a line of more sustainable products could hurt the reputation of the rest of the product portfolio. Also, developers quarrel with ambiguous consumer behavior as consumers demonstrate limited interest in sustainability, despite studies suggesting an increased willingness to buy more sustainably. Finally, product developers are bothered by competitors’ activities that are close to greenwashing. Misleading claims or self-made labels devalue the meaning of sustainability and hamper a credible communication of actual sustainability efforts.

Research Question 3:	**Which recommendations can be derived for the development of more sustainable products?**

The third research question is addressed through general recommendations derived from the qualitative study’s findings as well as some more specific findings from the quantitative study. For example, the qualitative study exposed that companies that are successfully bringing more sustainable products to the market codify clear and measurable objectives for their product developers. Thus, the product developers are offered guidance on how sustainability can be translated into technical parameters and on how far they are expected and allowed to push product sustainability. At the same time, these companies provide their

product developers with resources for experimenting to find more sustainable solutions. As a result, new materials and designs are successfully tested as established product concepts are challenged. Also, these companies have realized that they need partners in their journey towards product sustainability. They know that it is necessary to consider the entire supply network of a product, and they closely collaborate with partners – even from different industries – to benefit from external resources.

The quantitative study yielded more specific recommendations on how companies should communicate sustainability improvements. It was found that a stereotyped “green” exterior design signals superior product sustainability to most consumers. However, this comes at a price for most products, as it might also signal lower quality and also appears less attractive to consumers from an aesthetics point of view. In general, the more important a product is to the consumer (i.e. intensive evaluation of available alternatives, the product can be used to emphasize personality, etc.) the less a “green” design is beneficial for forming a purchase intention. Thus, product developers should be aware of the consequences of their design choices. The use of more sustainable materials on the other hand – also a powerful signal for superior product quality – has much fewer unintended side effects compared to a “green” exterior design. In fact, for some products, even the aesthetic evaluation benefited from the reference to bioplastics or recycled materials.

Additionally to the managerial implications, several theoretical implications were derived from the findings of both studies. First of all, research on sustainable product development should be matched to the companies’ needs since it appears that until today, too much idle power is generated in this respect. Thus, researchers should focus their attention on meaningful conceptual and empirical research to help product developers get started with sustainability. Also, the role of human factors should further be illuminated as the developer’s personality and attitude can have a crucial influence on the outcome of a development project. Moreover, research activities should also include the market perspective as marketing and development tasks are often highly intertwined. Finally, multidisciplinary research (i.e. combining perspectives from diverse fields like social sciences, engineering, and life sciences) is called for to draw a conclusive picture of the sustainability challenge in product development. Taken together, it is concluded that the research questions of this dissertation have been answered sufficiently and, thus, helpful recommendations for theory and practice are provided.

At some point in the future, research on sustainable product development should have evolved to the point where sustainability is simply considered an integral part of products and therefore ceases to exist as an individual research stream through being absorbed by

product development research in general. However, until this is the case, theory and practice should further dedicate considerable resources to gain experiences and build knowledge on the sustainability aspects of product development. Even though the challenge of developing a truly more sustainable product seems paramount for many product developers in the industry, they should not be awestruck. Rather they should look for suitable partners and start the journey one step at a time. They should refrain from hasty reactions and take their time to experiment with new materials, process technologies, and product concepts. Even if this might not yet be the case today, at some point in time the question of whether companies want to engage in sustainability efforts will become rhetorical: they will have to engage.

Companies should make sure they are not caught empty-handed when serious sustainability efforts become standard practice and, thus, sustainable product development as a field of research will be antiquated. Charter & Clark (2008, p. 256) subsume this nicely by predicting that “never mind how big, successful and powerful a business is now, if it does not practice sustainable innovation, it will go the way of the dinosaurs.”

Appendices

Appendix I: Sources of Newspaper Headlines

Ala-Kurikka, S. (2015). Lifespan of Consumer Electronics is Getting Shorter, Study Finds. *The Guardian*, March 3. http://www.theguardian.com/environment/2015/mar/03/lifespan-of-consumer-electronics-is-getting-shorter-study-finds

Balch, O. (2015). The Madness of Drinking Bottled Water Shipped Halfway Round the World. *The Guardian*, July 9. http://www.theguardian.com/sustainable-business/2015/jul/09/bottled-water-shipped-halfway-round--world-madness

Ellson, A. (2015). Workers Who Suffer for Fashion Week. *The Times*, September 16. http://www.thetimes.co.uk/tto/life/fashion/article4557869.ece

Harvey, C. (2016). The Staggering Economic Cost of Air Pollution. *The Washington Post*, January 29. https://www.washingtonpost.com/news/energy-environment/wp/2016/01/29/the-staggering-economic-cost-of-air-pollution/

Kirkpatrick, N. (2015). Making a Living in the Toxic World of Discarded Electronics. *The Washington Post*, April 15. https://www.washingtonpost.com/news/in-sight/wp/2015/04/15/the-children-who-make-a-living-in-the-toxic-world-of-discarded-electronics/

Kristof, N. (2015). Contaminating Our Bodies with Everyday Products. *The New York Times*, November 28. http://www.nytimes.com/2015/11/29/opinion/sunday/contaminating-our-bodies-with-everyday-products.html

Nixon, R. (2015). Food Waste Is Becoming Serious Economic and Environmental Issue, Report Says. *The New York Times*, February 25. http://www.nytimes.com/2015/02/26/us/food-waste-is-becoming-serious-economic-and-environmental-issue-report-says.html

Pearce, f. (2015). Overconsumption Is a Grave Threat to Humanity. *The New York Times*, June 8. http://www.nytimes.com/roomfordebate/2015/06/08/is-overpopulation-a-legitimate-threat-to-humanity-and-the-planet/overconsumption-is-a-grave-threat-to-humanity

Richtel, M. (2016). E-Commerce: Convenience Built on a Mountain of Cardboard. *The New York Times*, February 16. http://www.nytimes.com/2016/02/16/science/recycling-cardboard-online-shopping-environment.html

Taylor, D. (2016). Your Coffee Pod Machine Is Killing the Environment. *The Washington Post*, February 3. https://www.washingtonpost.com/video/business/your-coffee-pod-machine-is-killing-the-environment/2016/02/03/8907f01e-cac2-11e5-b9ab-26591104bb19_video.html

Whipple, T. (2015). Oceans of Plastic Threaten Hundreds of Marine Species. *The Times*, February 21. http://www.thetimes.co.uk/tto/environment/article4361020.ece

Wright, C. (2016). The Best Thing a Business Could Do for the Environment Is Shut Down. *The Guardian*, January 28. http://www.theguardian.com/sustainable-business/2016/jan/28/climate-change-capitalism-business-emotions-heathrow-protest-short-term-profits

Appendix II: Picture Sources

Image	Source	License
	**grgroup** think green design #102447277	Fotolia Vector License
	**J.C. Fields** Stanley High-Visibility Green Screwdrivers http://commons.wikimedia.org/wiki/File%3AStanley_high-visibility_green_screwdrivers.jpg	CC BY-SA 3.0
	**Samatha Marx** This is why I'm excited today http://flic.kr/p/6GFwUU	CC BY 2.0
	**Kārlis Dambrāns** iRobot Roomba 870 http://flic.kr/p/qazkqG	CC BY 2.0
	**raneko** Tesla Model S http://flic.kr/p/qbkmGk	CC BY 2.0
	**Andrew W. Sieber** Boeing Co N5020K http://flic.kr/p/5zpADB	CC BY-NC 2.0
	**olegganko** White Headphones #73168363	Fotolia Standard License L
	**tuomaslehtinen** Closeup of a grey office stapler #73905138	Fotolia Standard License L
	**dulsita** Vajilla de plastico #42007373	Fotolia Standard License L
	**emuck** Blaue Müllsäcke #71543947	Fotolia Standard License L
	**gerasimenuk** Red hairdryer on white background #70214191	Fotolia Standard License L
	**Olga Kovalenko** Toothbrush isolated on a white background #60607445	Fotolia Standard License L

Appendix III: Details on the Literature Reviewed

Authors	Type of Work	Focus	Contribution
Abdalla & Ebeid 2011	Conceptual	One or two bottom lines	Presenting a framework that incorporates a set of guidelines, methodologies, and tools to enable the development of more sustainable electronic products.
Albino et al. 2009	Empirical	One or two bottom lines	Investigating the interrelations between green product development and strategic corporate approaches towards the environment as well as sectoral or geographical specificities.
Alblas et al. 2014	Empirical	Triple bottom line	Investigating extant challenges for implementing and managing sustainability in product development through case study research.
Allione et al. 2012	Conceptual	One or two bottom lines	Complementing a library of innovative materials with eco-properties and subsequently developing a multi-criteria material selection guideline.
Ameta 2009	Conceptual	Triple bottom line	Reviewing metrics used for the development of more sustainable products and outlining future research directions.
Andersson et al. 1998	Conceptual	One or two bottom lines	Outlining a method for incorporating sustainability in product development and strategic planning by combining sustainability principles with LCA.
Armstrong & LeHew 2011	Literature Review	Triple bottom line	Exploring how apparel product development can profit from established processes or practices in other industries that lead innovation for sustainability.
Arnette et al. 2014	Literature Review	Triple bottom line	Reviewing 'Design for X' techniques under the heading of sustainability; calling for combining existing approaches to establish 'Design for Sustainability'.
Aschehoug & Boks 2011	Empirical	Triple bottom line	Identifying and categorizing success criteria for the implementation of sustainability information into product development processes of the automotive industry.
Aschehoug & Boks 2013	Literature Review	Triple bottom line	Reviewing the extant literature and compiling a framework structuring stakeholders' sustainability information relevant for product development.
Aschehoug et al. 2013	Empirical	Triple bottom line	Exploring the type and relevance of information on sustainability aspects already available in early development phases through case studies.
Askham et al. 2012	Conceptual	One or two bottom lines	Developing a tool for strategic decision-making in product development considering sustainability criteria and REACH information.
Azkarate et al. 2011	Conceptual	Triple bottom line	Developing (1) a sustainability index for assessing the sustainability of machine tools and (2) a design support system for sustainability assistance during product design.
Beng & Omar 2014	Conceptual	One or two bottom lines	Proposing a framework integrating axiomatic design principles to support sustainable product development with a focus on manufacturing, supply chain, and end-of-life management.
Bereketli & Genevois 2013	Conceptual	One or two bottom lines	Proposing an integrated 'quality function deployment for the environment' method that enables identifying sustainability-related improvement strategies; applying the method to a hand blender.
Bertoluci & Millet 2009	Conceptual	One or two bottom lines	Analyzing the impact of two design trends (functional enhancement of products and segmentation of production processes) on the environment by three case studies.
Bevilacqua et al. 2007	Conceptual	One or two bottom lines	Discussing an adaption of the 'Design for Environment' method to use LCA data both during NPD and redesign of existing products.
Bey & McAloone 2006	Conceptual	One or two bottom lines	Exemplifying the combined use of LCA methods and eco-design to develop sustainable product service systems.
Bieker 2005	Empirical	Triple bottom line	Exploring the effect of company culture on corporate sustainability management by case study research in R&D departments.
Bisilkas et al. 2012	Conceptual	Triple bottom line	Developing a model for investigating up to what extent sustainability should be incorporated into a product when accounting for market reactions.

Authors	Type of Work	Focus	Contribution
Boks & McAloone 2009	Conceptual	Triple bottom line	Illustrating the maturing process from eco-design to sustainable product design by outlining four research transitions as well as emerging research directions.
Boons & Lüdeke-Freund 2013	Literature Review	Triple bottom line	Reviewing the extant literature on business models in the context of technological, organizational, and social innovation; outlining an agenda for further research.
Buchert et al. 2014a	Conceptual	Triple bottom line	Analyzing current decision support methods for sustainable product development and building a taxonomy of these methods.
Buchert et al. 2014b	Conceptual	Triple bottom line	Analyzing and categorizing existing tools that support sustainable product development; deriving a process-based approach for method selection.
Buchert et al. 2014c	Conceptual	Triple bottom line	Proposing the integration of discrete decision trees with life-cycle sustainability assessment to allow for multi-criteria quantitative evaluation of design alternatives in early development.
Burschel 2003	Position Paper	Triple bottom line	Advocating to revive German design traditions like Bauhaus to foster product sustainability.
Byggeth et al. 2007a	Conceptual	Triple bottom line	Introducing a sustainable product development method including a modular system of questions that guide the process of considering sustainability.
Byggeth et al. 2007b	Conceptual	Triple bottom line	Introducing an iterative sustainability optimization procedure by combining a technical assessment with a sustainability evaluation.
Byggeth & Broman 2001	Conceptual	Triple bottom line	Developing a method for fostering sustainable product development that relates to a sustainability framework and a generic product development process.
Byggeth & Hochschorner 2006	Literature Review	One or two bottom lines	Analyzing eco-design tools whether they support balancing trade-offs and whether they support three-dimensional sustainability considerations.
Carlson & Rafinejad 2008	Conceptual	One or two bottom lines	Modeling sustainability in product development for an integrated exploration of strategic product development decisions and a product's sustainability impact.
Carlson & Rafinejad 2011	Literature Review	Triple bottom line	Providing an overview of (1) contemporary sustainability metrics and (2) guidelines for the transition towards incorporating sustainability in product development.
Chang et al. 2014	Literature Review	One or two bottom lines	Reviewing if LCA-related studies are applicable for the product development context; focusing on extant challenges and future research directions.
Charter 1998	Position Paper	Triple bottom line	Providing an overview of eco-design and ‘Design for Environment’; calling for integrating the social dimension into the product development process.
Charter & Clark 2008	Position Paper	Triple bottom line	Discussing organizational aspects (structure, vision, objectives, and commitment) that need to be taken into account for the development of more sustainable products.
Chen et al. 2012	Conceptual	One or two bottom lines	Proposing and testing a method for evaluating more sustainable designs employing the two-stage network Data Envelopment Analysis.
Chen & Liu 2014	Conceptual	One or two bottom lines	Modeling price variables and financial incentives in the context of deciding between virgin and recycled materials in product development.
Chiu & Chu 2012	Literature Review	Triple bottom line	Reviewing the extant literature on sustainable product design from a life-cycle perspective; discussing general ideas and limitations.
Choi et al. 2008	Conceptual	One or two bottom lines	Developing a framework for decision-making fostering the combined consideration of environmental and business aspects in sustainable product development.
Chu et al. 2011	Conceptual	One or two bottom lines	Presenting an approach for reducing the environmental impact of product development by evaluating the bills of material for design alternatives.
Clancy et al. 2013a	Conceptual	Triple bottom line	Surveying and evaluating approaches for assessing product sustainability in the context of replacing non-renewable materials in hygiene products.

Authors	Type of Work	Focus	Contribution
Clancy et al. 2013b	Conceptual	Triple bottom line	Developing a method for material development to facilitate the development of more sustainable products.
Clark et al. 2009	Conceptual	Triple bottom line	Presenting the 'Design for Sustainability' concept that accounts for life-cycle thinking; illustrating the concept's core by several case studies.
de Coster & Bateman 2012	Conceptual	One or two bottom lines	Outlining different sustainability strategies for the development of different product types as well as cost implications across the product life-cycle.
Cooper 1999	Position Paper	One or two bottom lines	Calling for improving the economic infrastructure to change consumption patterns and progress towards sustainable product development.
Curwen et al. 2012	Empirical	Triple bottom line	Investigating challenges and guiding principles for sustainable product development in the apparel industry through case study research.
Dangelico et al. 2013	Empirical	One or two bottom lines	Surveying the role of external competencies and knowledge on green product development; analyzing whether these factors have an impact on market opportunities or financial performance.
Dangelico & Pujari 2010	Empirical	One or two bottom lines	Investigating the development of environmentally sustainable products in SME through a multiple case study approach; developing a toolbox to meet identified challenges.
Deutz et al. 2010	Position Paper	One or two bottom lines	Advocating that sustainable waste management has to be established as a functional requirement for the product design process.
Dewberry & de Barros 2009	Conceptual	Triple bottom line	Outlining the need to rethink conventional approaches and presenting a method for radical innovation regarding sustainability.
Dewulf 2003	Conceptual	One or two bottom lines	Discussing how social sustainability can be considered in product development processes and whether design would be the crucial phase for this consideration.
Diegel et al. 2010	Position Paper	Triple bottom line	Outlining the opportunities additive manufacturing technologies present for fostering sustainable product development practices.
Dreux-Gerphagnon & Haoues 2011	Conceptual	Triple bottom line	Proposing a method to integrate the social dimension of sustainability into eco-design and LCA.
Driessen et al. 2013	Empirical	One or two bottom lines	Developing an integrative framework for green NPD based on literature and substantiating it by case studies.
Eddy et al. 2013	Conceptual	One or two bottom lines	Introducing a decision analysis method for sustainable product design allowing for conflicting sustainability criteria to be considered in early conceptual design.
Eigner et al. 2011	Conceptual	Triple bottom line	Proposing a monitoring and quantification concept for sustainable product development based on an understanding of sustainability as an integrated triangle.
Eigner et al. 2013	Conceptual	Triple bottom line	Presenting an approach to establish LCA tools as an integrated part of product life-cycle management to enable designers to share relevant product data.
Eigner & Schäfer 2014	Conceptual	Triple bottom line	Substantiating sustainability from an engineering perspective by presenting different sustainability operationalizations and methodological approaches.
Ekins 2010	Conceptual	One or two bottom lines	Investigating public sustainability policies as drivers of emerging eco-industries and far-reaching technological transitions.
Esslinger 2011	Position Paper	Triple bottom line	Calling on designers to be at the forefront of creating (1) new business models driven by sustainability and (2) culturally relevant and politically beneficial more sustainable products.
Fargnoli & Kimura 2006	Conceptual	One or two bottom lines	Developing a streamlined life-cycle approach focusing on the end-of-life of products and building on LCA criteria.
Fargnoli & Kimura 2007	Conceptual	One or two bottom lines	Defining an integrated method for assessing and improving the sustainability performance of products through the environmental effect analysis method and checklists.
Flores et al. 2008	Conceptual	Triple bottom line	Proposing a framework helping organizations to define a roadmap towards sustainable innovation; applying the framework in two case studies.

Authors	Type of Work	Focus	Contribution
Francis 2012	Conceptual	One or two bottom lines	Developing a method for gathering sustainability requirements from customers by using environmental default questions in an elaboration process.
Gagnon et al. 2012	Conceptual	Triple bottom line	Identifying differences between conventional and sustainable design processes; developing an integrated sustainable engineering process accounting for different sustainability levels.
Gam et al. 2009	Conceptual	Triple bottom line	Developing and testing a design model for sustainable apparel that integrates the cradle to cradle concept.
Gam et al. 2011	Conceptual	One or two bottom lines	Investigating the applicability of the 'Design for Disassembly' approach in apparel design.
Gaugler 2013	Conceptual	Triple bottom line	Discussing social and environmental risks related to materials; outlining a roadmap to counter these risks using cobalt as an example.
Gehin et al. 2008	Conceptual	One or two bottom lines	Developing a tool that helps to consider sustainable end-of-life strategies in early phases of product design.
Gerstlberger et al. 2014	Empirical	One or two bottom lines	Surveying the relationship between product innovation and activities aimed at improving the energy efficiency of production facilities.
Ghadimi et al. 2012	Conceptual	Triple bottom line	Developing a weighted fuzzy assessment method for evaluating product sustainability and testing this method within the automotive industry.
Gmelin & Seuring 2014a	Empirical	Triple bottom line	Exploring the role of product data management, process management, and engineering project management for sustainable product development by multiple case studies.
Gmelin & Seuring 2014b	Conceptual	Triple bottom line	Developing a conceptual framework highlighting the relations between sustainability, product development, and product life-cycle management.
Goepp et al. 2014	Conceptual	One or two bottom lines	Developing a design process and data models to support the consideration of sustainability in the design of remanufactured products.
Goffin 2012	Conceptual	Triple bottom line	Outlining key factors for embedding sustainability in NPD by assigning key issues and potential cross-functional conflicts to the stage-gate phases.
Golden et al. 2011	Position Paper	One or two bottom lines	Putting forward how the public sector and industry consortia are driving sustainable product design efforts and which needs should be addressed next.
Gremyr et al. 2014	Literature Review	One or two bottom lines	Exploring through reviews of case studies how improvement efforts based on the 'Robust Design Method' can contribute to sustainable product development.
Grießhammer et al. 2004	Conceptual	Triple bottom line	Analyzing existing sustainability assessment methods and outlining the consideration of social factors using the method 'PROSA' as an example.
Grießhammer et al. 2007	Conceptual	Triple bottom line	Developing an integrated approach to product sustainability assessment incorporating several established analytical tools.
Hallstedt et al. 2010	Conceptual	Triple bottom line	Developing an approach for assessing the integration of sustainability in a company's strategic decision system for product development; testing the approach by case studies.
Hallstedt et al. 2013	Empirical	Triple bottom line	Identifying relevant aspects for successfully implementing a strategic sustainability perspective in the product innovation process by interview studies.
Hallstedt & Thompson 2011	Empirical	One or two bottom lines	Identifying challenges and opportunities of sustainability-driven product development through cases in the aero industry.
Halog 2004	Conceptual	One or two bottom lines	Presenting a framework for integrating LCA, LCC, and QFD methodologies for the purpose of selecting product improvement alternatives under uncertainty.
Hanssen 1999	Conceptual	One or two bottom lines	Investigating findings of six sustainable product development cases with respect to ranking of improvement priorities and trade-offs between sustainability and other product features.
Hanusch 2011	Conceptual	One or two bottom lines	Compiling criteria for assessing the social sustainability of products; analyzing which of these criteria could be influenced by product development decisions.

Authors	Type of Work	Focus	Contribution
Hanusch & Birkhofer 2008	Position Paper	One or two bottom lines	Advocating the consideration of social factors in product development even though constructional measures have little direct influence on the social sustainability of products.
Hanusch & Birkhofer 2010	Conceptual	One or two bottom lines	Outlining a research approach to emphasize the consideration of social factors when designing products; taking into account criteria and responsibilities within a company.
Hasna 2010	Literature Review	Triple bottom line	Reviewing literature (1) to provide an overview of the development of sustainability science and (2) to investigate the relationship between sustainability and engineering.
Hassan et al. 2012	Conceptual	Triple bottom line	Presenting a way to combine morphological analysis theory and an artificial neural network approach to facilitate sustainable product development.
Heintz et al. 2014	Conceptual	One or two bottom lines	Developing a decision-making progress framework for considering sustainability in chemical product design by improved information sharing among stakeholders.
Hoedl 2012	Position Paper	One or two bottom lines	Discussing the interdependencies of sustainable product design and macroeconomic conditions like political decisions and economic prosperity.
Hossain et al. 2014	Conceptual	One or two bottom lines	Proposing the framework 'AutoLCA' for evaluating design alternatives based on the environmental footprint of a product's bill of materials.
Howarth & Hadfield 2006	Conceptual	Triple bottom line	Presenting a conceptual model for examination of sustainability risks and benefits related to design alternatives.
Hu & Bidanda 2009	Conceptual	One or two bottom lines	Modeling a decision support system to facilitate the evaluation of the sustainability of product life-cycles using a Markow decision process.
Hynds et al. 2014	Conceptual	One or two bottom lines	Developing a maturity model for assessing the state of integrating sustainability in product development allowing companies to benchmark themselves over time.
Inoue et al. 2012	Conceptual	Triple bottom line	Proposing a method for supporting decision-making in sustainable product development under uncertainty; applying the method to a multi-objective design problem.
Ioannou & Veshagh 2011	Empirical	Triple bottom line	Surveying key management issues like drivers and barriers associated with the integration of sustainability aspects in the design of new products.
Jaafar et al. 2007	Conceptual	Triple bottom line	Outlining the development of a generic product sustainability evaluation method by building upon a rating system.
Johansson 2008	Empirical	One or two bottom lines	Identifying and characterizing product properties essential for efficient disassembly processes through case study research.
Jolly-Desodt 2009	Conceptual	Triple bottom line	Proposing a decision support system for sustainability-related choices among design alternatives in the textile industry.
Kaebernick et al. 2003	Conceptual	One or two bottom lines	Developing a concept for sustainable product development integrating distinct methods for each stage of the product development process.
Kara et al. 2005	Conceptual	One or two bottom lines	Presenting a framework for integrating sustainable product development in different hierarchical levels; linking tools and activities to these levels.
Kara et al. 2014	Empirical	One or two bottom lines	Investigating the practices of manufacturers towards sustainable product development with respect to company characteristics by a multinational survey.
Kasarda et al. 2007	Conceptual	One or two bottom lines	Presenting the development concept 'Design for Adaptability' aiming at prolonging product life through designing products adaptable to change.
Kerga et al. 2011	Empirical	One or two bottom lines	Surveying how Italian manufacturing companies integrate sustainability into the process of new product development with a focus on legislation and tools.
Kersten et al. 2013	Empirical	One or two bottom lines	Employing an experimental approach to investigate the influence of different stakeholders on sustainability-related decisions in product development.
Klöpffer 2003	Position Paper	Triple bottom line	Calling for using life-cycle thinking for sustainability assessment by consolidating existing and new methods into one instrument.

Authors	Type of Work	Focus	Contribution
Kondoh & Mishima 2013	Conceptual	One or two bottom lines	Proposing an idea-generation method for the development of eco-products using life-cycle indicators, business rules, and illustrative cases.
Krishnan et al. 2013	Conceptual	One or two bottom lines	Discussing policy aspects of sustainable product design regarding energy efficiency household appliances.
de Lange et al. 2013	Literature Review	Triple bottom line	Reviewing existing approaches to assess the sustainability of product/packaging combinations; calling for more transparent and comparable assessment strategies.
Lee-Mortimer & Short 2009	Empirical	Triple bottom line	Investigating obstacles causing the lack of progress towards sustainable product development; outlining empirical research on product specifications as a possible obstacle.
Lewis 2005	Empirical	One or two bottom lines	Presenting the findings of a stakeholder survey in the Australian packaging industry aiming at shaping the discourse on environmental impacts.
Lindow et al. 2013a	Conceptual	Triple bottom line	Conceptualizing a knowledge-based engineering system for supporting engineers to understand the impact of their decisions during product development.
Lindow et al. 2013b	Conceptual	Triple bottom line	Presenting two approaches for supporting sustainable product development: (1) a management-oriented sustainability dashboard and (2) a design method utilizing preference sets.
Ljungberg 2007	Literature Review	One or two bottom lines	Reviewing extant approaches to improve products through conscious material selection and new design methodologies.
Lobos & Babbitt 2013	Conceptual	One or two bottom lines	Presenting a two-part conceptual approach to combat planned obsolescence in the design of information and communication technology.
Luthe et al. 2013	Conceptual	Triple bottom line	Proposing a systems approach for sustainable product design combining LCA and virtual development and applying this approach to the case of skis.
Masera 2001	Position Paper	Triple bottom line	Investigating the effect of sustainable product development in local micro and small enterprises on the situation of communities in developing countries.
Matheis & Fischer 2014	Conceptual	One or two bottom lines	Introducing the ‘cube of sustainability’ method supporting the integration of customer-orientation and other requirements in product development.
Maxwell & van der Vorst 2003	Conceptual	Triple bottom line	Introducing the key features of a method for identifying, assessing, and implementing options for sustainable design of products and services.
May et al. 2012	Empirical	One or two bottom lines	Surveying the implementation of sustainability into product development focusing on legislation and tools.
Mayyas et al. 2013	Conceptual	One or two bottom lines	Proposing a material selection method based on a set of quantifiable measures of material sustainability.
McDonough & Braungart 2002	Position Paper	Triple bottom line	Introducing the idea of the triple top line aiming at refocusing product development from limiting end of pipe liabilities to creating sound products from the start.
de Medeiros et al. 2014	Literature Review	One or two bottom lines	Consolidating extant research on environmentally sustainable product innovation and mapping critical success factors driving product success.
Melles et al. 2011	Conceptual	Triple bottom line	Identifying critical features of socially sustainable product design and illustrating the evolving role and necessary competences of designers.
Metta & Badurdeen 2013	Conceptual	Triple bottom line	Emphasizing the need for coordinating decisions in product development and supply chain design; proposing a framework to perform this coordination.
Ness et al. 2007	Conceptual	Triple bottom line	Reviewing and categorizing sustainability assessment tools; discussing their fit with the more current understanding of sustainability.
Ny et al. 2008	Conceptual	Triple bottom line	Developing a template for sustainable product development helping to understand major sustainability challenges and opportunities related to a product category.
Ny et al. 2013	Conceptual	Triple bottom line	Investigating how extant tools for sustainable product development could be adapted for developing sustainable product service systems.

Authors	Type of Work	Focus	Contribution
Ogunseitan & Schoenung 2012	Position Paper	Triple bottom line	Advocating a stronger integration of toxicity metrics into material databases to better assess the impact of materials on product sustainability.
Olson et al. 2011	Conceptual	One or two bottom lines	Introducing a method to incorporate sustainability considerations in the early design stages and to account for traditional supply chain metrics.
Palousis et al. 2010	Conceptual	Triple bottom line	Outlining a sustainability risk assessment method for product development to factor in the effects of sustainability risks on life-cycle cost.
de Pauw et al. 2015[36]	Conceptual	One or two bottom lines	Proposing two constituents to extant life-cycle-based assessment of products to include aspects of nature-inspired design.
Petala et al. 2010	Empirical	Triple bottom line	Exploring the challenges of incorporating sustainability in early stages of NPD by analyzing the contents of NPD briefs within the FMCG industry.
Pettersen & Boks 2008	Conceptual	Triple bottom line	Discussing ethical dilemmas arising when engineering solutions for sustainable behavior and outlining adequate solutions for behavioral change.
Rahimifard et al. 2009	Literature Review	One or two bottom lines	Reviewing applications and case studies to identify relevant drivers, barriers, and challenges in the context of sustainable product recovery and recycling.
Ramani et al. 2010	Literature Review	One or two bottom lines	Reviewing the status of integrating life-cycle data into eco-design tools; providing a framework for further research.
Rathod et al. 2011	Conceptual	One or two bottom lines	Integrating 'environmentally conscious quality function deployment' (ECQFD) and LCA; applying the method in a case study.
Romli et al. 2015	Conceptual	One or two bottom lines	Developing a decision-making method by combining LCA, an eco-design process model, and an adapted QFD; applying the method to a case product.
Sheldrick & Rahimifard 2013	Literature Review	One or two bottom lines	Providing an overview of the evolution from eco-design to sustainable design; assessing current practice and identifying future research challenges.
Short 2008	Position Paper	Triple bottom line	Addressing the actual meaning of sustainable engineering and resulting implications for engineers in industry; identifying six key principles that underpin sustainable engineering.
de Silva et al. 2009	Conceptual	Triple bottom line	Proposing a scoring method for quantitative sustainability evaluation in developing consumer electronic products.
Spangenberg et al. 2010	Conceptual	Triple bottom line	Presenting a research project aiming at embedding sustainability in design as well as design in sustainability; describing the framework of the project, obstacles, and lessons learned.
Stark et al. 2008	Conceptual	Triple bottom line	Proposing an approach utilizing scenarios and a competence management tool for facilitating the consideration of sustainability in product development processes.
Strömberg et al. 2015	Conceptual	Triple bottom line	Creating a map of pathways of sustainable behavior and outlining how to target specific behavior classes by product design.
Subic et al. 2009	Literature Review	One or two bottom lines	Reviewing sustainability-related issues associated with the use of composites or synthetic fibers in the development of sports products.
Sutcliffe et al. 2009	Conceptual	Triple bottom line	Developing a framework mapping different aspects of sustainability against product life-cycle stages for supporting decision-making in NPD.
Tabone et al. 2010	Conceptual	One or two bottom lines	Evaluating the efficacy of green design principles by conducting LCA for biopolymers and petroleum-based polymers and comparing the findings of both approaches.
Tambouratzis et al. 2014	Conceptual	One or two bottom lines	Proposing a computational intelligence-based method for identifying the properties of maximally sustainable materials for a given application.

[36] This article as well as Romli et al. 2015 and Strömberg et al. 2015 were published as EarlyView in 2014 and thus fall into this review's period. They appeared in the journal in 2015.

Authors	Type of Work	Focus	Contribution
Thompson et al. 2011a	Empirical	Triple bottom line	Exploring how sustainability evaluations can be successfully integrated into product innovation emphasizing the product service system approach.
Thompson et al. 2011b	Empirical	Triple bottom line	Exploring where and how sustainability considerations are taken into account in the product innovation process through interviews in Swedish companies.
Thompson et al. 2012	Conceptual	Triple bottom line	Developing introductory approaches for a decision support process guiding product developers during development, evaluation, and validation of sustainable product concepts.
Tingström et al. 2006	Empirical	One or two bottom lines	Exploring how ABB integrated sustainability within their mainstream product development process model.
Tseng et al. 2012	Conceptual	One or two bottom lines	Developing a web-based system helping to include environmental sustainability considerations in conceptual product development.
van Weenen 1995	Position Paper	Triple bottom line	Advocating the shift from reducing environmental impacts towards the concept of sustainable product development.
Venkatesh et al. 2013	Conceptual	One or two bottom lines	Investigating the suitability of different wood polymer composites and possible design applications to promote long-term resource sustainability.
Verhulst & Boks 2012a	Empirical	Triple bottom line	Studying different trajectories and approaches companies take towards the implementation of life-cycle thinking and sustainable design through case study research.
Verhulst & Boks 2012b	Empirical	Triple bottom line	Investigating the emergence of sustainable business models related to the implementation of sustainable design strategies through case study research.
Verhulst & Boks 2012c	Empirical	Triple bottom line	Exploring the role of the two human factors ‘resistance against sustainability’ and ‘internal communication’ for implementing sustainable product development.
Verhulst & Boks 2014	Empirical	Triple bottom line	Investigating the role of the individual employee for the success of sustainable product development implementation through case study research.
Verhulst et al. 2012	Empirical	Triple bottom line	Discussing aspects related to the implementation of sustainable product innovation focusing on human aspects; exploring how sustainable business models emerge.
Vinodh et al. 2014	Conceptual	One or two bottom lines	Proposing a model integrating ECQFD, the theory of inventive problem solving, and an analytic hierarchy process.
Vinodh & Rajanayagam 2010	Conceptual	One or two bottom lines	Presenting findings from a case study applying environmental analyses and ‘Design for Manufacturability’ principles for the redesign of an exemplary product.
Vinodh & Rathod 2010	Conceptual	One or two bottom lines	Proposing a model integrating ECQFD and LCA approaches for sustainable product development.
Waage 2007	Conceptual	Triple bottom line	Drawing a roadmap for integrating systems and sustainability perspectives into decisions in product development, manufacturing, and logistics.
Wang et al. 2010	Conceptual	One or two bottom lines	Proposing a method building on ECQFD and LCA for facilitating sustainable product design.
Wever & Boks 2007	Conceptual	One or two bottom lines	Discussing possible adaptations of extant methods to allow for developing more sustainable products in the Fuzzy Front End.
Winkler 2011	Conceptual	One or two bottom lines	Presenting a method of sustainable engineering for considering reversible process structures based on the second law of thermodynamics.
Woll et al. 2011	Conceptual	Triple bottom line	Suggesting a method for cross-disciplinary evaluation of product sustainability utilizing the house of quality approach and aspects from LCA methods.
Xing et al. 2013	Conceptual	One or two bottom lines	Developing a multi-dimensional assessment model to support the sustainability evaluation of product service system alternatives.
Yan et al. 2009	Conceptual	One or two bottom lines	Proposing a more sustainable product conceptualizing system to integrate functional, marketing, and commercial aspects and product sustainability considerations.
Zarandi et al. 2011	Conceptual	One or two bottom lines	Proposing a method for preliminary filtering of materials for more sustainable products; developing a prototype expert system.

Appendix IV: Interview Guideline for Qualitative Analysis

Interview Guideline

Part A: Introduction

1. Please provide a brief overview of your company and your responsibilities within the company.

Part B: Organization of Product Development Process

1. How do you structure your product development process?
2. How do you make fundamental development decisions? How is the decision-making authority distributed among product development members?
3. How do you integrate supply chain partners into your product development process?

Part C: Sustainability

1. How do you define „sustainability" within your company?
2. Why and how is your company getting involved with sustainability? How are activities related to sustainability institutionalized within your company?
3. Who can be seen as major driving force for sustainability activities within your company?

Part D: Development of Sustainable Products

1. How do you define „sustainable product"? What makes a product sustainable?
2. What would be a sustainable product from your domain?
3. How do you integrate sustainability into your product development process?
4. How do you identify trade-offs with respect to sustainable products? How do you handle them?

Appendix V: Proof Quotes for Findings of Qualitative Analysis

Support for	Quote from Participant
Proposition 1	I define sustainability in the sense that our consumers can enjoy using our products for a long period. That is what I make of sustainability in our context. **#4, Leisure and sports equipment**
	Our products are in use for 20 years while others would be broken within six months. That is a level of sustainability that you could not even calculate. The material is not touched again, there is no production, there is no logistics, and the consumers do not have to get something new. Quite inapprehensible how sustainable that is, right? **#8, Household articles**
	Like I said, sustainability can mean functionality as well. Think of the demographic change: a keep-fresh pack that can be easily opened by aging people with shaky hands is a sustainable product that helps to cope with everyday life. That is another way of defining sustainability: through product features and handling. **#10, Household articles**
	That one chooses raw materials from renewable sources or recycled materials; I think that is most often meant when people talk about sustainability. **#13, Stationery**
	I think our products are sustainable through their functions and also because they can alter their users' behavior. For example, if you manage to design an attractive bundle buggy, then people rather walk for shopping and leave the car at home. **#14, Personal items**
	For us, sustainability means offering products that are not trendy or fashionable and that do not go out of style fast. **#19, Leisure and sports equipment**
	Sustainability is defined through the damage my product does to the environment. That is what I personally understand as sustainability. Starting with the manufacturing of each component and ending with the product's disposal – how much damage did the product do to the environment? **#21, Body care products**
Proposition 2	At some point, one had the impression that sustainability is so worn out that people cannot bear to hear it anymore. However, it is actually going in the opposite direction. If you do not jump on the bandwagon and progress into this direction, then you will be outpaced in no time. **#1, Household commodities**
	We experience repeated inquiries from consumers about the manufacturing of the product and the materials we use – probably stimulated by television reports about working standards in countries like Bangladesh. Such media coverage always triggers a temporary interest in knowing a little more about the product's origin. **#5, Medical and therapeutic products**
	I think sustainability considerations will become obligatory; I truly believe that. (…) Also, the gap between the cost-driven companies and the strong brands will further emerge. And those companies in the spotlight of public attention will definitely have to prove their actions regarding sustainability. **#17, Toys**
	We all witnessed the policy efforts to limit the power consumption of vacuum cleaners. Because more power does not mean that they actually perform better. I can image that in the long run such regulation will also be in place for power tools. **#26, Home and garden tools**
	I believe this topic will become more important in the future. Especially when the standard of living improves further throughout the big Asian countries. (…) Things will change, I truly believe that. **#27, Home and garden tools**
	We know what our products are made of. And these fossil raw materials will become scarce in the near future. Whatever may still sound absurd today will be mandatory tomorrow when everything else gets more and more expensive. It has always been this way. **#28, Home and garden commodities**
Proposition 3	I am sure it has something to do with our size...or lack thereof. We are completely at the peril of the suppliers and dare we say we want something more sustainable. They just give us the boot. I really miss suppliers pitching ecologically sustainable products to us. **#3, Household commodities**
	If I can change the packaging, then this can make the product more sustainable and also more profitable. But we are really feeling the limitations of being a smaller player in the market. We can't get our suppliers to make the changes necessary just for us because that would require them to alter their design. We can only hope they go there on their own eventually. **#3, Household commodities**
	Everyone is always looking to the automotive sector to see how it is done. But they have a wholly different level of influence on their suppliers. If one of the big brands approaches a supplier to get something changed, say a material, then the supplier jumps to action. We come in with a request, and they might listen politely, but that is the end of that. **#11, Furniture**
	Volume buys you influence. With respect to polymers, well, our products do not need that much plastic; there are other firms with way larger quantities. These guys have influence and can ask for more sustainable inputs, we just get laughed at, we have no say. Revenue makes relationships. **#13, Stationery**

Support for	Quote from Participant
	Sadly, our standard material is still polyester, and we will not be able to change that. I mean, it is not toxic or anything. However, without polyester, we probably wouldn't have any product. **#14, Personal items**
	The challenge for us emerges to get access to the more sustainable materials. We've been through quite a lot actually. When we first approached companies to reuse their waste as inputs for our products, they were skeptical: 'It's just trash, why would you want it?' Then we educated them on the possibilities and when they caught the drift, a couple of months in, it turned to: 'We have our own use for this stuff now; you're not getting anything from us anymore'. And you are back to square one, looking for the next firm. It's frustrating. **#15, Stationery**
	When we first got involved in this sustainability effort, we approached the supplier with the goal to make 100 or 200 units. If you suggest engaging in a joint development effort with these kinds of numbers, people laugh at you. We actually had that happen to us. **#16, Personal items**
	We tried to integrate some suppliers in sustainability efforts, but...well, let's just say we are not the automotive industry. They approach someone with two million units, and we want to talk about 2,000. The suppliers' enthusiasm to pursue this with us is...limited...to put it nicely. **#26, Home and garden tools**
	If a company like Bosch approaches BASF because they want to have a new material for a switch they produce 20 million times, sure BASF will assign 10 of their people to find something as soon as possible. If we approach our supplier for plastic injection molding parts and ask for a new material for our annual 10,000 valves, they will not care. Even though we are by far the biggest player on our market, we always have to struggle with minimum order quantities. **#31, Leisure and sports equipment**
Proposition 4	We developed an eco-line one time, where we very much emphasized sustainability. Basically, the maximum you can do. The bottle was made from 100 percent recycled material, all ingredients were made from renewable resources, everything was certified. However, it is not that consumers reward that in any way. **#3, Household commodities**
	Henkel experienced that as well with a similar line of products. Even though they spent millions on advertising, their expectations were far from being met. **#3, Household commodities**
	I find it interesting to observe companies developing a line of more sustainable products. And when these products do not meet their sales expectations, they are killed. Sure, you can kill an entire product line because you made a mistake or something, but you cannot kill the idea of product sustainability, right? But that happens a lot. Then it becomes clear that sustainability was not really at these companies' hearts. **#8, Household articles**
	With this line of sustainable products, we want to show that we care about sustainability also beyond our internal processes. **#10, Household articles**
	We know similar concepts from the toys industry. For example, one manufacturer of sandbox toys recently introduced a "green" line of products. The products are rather pastel-colored and are made from biopolymers. **#19, Leisure and sports equipment**
	For many of the larger firms, I can't shake the impression of greenwashing. They just pick one little issue out of the buffet of options to enhance sustainability and implement it as a quick win for a new product line because they really lack the commitment to systematically overhaul their entire production **#23, Federal authority**
Proposition 5	These eco-products you find in the supermarket and their packaging are green for a reason, right? Most of the time also the detergent itself is green. That happens for a reason. **#11, Furniture and lighting**
	I would try to visually differentiate such a sustainable product line. People should have the chance to recognize it. For example, if I would make a wooden product, then it should look like wood. Today, eco-products definitely have to have that eco-look on them. **#14, Personal items**
	I worked for another company before, and we were engaged in developing a set of stationery from cork as part of an eco-line. It had a strong ecological touch, especially regarding its visual appearance. **#19, Leisure and sports equipment**
	We know similar concepts from the toys industry. For example, one manufacturer of sandbox toys recently introduced a "green" line of products. The products are rather pastel-colored and are made from biopolymers. However, they managed to create an attractive product despite the limited chromaticity. **#19, Leisure and sports equipment**
	You try to follow the market if you design a separate eco-line that looks odd. The reason is that not all consumers can already decode such products. **#19, Leisure and sports equipment**
Proposition 6	Unlike us, our competitors do not go down that road far enough. They do not truly embrace sustainability. They just change the material of one component and still use the old material for the rest of the product. **#16, Personal items**
	What we did as some first steps were pretty easy things. (…) We focused on areas that are easily measurable and where changes are easy to implement. **#17, Toys**

Support for	Quote from Participant
	I know about projects with the goal of doing something really environmentally friendly. However, actually all of these projects got nowhere near far enough from my point of view because they are only focused on material issues. **#19, Leisure and sports equipment**
	Through such an approach you unnecessarily limit your target group to these do-gooders that buy such products out of idealism and that eventually accept possible down-sides. **#30, Consumer electronics**
	In my company, nobody would accept a product that looks stereotyped eco-friendly. They would say: 'Thanks for your effort, but we cannot sell that.' **#30, Consumer electronics**
	A product is a successful product if it is designed in an attractive way. Whether this means choosing brown or rather pink as the color is another question. At least for me a product does not have to be colored in earthy tones to give me a feeling of environmental friendliness. **#31, Leisure and sports equipment**
Proposition 9	That one chooses raw materials from renewable sources or recycled materials. I think that is most often meant when people talk about sustainability. **#13, Stationery**
	However, what we experience – especially with big companies – is that they always focus on one specific area. This may be materials or an improvement of energy efficiency. They exclusively focus on one area and try to achieve improvements there. And when you propose to look at other important aspects, they have not thought about that before or have problems to integrate that into their development process. **#23, Federal authority**
	It is probably the material. The material usage. That is something that could be improved regarding sustainability and that we are actually working on. **#26, Home and garden tools**
	We try to make sure that environmentally friendly technology and cultivation methods are applied to produce the materials we use for our products. **#32, Body care products**
Proposition 10 & Proposition 11	Sustainability is not a separate issue we focus on. It is considered together with all other aspects. It is not yet defined as stand-alone criteria or requirement. **#3, Household commodities**
	In our product development process, sustainability is not very high on the agenda. I mean, it is not that we ever established certain criteria to ensure that we are especially environmentally friendly or something. **#4, Leisure and sports equipment**
	We have a close look at sustainability issues, but I would not call it a target system yet. That is something I will work on in the future – setting clear sustainability requirements for product development. **#9, Domestic appliances**
	That is exactly what I meant when I said that the industry does not know the sustainability requirements yet. What requirements do we have to fulfill if we want to be sustainable? What do we have to do? At which level am I allowed to lean back since I'm sustainable now? **#19, Leisure and sports equipment**
	Well… we consider sustainability in our minds. (…) Yes, I think it is really more of a notional thing until now. Sustainability is not yet backed up methodologically in our development process. **#21, Body care products**
	I think that will keep us very busy over the next years. We have some ideas that we want to elaborate, but the actual indicators and measures are really hard to find. **#28, Home and garden commodities**
Proposition 12	For example, we have some product functions that can be achieved best through fluorine-based ingredients. However, they are not exactly good for the environment. There are some alternatives. However, consumers would complain because product quality would suffer. **#3, Household commodities**
	From the start, we avoided phosphate for our products. As a result, our early products were not able to match the competing products' performance because there was no suitable alternative to phosphate back then. **#12, Household commodities**
	Also, if we would have to limit our material range, we would have to boil down our product portfolio as well. We simply wouldn't be able to offer some of our products anymore. **#13, Stationery**
	Of course, we would want to develop ink that decomposes quickly if it ends up in the groundwater. However, this would come at a cost. The bacteria do not wait until the ink gets into the groundwater; they are all over the place as soon as the consumers open the cap for the first time. And then we would have mold growing on the pen. **#15, Stationery**
	Our product performance can suffer. The durability of the product decreases, and we would get all kinds of customer complaints. **#21, Body care products**
Proposition 13	I am constantly faced with the question if it makes sense to use food production resources to make our products, or are we keeping someone from growing the food they need? There are so many up- and downsides, this is far from the silver bullet as things currently stand. **#1, Household commodities**
	The technical performance just isn't the same. If we were to use regular plastics for this product, we would get a much better performance from a technical standpoint. **#1, Household commodities**

Support for	Quote from Participant
	The waste treatment plants currently aren't ready to deal with bioplastics. They have to sort out all of it because it wrecks their equipment in the long run. They just end up burning it. For us, bioplastics make no sense right now; I just don't consider it sustainable in the current situation until the recycling issue changes. **#10, Household articles**
	Public perception is something we monitor very closely. We have seen that happen with other firms out there, Danone, for example, with their PLA[37] cups. There is someone with a good idea to begin with, and then it all blows up in their face because the environmental performance is questioned. That really gave bioplastics a poor image. **#13, Stationery**
	The material did not behave like we had thought it would. We had a much larger variability than expected; specs were a huge problem. **#17, Toys**
	We have the choice between a conventional input and materials from bioplastics. To get the performance right, I have to use more than double the inputs from the renewable stuff compared to petroleum-based plastics. **#18, Home and garden commodities**
	One material we could use is made from grains, which is food! So we could make our packaging from this, and then people throw it in the trash? I cannot see how that could be sustainable. **#18, Home and garden commodities**
	I would suggest that consumers at large are skeptical towards plastics from alternative sources. There is so much uncertainty. **#20, Stationery**
	We looked at many alternative materials, renewable ones. We tested everything we could find, but we couldn't get it to work yet. It just won't meet quality standards. **#20, Stationery**
	We have looked at using the castor bean to make bioplastics for our products, but that is a very delicate topic. Not because it does not work but because a good idea can turn into a PR[38] disaster in no time. **#21, Body care products**
Proposition 14	We could have long discussions if it makes sense that our Italian supplier works with FSC-certified[39] wood that grows in a Polish forest, that is then transported to Italy, then processed in Italy, then sent off to France where the processing continues, then shipped to us. And in the end, we deliver the finished product to a customer in Poland. I mean, just because the wood is FSC-certified that does not mean that the whole process is environmentally friendly. **#11, Furniture and lighting**
	Calculating sustainability for our extremely long supply chain is something we could not do. **#11, Furniture and lighting**
	Of course, I would like to know where every single component comes from. For some parts, I know that pretty well. However, there are also components that are bought from German suppliers and they, in turn, buy their material in China. This means we do not really know where it comes from. And that is something I as a designer cannot oversee. **#30, Consumer electronics**
Proposition 15	One of our factories took the initiative and got FSC-certified in 2003. Nobody was telling them to do this. In 2004, I visited them, and they told me that they would be able to produce FSC-certified pens. I thought this would be a great idea and talked to our marketing guys: 'We do not want FSC. Nobody needs such pens' they said. This great opportunity just fell on deaf ears. **#15, Stationery**
	We introduced electrical injection molding machines (…). And of course, we bought the best machines available – also from an economic point of view. We saved more than half of our previous energy demand, which is quite something, right? But still, there was much awareness training and persuading to be done. People in manufacturing were very critical and said the new machines would not be as good as the old hydraulic machines. You literally had to take them by the hand and persuade them of the quality and new possibilities we now had. **#15, Stationery**
	The biggest roadblocks exist within the company. That is where it all starts. But for this new more sustainable material that I found, the supplier equipped me with loads of brochures and case studies. They showcased that also huge companies like HP, Nike, and Apple use this material. And if you circulate these brochures within your company, suddenly everyone says: 'If they are on the bus, I like it as well.' If you have some cases with well-known companies pulling this topic, then things get a lot easier for you. **#17, Toys**
	But if you just go for more sustainability – I already told you about the water-based paint we now use instead of the solvent-based paint for some of our products – then marketing is all over the place (…). Now, after we have introduced it without their endorsement, they hold long speeches how great and environmentally friendly our new paint is. **#30, Consumer electronics**
Proposition 16	Sadly, at the end of the day, the consumers are not really interested in sustainability. Maybe their interest will grow a little through these days' hype. However, the purchasing decision is still driven by the product design. At least that is the situation in our industry. **#2, Apparel**

[37] PLA = Polylactic Acid.

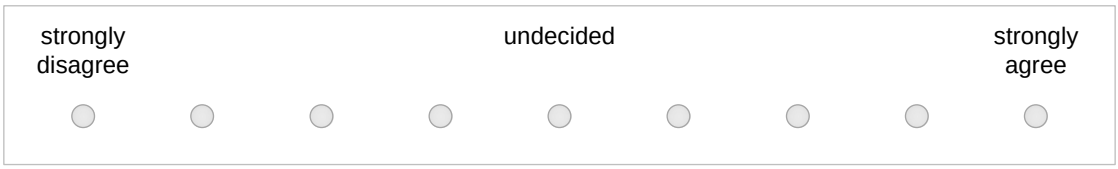
[38] PR = Public Relations.

[39] FSC = Forest Stewardship Council.

Support for	Quote from Participant
	I do think that major parts of the population are indeed sensitized for sustainability and green products. However, at the register, most are not willing to pay more – especially families that have to squeeze every Euro. **#4, Leisure and sports equipment**
	We surveyed our customers about their material preferences, and they clearly indicated that they could not care less – just keep the price down. **#6, Household commodities**
	Our research clearly shows that consumers could not care less. They think that sustainability is nice to have but also think that one pen does not make a difference. That is why they are not on the look for more sustainable alternatives. **#13, Stationery**
	However, as soon as it comes to spending money, people are like: 'No, not really. 20 Euro more for having a clean conscious? No, thank you.' **#19, Leisure and sports equipment**
	Consumers will not care as long as there is no regulation in place that sanctions or subsidizes certain products. They are simply not interested that much. **#20, Stationery**
	If consumers cared about sustainability, they would not buy cheap products that go bust after using them for an hour. **#26, Home and garden tools**
	Sustainability would not be a selling point for our products. Consumers primarily look for design, performance, and safety. They will buy whatever does well in this respect. **#31, Leisure and sports equipment**
Proposition 17	I would really like to know how one could influence consumers towards buying more sustainably. What do I have to do that in the end consumers not only buy something because it looks nice but also because they know about the product's environmental benefits and good working conditions? **#2, Apparel**
	Many companies are failing to bring some unsustainable, shitty products to market, but there are also many companies failing with sustainability. It does not pay if the consumers do not get the point about product sustainability. I think it is always challenging to actually make this point. **#8, Household articles**
	The authorities are not able to control everything. But we know very well what kinds of products are offered on the retailers' shelves. Especially when it gets back to school, every discounter promotes cheap stationery. We can only watch helplessly. And then a few weeks later we find reports in online forums about how much better the crayons from discounter XY are compared to the products from German manufacturers. We know why that is the case, but we cannot do anything about it. **#15, Stationery**
	I mean, small children utter their toys all the time, right? They basically suck on petroleum-lollipops. So, I would expect that plant-based plastics should be a huge selling point for toys. But people do not get the point. I think they just don't understand the relations. They probably don't even know what most plastics are made of. **#17, Toys**
	The product should not smell like compost, but it should feature perceivable information that consumers actually can decode. If we put some sustainability stickers on our products, then nobody cares. However, if these stickers would serve as a suitable possibility of comparison, then it gets interesting. **#26, Home and garden tools**
Proposition 18	Sustainability has become a trendy catch-phrase that companies use to sell their products. I doubt that most companies have a genuine interest in sustainability. **#6, Household commodities**
	If you print the FSC label onto your catalog, nobody will question what that actually means. It only means that the paper the catalog is made of is certified. It has no implication for any of the products in the catalog. And such things happen a lot. They are exploited by marketing because most retailers or consumers do not know what it means anyway. **#11, Furniture and lighting**
	I have a simple rule of thumb: the greener the logos, the websites, and the slogans, the less trustworthy they are. I know that this is an oversimplification, but it holds true most of the time. **#15, Stationery**
	Our competitors but also other companies producing outdoor equipment make a huge fuzz about sustainability at the moment. And if you look at it closely they are all talking trash. And we definitely don't want to join those chants. **#31, Leisure and sports equipment**

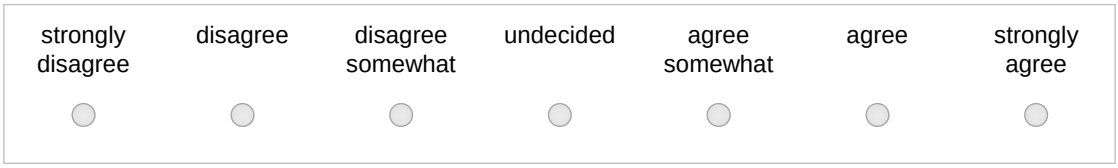
Appendix VI: Scales Used for Quantitative Analysis

Scale 1: Agreement (9 point Likert scale)



Scale 2: Opinion (7 point Likert scale)

Scale 3: Agreement (7 point Likert scale)



Scale 4: Self-assessment (7 point Likert scale)

Appendix VII: PS 1 - Questionnaire

PRODUCT CLASSIFICATION

1. Classification

Please indicate for each product category how much you agree with the following statements. **(Scale 1)**

A: The product typically is of high value.

B: The product is a durable product. I typically use it over a long period of time.

C: I typically purchase the product with a low frequency.

D: Purchasing the product typically is a highly involving activity.

E: I am engaged in intensive information search before purchasing the product.

F: I consciously evaluate the alternatives available before purchasing the product.

G: I typically use purchasing advice or services (e.g. online reviews) before purchasing the product.

H: Friends' opinions and their recommendations have a considerable impact on my decision to purchase the product.

I: I can express my personality through the product.

J: Fashion trends have a considerable impact on my decision which alternative I purchase.

K: Through choosing between different product alternatives I can make a big difference in terms of environmental sustainability.

L: Through choosing between different product alternatives I can make a big difference in terms of social sustainability.

2. Possession of Products

Please indicate which products you possess.

A: Headphones

B: Stapler

C: Plastic Dishes

D: Garbage Bags

E: Hair Blower

F: Toothbrush

3. Price

Please indicate which price you typically pay for the product. If you haven't bought one yet, please indicate what you expect to pay (in $).

A: Headphones

B: Stapler

C: Plastic Dishes

D: Garbage Bags

E: Hair Blower

F: Toothbrush

DEMOGRAPHICS

10. Age

What is your age?

11. Gender

What is your gender?

A: Female

B: Male

12. Education

What is the highest degree of level of school you have completed?

A: Less than high school degree

B: High school degree or equivalent

C: Undergraduate degree

D: Graduate degree

E: Doctorate degree

13. Income

What was your total income before taxes during the past 12 months?

A: Less than $25,000

B: $25,000 to $34,999

C: $35,000 to $49,999

D: $50,000 to $74,999

E: $75,000 to $99,999

F: $100,000 to $149,999

G: $150,000 or more

14. Comments

Is there anything you would like to tell us with respect to this survey?

Appendix VIII: PS 1 - Results of One-way ANOVA and Descriptive Statistics

Item		df1	df2	F	Sig. (2-tailed)	P1 Head-phones		P2 Stapler		P3 Picnic Dishes		P4 Garbage Bags		P5 Hair Blower		P6 Tooth-brush	
						M_{P1}	SD_{P1}	M_{P2}	SD_{P2}	M_{P3}	SD_{P3}	M_{P4}	SD_{P4}	M_{P5}	SD_{P5}	M_{P6}	SD_{P6}
1A	Value	5	213.60	60.44	< .001***	6.78	1.71	3.90	2.19	3.03	2.03	2.77	2.09	6.04	1.79	3.65	2.57
1B	Durability	5	212.12	65.21	< .001***	6.30	2.23	7.76	1.33	5.18	2.62	2.89	2.23	7.16	1.53	5.43	2.15
1C	Purchase Frequency	5	213.88	100.69	< .001***	7.13	2.11	7.90	1.49	6.63	2.30	2.90	1.89	7.67	1.83	3.93	1.97
1D	Involvement	5	213.20	40.78	< .001***	5.89	2.44	2.59	1.68	2.68	1.84	2.19	1.54	5.13	2.38	4.01	2.29
1E	Information Search	5	213.86	110.39	< .001***	7.13	1.72	2.41	1.86	2.09	1.50	2.09	1.59	5.23	2.41	2.86	1.92
1F	Evaluation	5	213.97	43.33	< .001***	7.34	1.89	3.48	2.45	3.32	2.33	3.70	2.51	5.51	2.56	4.54	2.56
1G	Advice	5	214.14	75.66	< .001***	6.99	2.08	2.47	1.99	2.10	1.80	2.03	1.75	5.15	2.76	2.61	2.05
1H	Recommendation	5	213.49	20.19	< .001***	5.47	2.67	2.42	1.71	2.35	1.92	2.39	1.85	3.89	2.68	3.00	2.30
1I	Personality	5	214.15	36.99	< .001***	6.61	2.30	2.89	2.20	3.32	2.55	2.25	1.85	3.78	2.61	3.56	2.33
1J	Fashion Trends	5	212.97	8.45	< .001***	3.92	2.84	2.01	1.41	2.37	1.88	1.89	1.46	3.00	2.35	2.39	1.84
1K	Environmental Sustainability	5	461	26.08	< .001***	4.13	2.36	3.68	2.22	6.46	2.28	6.71	2.23	4.29	2.21	4.25	2.34
1L	Social Sustainability	5	461	6.25	< .001***	4.15	2.23	3.66	2.22	5.04	2.28	5.05	2.45	3.92	2.19	3.69	2.12
3	Price ($)	5	210.53	213.17	< .001***	55.43	59.19	8.82	4.79	8.30	6.95	6.28	3.96	31.85	17.53	4.25	2.72

Appendix IX: PS 1 - Results of Games-Howell Test

Item			**P2** Stapler	**P3** Picnic Dishes	**P4** Garbage Bags	**P5** Hair Blower	**P6** Tooth-brush
1A	Value	**P1** Headphones	<.001***	<.001***	<.001***	.084*	<.001***
		P2 Stapler		.103	.015**	<.001***	.989
		P3 Picnic Dishes			.972	<.001***	.563
		P4 Garbage Bags				<.001***	.202
		P5 Hair Blower					<.001***
1B	Durability	**P1** Headphones	<.001***	.047**	<.001***	.059*	.147
		P2 Stapler		<.001***	<.001***	.102	<.001***
		P3 Picnic Dishes			<.001***	<.001***	.987
		P4 Garbage Bags				<.001***	<.001***
		P5 Hair Blower					<.001***
1C	Purchase Frequency	**P1** Headphones	.092*	.724	<.001***	.514	<.001***
		P2 Stapler		.001***	<.001***	.956	<.001***
		P3 Picnic Dishes			<.001***	.025**	<.001***
		P4 Garbage Bags				<.001***	.016**
		P5 Hair Blower					<.001***
1D	Involvement	**P1** Headphones	<.001***	<.001***	<.001***	.357	<.001***
		P2 Stapler		>.999	.613	<.001***	<.001***
		P3 Picnic Dishes			.448	<.001***	.002***
		P4 Garbage Bags				<.001***	<.001***
		P5 Hair Blower					.045**
1E	Information Search	**P1** Headphones	<.001***	<.001***	<.001***	<.001***	<.001***
		P2 Stapler		.846	.860	<.001***	.678
		P3 Picnic Dishes			>.999	<.001***	.075*
		P4 Garbage Bags				<.001***	.087*
		P5 Hair Blower					<.001***
1F	Evaluation	**P1** Headphones	<.001***	<.001***	<.001***	<.001***	<.001***
		P2 Stapler		.998	.994	<.001***	.105
		P3 Picnic Dishes			.922	<.001***	.031**
		P4 Garbage Bags				<.001***	.322
		P5 Hair Blower					.196
1G	Advice	**P1** Headphones	<.001***	<.001***	<.001***	<.001***	<.001***
		P2 Stapler		.829	.674	<.001***	.998
		P3 Picnic Dishes			>.999	<.001***	.588
		P4 Garbage Bags				<.001***	.417
		P5 Hair Blower					<.001***
1H	Recommendation	**P1** Headphones	<.001***	<.001***	<.001***	.004***	<.001***
		P2 Stapler		>.999	>.999	.001***	.498
		P3 Picnic Dishes			>.999	.001***	.427

Item			**P2** Stapler	**P3** Picnic Dishes	**P4** Garbage Bags	**P5** Hair Blower	**P6** Tooth-brush
		P4 Garbage Bags				.001***	.482
		P5 Hair Blower					.251
1I	Personality	**P1** Headphones	<.001***	<.001***	<.001***	<.001***	<.001***
		P2 Stapler		.866	.372	.185	.463
		P3 Picnic Dishes			.037**	.863	.991
		P4 Garbage Bags				.001***	.003***
		P5 Hair Blower					.993
1J	Fashion Trends	**P1** Headphones	<.001***	.001***	<.001***	.230	.002***
		P2 Stapler		.762	.994	.021**	.725
		P3 Picnic Dishes			.472	.425	>.999
		P4 Garbage Bags				.006***	.436
		P5 Hair Blower					.475
1K	Environmental Sustainability	**P1** Headphones	.828	<.001***	<.001***	.998	>.999
		P2 Stapler		<.001***	<.001***	.517	.649
		P3 Picnic Dishes			.981	<.001***	<.001***
		P4 Garbage Bags				<.001***	<.001***
		P5 Hair Blower					>.999
1L	Social Sustainability	**P1** Headphones	.730	.141	.160	.987	.789
		P2 Stapler		.002***	.003***	.974	>.999
		P3 Picnic Dishes			>.999	.025**	.003***
		P4 Garbage Bags				.032**	.005***
		P5 Hair Blower					.986
3	Price	**P1** Headphones	<.001***	<.001***	<.001***	.238	<.001***
		P2 Stapler		.640	.015**	<.001***	<.001***
		P3 Picnic Dishes			.807	<.001***	<.001***
		P4 Garbage Bags				<.001***	.003***
		P5 Hair Blower					<.001***

Appendix X: PS 2 - Questionnaire

PRODUCT EVALUATION

1. Product Quality

Please indicate your opinion about the product: **(Scale 2)**

A: The likelihood that the product is reliable is:
B: The workmanship of the product is:
C: The quality of the product is:
D: The likelihood that the product is dependable is:

2. Environmental Sustainability

Please indicate how much you agree with the following statements. **(Scale 3)**

A: The product is produced in an environmentally friendly way.
B: The product is usable in an environmentally friendly way.
C: The product is disposable in an environmentally friendly way.
D: All things considered, this is an environmentally friendly product.

3. Social Sustainability

Please indicate how much you agree with the following statements. **(Scale 3)**

A: The product is produced in a socially beneficial way.
B: The product is usable in a socially beneficial way.
C: The product is disposable in a socially beneficial way.
D: All things considered, this is a socially beneficial product.

4. Purchase Intention

Please indicate how much you agree with the following statements. **(Scale 3)**

A: I would like to try this product.
B: I would buy this product if I happen to see it in a store.
C: I would actively seek out this product (in a store to purchase it).
D: I would recommend this product to a friend.

5. Price

Please indicate your opinion about the product.

A: If you would need one, what would you be willing to pay for the product? (in $)

6. Aesthetics

I perceive the product as: **(Semantic Differentials on a 7 point scale)**

A: offensive | enjoyable
B: poor-looking | nice-looking
C: displeasing | pleasing

D: unattractive | attractive

E: appearing bad | appearing good

F: ugly | beautiful

OVERALL QUESTIONS

7. Manipulation Check for Design Manipulation

Please indicate the main colors of the products you just evaluated.

A: Headphones: _____

B: Stapler: _____

C: Picnic Dishes: _____

D: Garbage Bags: _____

E: Hair Blower: _____

F: Toothbrush: _____

8. Manipulation Check for Material Manipulation *(not used in Preliminary Studies 2 and 3)*

Please indicate which materials the products you just evaluated were made from.

A: Headphones: _____

B: Stapler: _____

C: Picnic Dishes: _____

D: Garbage Bags: _____

9. Green Consumption

Please indicate how much you agree with the following statements. **(Scale 3)**

A: It is important to me that the products I use do not harm the environment.

B: I consider the potential environmental impact of my actions when making many of my decisions.

C: My purchase habits are affected by my concern for our environment.

D: I am concerned about wasting the resources of our planet.

E: I would describe myself as environmentally responsible.

F: I am willing to be inconvenienced in order to take actions that are more environmentally friendly.

10. Socially Sustainable Consumption

Please indicate how much you agree with the following statements. **(Scale 3)**

A: I buy a product only if I believe that workers' human rights are adhered to.

B: I buy a product only if I believe that no illegal child labor is involved.

C: I buy a product only if I believe that workers are not discriminated against.

D: I buy a product only if I believe that workers are not abused.

E: I buy a product only if I believe that workers are treated fairly or are fairly compensated.

11. Ambivalence

Please answer the following questions. **(Scale 4)**

A: How indecisive were you when evaluating the products?

B: How conflicted did you feel when evaluating the products?

C: How much mixed emotion did you feel when evaluating the six products?

DEMOGRAPHICS

12. Age

What is your age?

13. Gender

What is your gender?

A: Female

B: Male

14. Education

What is the highest degree of level of school you have completed?

A: Less than high school degree

B: High school degree or equivalent

C: Undergraduate degree

D: Graduate degree

E: Doctorate degree

15. Income

What was your total income before taxes during the past 12 months?

A: Less than $25,000

B: $25,000 to $34,999

C: $35,000 to $49,999

D: $50,000 to $74,999

E: $75,000 to $99,999

F: $100,000 to $149,999

G: $150,000 or more

16. Comments

Is there anything you would like to tell us with respect to this survey?

Appendix XI: PS 2 - Results of t-Tests and Descriptive Statistics

Product	Item		T	df	Sig. (2-tailed)	$M_{Original}$	M_{Green}	$SD_{Original}$	SD_{Green}	d
P1 Head-phones	Product Quality	Composite (α=.955)	2.61	126	.010**	5.22	4.66	1.11	1.33	.46
	Environmental Sustainability	Composite (α=.943)	4.28	126	< .001***	3.37	4.42	1.34	1.42	.76
	Social Sustainability	Composite (α=.942)	2.22	126	.028**	4.07	4.62	1.41	1.41	.39
	Purchase Intention	Composite (α=.935)	1.68	126	.096*	4.43	3.97	1.51	1.57	.30
	Willingness to Pay ($)		2.11	126	.037**	40.30	29.03	34.96	20.41	.40
	Aesthetics	Composite (α=.971)	4.33	105.80	< .001***	5.57	4.48	1.12	1.67	.77
P2 Stapler	Product Quality	Composite (α=.924)	.73	126	.464	5.21	5.05	1.09	1.30	.13
	Environmental Sustainability	Composite (α=.934)	4.17	126	< .001***	3.56	4.58	1.25	1.49	.74
	Social Sustainability	Composite (α=.942)	2.60	126	.011**	3.99	4.61	1.26	1.40	.47
	Purchase Intention	Composite (α=.910)	1.48	126	.143	3.72	4.08	1.30	1.50	.26
	Willingness to Pay ($)		2.84	125	.005***	6.27	9.51	5.66	7.00	.51
	Aesthetics	Composite (α=.958)	.18	126	.855	4.93	4.88	1.15	1.44	.04
P3 Picnic Dishes	Product Quality	Composite (α=.924)	.86	126	.393	5.13	5.30	1.13	1.09	.15
	Environmental Sustainability	Composite (α=.923)	4.49	126	< .001***	3.90	4.89	1.19	1.30	.79
	Social Sustainability	Composite (α=.922)	2.42	126	.017**	4.17	4.70	1.30	1.09	.44
	Purchase Intention	Composite (α=.942)	.97	126	.332	3.86	4.12	1.58	1.36	.18
	Willingness to Pay ($)		1.95	126	.054*	7.67	9.75	6.71	7.12	.30
	Aesthetics	Composite (α=.949)	1.18	126	.242	5.16	4.80	1.14	1.32	.29
P4 Garbage Bags	Product Quality	Composite (α=.926)	.08	126	.934	4.86	4.88	1.35	1.02	.02
	Environmental Sustainability	Composite (α=.970)	5.10	126	< .001***	3.58	5.02	1.62	1.57	.90
	Social Sustainability	Composite (α=.961)	3.79	126	< .001***	3.94	4.92	1.57	1.35	.67
	Purchase Intention	Composite (α=.937)	2.23	126	.028**	3.84	4.43	1.52	1.44	.40
	Willingness to Pay ($)		.72	125	.471	6.62	6.43	5.44	4.16	.04
	Aesthetics	Composite (α=.957)	.40	126	.694	4.42	4.50	1.23	1.21	.06

Product	Item		T	df	Sig. (2-tailed)	$M_{Original}$	M_{Green}	$SD_{Original}$	SD_{Green}	d
P5 Hair Blower	Product Quality	Composite (α=.938)	2.87	120.35	.005***	5.47	4.92	.88	1.29	.50
	Environmental Sustainability	Composite (α=.941)	1.11	126	.269	3.28	3.55	1.36	1.47	.19
	Social Sustainability	Composite (α=.942)	.58	126	.563	3.75	3.90	1.42	1.39	.11
	Purchase Intention	Composite (α=.954)	.64	126	.525	3.77	3.58	1.65	1.73	.11
	Willingness to Pay ($)		1.69	126	.094*	24.97	22.46	16.88	14.34	.16
	Aesthetics	Composite (α=.960)	3.22	124.66	.002***	5.32	4.58	1.13	1.47	.56
P6 Tooth-brush	Product Quality	Composite (α=.917)	1.55	116.83	.123	5.49	5.26	.82	1.30	.21
	Environmental Sustainability	Composite (α=.914)	3.85	126	< .001***	3.74	4.67	1.31	1.43	.68
	Social Sustainability	Composite (α=.937)	1.39	126	.169	4.23	4.60	1.40	1.59	.25
	Purchase Intention	Composite (α=.929)	1.45	126	.149	4.45	4.07	1.39	1.59	.25
	Willingness to Pay ($)		.95	123	.344	3.96	4.33	3.00	3.22	.12
	Aesthetics	Composite (α=.961)	.50	126	.617	4.89	5.01	1.29	1.42	.09

Appendix XII: PS 3 - Results of t-Tests and Descriptive Statistics

Product	Item		T	df	Sig. (2-tailed)	$M_{Original}$	M_{Green}	$SD_{Original}$	SD_{Green}	d
P1 Head-phones	Product Quality	Composite (α=.952)	2.92	95.26	.004***	4.95	4.17	1.18	1.47	.59
	Environmental Sustainability	Composite (α=.855)	4.74	99	< .001***	3.19	4.30	.98	1.35	.94
	Social Sustainability	Composite (α=.840)	3.33	99	.001***	3.43	4.18	1.01	1.25	.66
	Purchase Intention	Composite (α=.865)	1.70	99	.093*	3.87	3.37	1.41	1.50	.34
	Willingness to Pay (€)		.22	99	.824	40.60	39.25	26.33	31.05	.05
	Aesthetics	Composite (α=.916)	3.47	99	.001***	4.94	4.17	1.04	1.18	.69
P2 Stapler	Product Quality	Composite (α=.921)	.02	99	.986	5.46	5.23	.98	1.15	.22
	Environmental Sustainability	Composite (α=.831)	3.76	99	< .001***	3.51	4.35	1.06	1.20	.74
	Social Sustainability	Composite (α=.873)	2.37	99	.020**	3.97	4.51	1.18	1.13	.47
	Purchase Intention	Composite (α=.779)	.01	99	.991	4.13	4.13	1.34	1.26	0
	Willingness to Pay (€)		.84	99	.403	7.73	8.47	4.14	4.58	.17
	Aesthetics	Composite (α=.917)	.75	99	.453	4.80	4.65	.91	1.05	.15
P3 Picnic Dishes	Product Quality	Composite (α=.889)	.43	99	.670	5.14	5.23	1.05	1.13	.08
	Environmental Sustainability	Composite (α=.833)	3.45	99	.001***	3.83	4.67	1.18	1.24	.69
	Social Sustainability	Composite (α=.840)	2.10	99	.038**	4.15	4.66	1.29	1.14	.42
	Purchase Intention	Composite (α=.815)	.98	99	.328	3.81	4.08	1.42	1.25	.20
	Willingness to Pay (€)		1.03	99	.304	6.94	8.06	4.07	5.50	.23
	Aesthetics	Composite (α=.907)	2.08	99	.040**	4.76	4.33	1.09	1.01	.41
P4 Garbage Bags	Product Quality	Composite (α=.928)	.53	99	.596	4.91	5.03	1.28	1.00	.10
	Environmental Sustainability	Composite (α=.908)	5.47	99	< .001***	2.84	4.33	1.33	1.39	1.10
	Social Sustainability	Composite (α=.890)	3.09	99	.003***	3.77	4.53	1.24	1.23	.62
	Purchase Intention	Composite (α=.811)	.19	99	.853	4.53	4.48	1.41	1.45	.04
	Willingness to Pay (€)		.82	99	.417	2.60	2.42	1.42	1.18	.14
	Aesthetics	Composite (α=.855)	.95	99	.345	4.05	4.19	.75	.71	.19

Product	Item		T	df	Sig. (2-tailed)	$M_{Original}$	M_{Green}	$SD_{Original}$	SD_{Green}	d
P5 Hair Blower	Product Quality	Composite (α=.958)	3.78	79.74	< .001***	5.07	4.16	.88	1.48	.75
	Environmental Sustainability	Composite (α=.912)	1.36	99	.177	2.79	3.14	1.22	1.30	.28
	Social Sustainability	Composite (α=.863)	.70	99	.489	3.59	3.77	1.29	1.20	.14
	Purchase Intention	Composite (α=.879)	3.93	99	< .001***	3.89	2.78	1.48	1.36	.78
	Willingness to Pay (€)		.90	99	.370	25.00	25.24	9.68	20.66	.02
	Aesthetics	Composite (α=.934)	7.13	82.42	< .001***	4.82	3.36	.77	1.22	1.43
P6 Tooth-brush	Product Quality	Composite (α=.942)	.70	99	.487	5.35	5.43	1.23	1.01	.07
	Environmental Sustainability	Composite (α=.842)	4.57	99	< .001***	3.36	4.46	1.17	1.25	.91
	Social Sustainability	Composite (α=.870)	3.88	99	< .001***	3.91	4.88	1.31	1.20	.77
	Purchase Intention	Composite (α=.862)	.39	99	.699	4.36	4.48	1.55	1.42	.08
	Willingness to Pay (€)		.17	98	.863	2.73	2.68	1.61	1.06	.04
	Aesthetics	Composite (α=.928)	.79	99	.430	4.77	4.94	1.06	1.14	.15

Appendix XIII: PS 2 and 3 - Comparison of Results

Product	Item	Original Exterior Design						"Green" Exterior Design					
		T	df	Sig. (2-tailed)	M_{PS2}	M_{PS3}	d	T	df	Sig. (2-tailed)	M_{PS2}	M_{PS3}	d
P1 Head-phones	Product Quality	1.22	116	.227	5.20	4.95	.22	1.86	111	.066*	4.66	4.17	.35
	Environmental Sustainability	.96	115.99	.338	3.39	3.19	.17	.44	111	.659	4.42	4.30	.08
	Social Sustainability	2.80	116	.006***	4.08	3.43	.52	1.74	111	.085*	4.62	4.18	.33
	Purchase Intention	2.06	116	.042**	4.42	3.87	.38	2.06	111	.042**	3.97	3.37	.39
	Aesthetics	3.08	116	.003***	5.56	4.94	.57	1.15	108.65	.253	4.48	4.17	.21
P2 Stapler	Product Quality	1.31	107	.194	5.20	5.46	.25	.80	120	.428	5.05	5.23	.15
	Environmental Sustainability	.34	107	.734	3.58	3.51	.07	.95	120	.344	4.59	4.35	.17
	Social Sustainability	.12	107	.908	4.00	3.97	.02	.40	120	.687	4.61	4.51	.07
	Purchase Intention	1.54	107	.126	3.74	4.13	.30	.09	120	.930	4.11	4.13	.02
	Aesthetics	.67	107	.507	4.93	4.80	.13	1.04	120	.299	4.89	4.65	.19
P3 Picnic Dishes	Product Quality	.04	122	.972	5.13	5.14	.01	.17	105	.862	5.27	5.23	.03
	Environmental Sustainability	.30	122	.768	3.90	3.83	.05	.79	105	.430	4.86	4.67	.15
	Social Sustainability	.10	122	.924	4.18	4.15	.02	.09	105	.927	4.68	4.66	.02
	Purchase Intention	.17	122	.869	3.86	3.81	.03	.16	105	.877	4.11	4.08	.03
	Aesthetics	1.95	122	.054*	5.16	4.77	.36	2.11	105	.037**	4.81	4.33	.41
P4 Garbage Bags	Product Quality	.22	115	.826	4.86	4.91	.04	.83	112	.408	4.87	5.04	.16
	Environmental Sustainability	2.77	111.56	.007***	3.60	2.84	.51	2.34	112	.021**	5.01	4.33	.45
	Social Sustainability	.75	109.90	.457	3.96	3.77	.14	1.50	112	.137	4.91	4.54	.29
	Purchase Intention	2.48	115	.015**	3.86	4.53	.46	.20	112	.846	4.42	4.48	.04
	Aesthetics	2.13	95.48	.036**	4.45	4.05	.39	1.79	111.94	.076*	4.51	4.19	.31
P5 Hair Blower	Product Quality	2.26	109	.026**	5.45	5.07	.43	3.03	118	.003***	4.92	4.16	.56
	Environmental Sustainability	2.01	109	.047**	3.29	2.79	.38	1.71	118	.090*	3.58	3.14	.32
	Social Sustainability	.64	109	.523	3.76	3.59	.12	.62	118	.540	3.91	3.77	.11
	Purchase Intention	.38	109	.705	3.78	3.89	.07	2.77	118	.007***	3.59	2.78	.51

Product	Item	Original Exterior Design						"Green" Exterior Design					
		T	df	Sig. (2-tailed)	M_{PS2}	M_{PS3}	d	T	df	Sig. (2-tailed)	M_{PS2}	M_{PS3}	d
	Aesthetics	2.62	109	.010**	5.31	4.82	.50	4.85	118	< .001***	4.60	3.36	.90
P6 Toothbrush	Product Quality	.58	123	.560	5.46	5.35	.11	.75	104	.454	5.26	5.43	.15
	Environmental Sustainability	1.79	123	.076*	3.76	3.36	.32	.78	104	.439	4.67	4.46	.15
	Social Sustainability	1.33	123	.187	4.23	3.91	.24	1.01	104	.316	4.60	4.88	.20
	Purchase Intention	.34	123	.738	4.45	4.36	.06	1.37	104	.175	4.07	4.48	.27
	Aesthetics	.57	123	.573	4.89	4.77	.10	.25	104	.804	5.01	4.94	.05

Appendix XIV: Main Experiment - Results of Two-way ANOVA

Product	Item		Main Effects of Exterior Design				Main Effects of Material Information				Interaction Effects				Homo-scedastic Data
			df1	df2	F	Sig. (2-tailed)	df1	df2	F	Sig. (2-tailed)	df1	df2	F	Sig. (2-tailed)	
E1 Head-phones	Product Quality	Composite (α=.961)	1	504	14.20	<.001***	3	504	.78	.507	3	504	.71	.548	
	Environmental Sustainability	Composite (α=.951)	1	504	20.71	<.001***	3	504	59.28	<.001***	3	504	1.87	.134	
	Social Sustainability	Composite (α=.943)	1	504	15.45	<.001***	3	504	32.96	<.001***	3	504	.08	.973	
	Purchase Intention	Composite (α=.953)	1	504	2.56	.110	3	504	11.45	<.001***	3	504	.90	.440	
	Willingness to Pay		1	504	11.62	.001***	3	504	3.17	.024**	3	504	.28	.843	✓
	Aesthetics	Composite (α=.962)	1	504	51.84	<.001***	3	504	2.71	.044**	3	504	1.01	.387	
E2 Stapler	Product Quality	Composite (α=.939)	1	504	.02	.886	3	504	4.15	.006***	3	504	1.36	.254	✓
	Environmental Sustainability	Composite (α=.930)	1	504	25.68	<.001***	3	504	56.56	<.001***	3	504	3.95	.008***	
	Social Sustainability	Composite (α=.942)	1	504	11.72	.001***	3	504	38.24	<.001***	3	504	2.96	.032**	
	Purchase Intention	Composite (α=.929)	1	504	4.74	.030**	3	504	12.06	<.001***	3	504	1.55	.201	✓
	Willingness to Pay		1	504	17.18	<.001***	3	504	3.24	.022**	3	504	1.00	.391	
	Aesthetics	Composite (α=.958)	1	504	.59	.444	3	504	3.54	.015**	3	504	.49	.686	

Product	Item		Main Effects of Exterior Design				Main Effects of Material Information				Interaction Effects				Homo-scedastic Data
			df1	df2	F	Sig. (2-tailed)	df1	df2	F	Sig. (2-tailed)	df1	df2	F	Sig. (2-tailed)	
E3 Picnic Dishes	Product Quality	Composite (α=.935)	1	504	5.49	.020**	3	504	4.56	.004***	3	504	1.11	.344	✓
	Environmental Sustainability	Composite (α=.940)	1	504	32.37	<.001***	3	504	96.95	<.001***	3	504	2.34	.073*	
	Social Sustainability	Composite (α=.944)	1	504	22.29	<.001***	3	504	45.49	<.001***	3	504	1.61	.186	
	Purchase Intention	Composite (α=.949)	1	504	2.07	.151	3	504	19.94	<.001***	3	504	.29	.829	✓
	Willingness to Pay		1	504	9.44	.002***	3	504	3.37	.018**	3	504	.17	.919	✓
	Aesthetics	Composite (α=.959)	1	504	5.11	.024**	3	504	5.32	.001***	3	504	.31	.819	✓
E4 Garbage Bags	Product Quality	Composite (α=.948)	1	504	1.52	.218	3	504	11.93	<.001***	3	504	.68	.568	✓
	Environmental Sustainability	Composite (α=.970)	1	504	22.84	<.001***	3	504	107.28	<.001***	3	504	4.30	.005***	
	Social Sustainability	Composite (α=.963)	1	504	17.06	<.001***	3	504	67.33	<.001***	3	504	1.46	.225	
	Purchase Intention	Composite (α=.952)	1	504	5.94	.015**	3	504	40.30	<.001***	3	504	.44	.721	
	Willingness to Pay		1	504	.06	.805	3	504	2.90	.034**	3	504	.38	.765	✓
	Aesthetics	Composite (α=.950)	1	504	.00	.995	3	504	11.98	<.001***	3	504	.42	.740	✓

Appendix XV: Main Experiment - Descriptive Statistics

Product	Item		Exterior Design					Material Information							
			$M_{Original}$	$SD_{Original}$	M_{Green}	SD_{Green}	d	M_{FB}	SD_{FB}	M_{PC}	SD_{PC}	M_{BB}	SD_{BB}	M_{NI}	SD_{NI}
E1 Head-phones	Product Quality	Composite (α=.961)	5.27	1.07	4.87	1.35	.33	5.10	1.28	5.17	1.24	5.04	1.16	4.95	1.25
	Environmental Sustainability	Composite (α=.951)	4.14	1.71	4.73	1.79	.34	3.35	2.02	5.52	1.18	5.11	1.32	3.88	1.47
	Social Sustainability	Composite (α=.943)	4.26	1.56	4.75	1.59	.31	3.59	1.78	5.16	1.26	5.04	1.29	4.34	1.43
	Purchase Intention	Composite (α=.953)	4.19	1.59	3.94	1.85	.15	3.36	1.84	4.47	1.55	4.29	1.74	4.21	1.55
	Willingness to Pay ($)		32.72	26.82	24.47	20.71	.34	25.43	24.97	26.76	19.44	27.34	21.10	34.84	29.29
	Aesthetics	Composite (α=.962)	5.48	1.14	4.55	1.71	.64	4.71	1.53	5.13	1.65	5.20	1.36	5.04	1.51
E2 Stapler	Product Quality	Composite (α=.939)	5.36	1.07	5.37	1.18	.01	5.46	1.09	5.59	1.03	5.28	1.14	5.13	1.20
	Environmental Sustainability	Composite (α=.930)	4.34	1.67	4.95	1.58	.38	3.63	1.82	5.57	1.20	5.25	1.23	4.11	1.47
	Social Sustainability	Composite (α=.942)	4.45	1.54	4.85	1.49	.26	3.76	1.68	5.41	1.13	5.06	1.34	4.32	1.37
	Purchase Intention	Composite (α=.929)	4.05	1.51	4.33	1.58	.18	3.69	1.69	4.56	1.54	4.59	1.36	3.91	1.41
	Willingness to Pay ($)		6.95	4.73	8.53	5.39	.31	6.60	4.01	8.01	4.56	8.43	4.88	7.99	6.59
	Aesthetics	Composite (α=.958)	5.08	1.20	4.99	1.46	.07	4.94	1.34	5.35	1.17	4.91	1.50	4.90	1.31

Product	Item		Exterior Design					Material Information							
			$M_{Original}$	$SD_{Original}$	M_{Green}	SD_{Green}	d	M_{FB}	SD_{FB}	M_{PC}	SD_{PC}	M_{BB}	SD_{BB}	M_{NI}	SD_{NI}
E3 Picnic Dishes	Product Quality	Composite (α=.935)	5.32	1.15	5.56	1.10	.21	5.31	1.16	5.56	1.15	5.68	1.06	5.20	1.11
	Environmental Sustainability	Composite (α=.940)	4.45	1.72	5.13	1.64	.40	3.27	1.89	5.76	1.02	5.64	1.20	4.32	1.33
	Social Sustainability	Composite (α=.944)	4.49	1.61	5.07	1.43	.38	3.76	1.84	5.47	1.13	5.37	1.27	4.40	1.24
	Purchase Intention	Composite (α=.949)	4.05	1.69	4.26	1.60	.13	3.32	1.75	4.57	1.47	4.68	1.54	3.97	1.49
	Willingness to Pay ($)		6.32	5.26	7.59	5.98	.23	5.54	5.10	6.93	5.45	6.64	4.42	8.56	6.94
	Aesthetics	Composite (α=.959)	5.17	1.33	4.89	1.46	.20	4.64	1.54	5.18	1.40	5.29	1.35	5.01	1.23
E4 Garbage Bags	Product Quality	Composite (α=.948)	5.04	1.21	5.21	1.26	.14	4.82	1.28	5.65	1.11	5.26	1.20	4.87	1.17
	Environmental Sustainability	Composite (α=.970)	4.23	2.00	5.09	1.86	.45	2.91	1.95	5.91	1.09	5.72	1.21	4.37	1.75
	Social Sustainability	Composite (α=.963)	4.27	1.79	4.98	1.67	.41	3.23	1.77	5.61	1.35	5.40	1.25	4.48	1.53
	Purchase Intention	Composite (α=.952)	4.13	1.66	4.59	1.76	.27	3.26	1.68	5.13	1.59	5.05	1.42	4.16	1.50
	Willingness to Pay ($)		5.60	3.85	6.33	5.41	.16	4.88	3.44	6.33	6.37	6.30	4.04	6.52	4.76
	Aesthetics	Composite (α=.950)	4.44	1.23	4.50	1.38	.05	3.95	1.24	4.82	1.32	4.71	1.29	4.46	1.22

Appendix XVI: Main Experiment - Results of Games-Howell Test

Product	Item	Sig. (2-tailed)					
		$M_{FB} \Leftrightarrow M_{PC}$	$M_{FB} \Leftrightarrow M_{BB}$	$M_{FB} \Leftrightarrow M_{NI}$	$M_{PC} \Leftrightarrow M_{BB}$	$M_{PC} \Leftrightarrow M_{NI}$	$M_{BB} \Leftrightarrow M_{NI}$
P1 Head-phones	Product Quality	.970	.983	.791	.845	.516	.938
	Environmental Sustainability	<.001***	<.001***	.071*	.054*	<.001***	<.001***
	Social Sustainability	<.001***	<.001***	.001***	.882	<.001***	<.001***
	Purchase Intention	<.001***	<.001***	<.001***	.824	.536	.982
	Willingness to Pay	.729	.490	.023**	.979	.189	.346
	Aesthetics	.145	.034**	.288	.979	.973	.817
P2 Stapler	Product Quality	.759	.606	.101	.111	.005***	.702
	Environmental Sustainability	<.001***	<.001***	.101	.157	<.001***	<.001***
	Social Sustainability	<.001***	<.001***	.023**	.109	<.001***	<.001***
	Purchase Intention	<.001***	<.001***	.671	.998	.003***	.001***
	Willingness to Pay	.080*	.131	>.999	.997	.184	.257
	Aesthetics	.047**	.998	.996	.045**	.019**	>.999
P3 Picnic Dishes	Product Quality	.308	.054*	.874	.824	.049**	.004***
	Environmental Sustainability	<.001***	<.001***	<.001***	.827	<.001***	<.001***
	Social Sustainability	<.001***	<.001***	.009***	.919	<.001***	<.001***
	Purchase Intention	<.001***	<.001***	.010***	.948	.005***	.002***
	Willingness to Pay	.485	.364	.025**	.998	.412	.499
	Aesthetics	.017**	.003***	.164	.927	.691	.323
P4 Garbage Bags	Product Quality	<.001***	.019**	.986	.045**	<.001***	.042**
	Environmental Sustainability	<.001***	<.001***	<.001***	.552	<.001***	<.001***
	Social Sustainability	<.001***	<.001***	<.001***	.614	<.001***	<.001***
	Purchase Intention	<.001***	<.001***	<.001***	.982	<.001***	<.001***
	Willingness to Pay	.495	.031**	.077*	.673	.806	.998
	Aesthetics	<.001***	<.001***	.004***	.899	.131	.406

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