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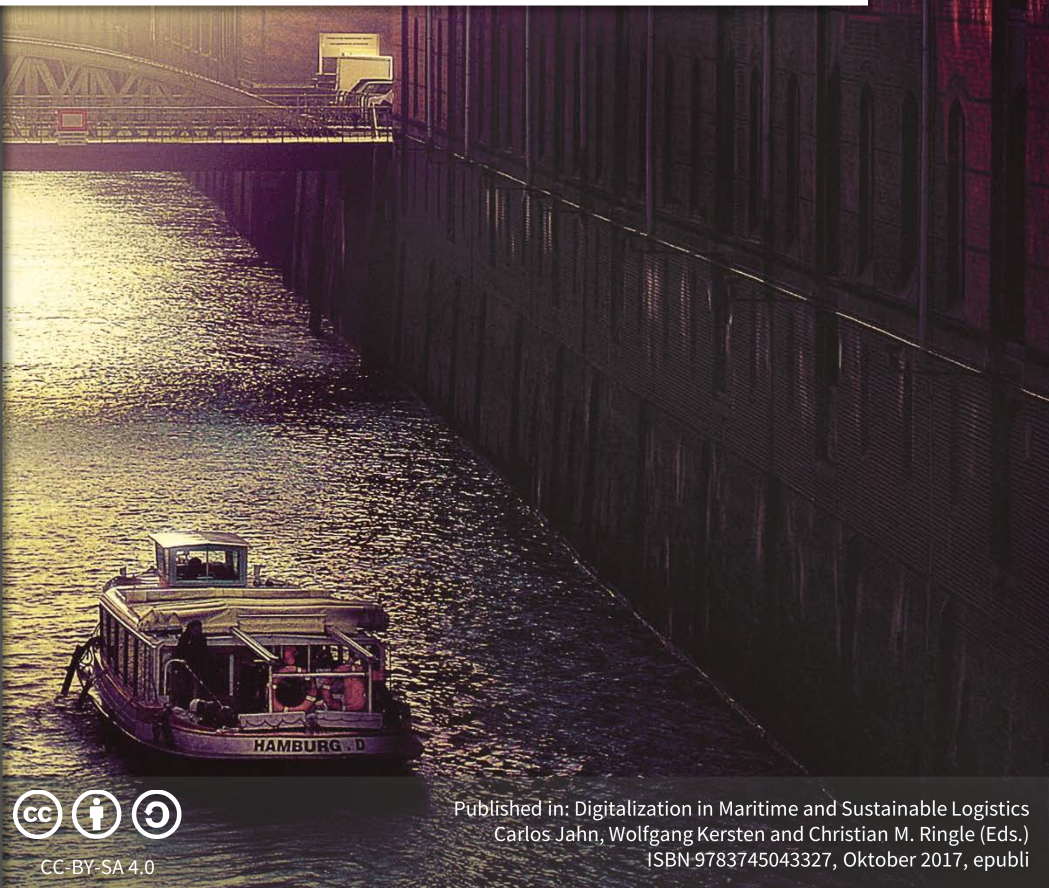

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Smart Logistics of organic waste collection in cities

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Waste management is a growing problem all around the world with implications to society, environment, health and economy. In this context, the waste is considered as the last step in the consuming process. However, a smart waste management is possible by the generation of value from the garbage and the optimization of collection routes, landfills location and the determination of the transport fleet. This article addresses the problem of value generation from organic waste in cities, which is used for the compost generation, biofuels (as an alternative to fossil fuels) and specialized landfills.

The objective of this paper is to develop a conceptual decision support system (DSS) that allows efficient linkages between large organic garbage generators inside the cities (e.g. restaurants, health and educational institutions, food markets) with organic waste consumers, located outside the urban boundaries, who are responsible for recycling and generating value from the garbage (e.g. farms, special landfills, compost and biofuels). The DSS proposes both collection and delivery routes in combination with the fleet required where the information can be updated in order to reflect changes in supply and demand. Because of that, there is a benefit to the waste management and a reduction in the volume of organic waste in municipal landfills. The approach originality is based in the integration of suppliers, demands and transport services in a collaborative DSS that combines different techniques and theories.

The managerial implications are related with new waste value and its value chain, with new services in the decision process with impact in the sustainability.

Keywords: organic waste; smart logistics; decision support system; municipality waste management

1 Introduction

Each year the volume of garbage generated increases with the growth of the population and its centralization in the cities, which causes it territorial expansion and the known consequences (e.g. more time to move inside the city, impact on transport, new urban logistics, etc.). According to last sources, only half of the population has access to a controlled waste elimination system (Hoornweg & Bhada-Tata, 2012) and because of that, the waste management is a global problem with impacts in the society, cities, environment and economy. However, in the last decades there were some successful cases related with smart waste management, they have demonstrated to be a good business with important benefits as public saving, reduction in greenhouse gases, new jobs creation, contamination reduction, landfill longer life and better economic benefits.

The urban waste is classified in organic, recycle inorganic, non-recycle inorganic and special or dangerous garbage (Greco et al, 2015). In this paper, the object under study is the solid organic waste.

Even though traditional solutions to waste management have been implemented in landfills, many of them (in most of the Latin-American countries) are still uncontrolled in regard to the impact on the environment, society, and health, because they don't satisfy the technical requirements of polluting soil, water, and air.

In addition, the solid organic waste in landfills increase the negative effects because of the methane, deep-water pollution and smells; in other hand, there is more economics costs. This problem is more visible because the waste accumulation and overproduction, and the solid organic waste in landfills is not sustainable in time. Like the other kinds of waste, the solution is related to prevent its generation and its re-introduction to productive systems, which means that an intelligent waste management system could solve help in solving not only environment issues, but also promoting new jobs positions. This is a paradigm shift where the garbage is seen not as a burden but as an opportunity.

Reducing, reusing, recycling and recovering waste will reduce the demand for natural resources, but the base of this change is the education, information and awareness raising on the whole population.

The European community is the most advanced in programs and strategies related with the smart waste management, countries such as the Netherlands, Sweden, Norway, Germany and Austria. They have special programs characterized by being eco-cycle models where the basis is separation at source and facilities that generate energy by means of garbage, with a landfills reduction and incineration.

There are different works with approaches related to the waste usage and energy generation. Also, others works are related to some logistics aspects where new technology is introduced considering new aspects. In this paper, the approach is oriented with a decision support system to design the collection routes and the required fleet. This proposal has an impact in the organic waste management and generating value, combining different techniques and new technologies.

The Literature review is presented in the Section 2 detailing different works related with the smart waste management. In the Section 3, an approach for smart logistics in the urban area to smart waste management detailed. At the end, Conclusions and Future works are presented.

2 Literature Review

There is a vast literature related to the intelligent waste management, with focus in organic waste and generate energy (using incineration), compost or biofuel. Using the keywords ”organic waste” in Google scholar is possible to find 6230 articles and 272 papers only this year. The majority of this works use the organic waste to produce methane or other derivate (Frei-Baffoe et al, 2015; Banacu et al, 2016; Hierro, 2016; Cardavid and Bolaños, 2015; Chavez and Rodriguez, 2016). Other kind of works are related to urban logistics, specifically with the collection and disposition of the waste in landfills (Chen et al, 2016; Yusof et al, 2017; Brouko et al, 2017; Anagnostopoulos et al, 2015; Hua et al, 2016). On the other hand, the location and number of landfills or plants to process garbage are among other research topics (Kasliwal and Suryawanshi, 2016; Nelles et al, 2016; Amritha and Anilkumar, 2016; Simone et al, 2016; Hrebicak et al, 2016). With new technologies and new challenges, the smart organic waste management needs new development (Nelles et al, 2016).

Banacu et al. (2016) identify and analyze the concepts and strategies for waste recycling with the goal to reduce the negative impact on the environment, human health and natural resource. In this paper, they remark the requirement of creating a suitable channels collection and transport to locations where waste can be reused. In our work, this requirement is considered.

Chen et al. (2016) develop an approach with IoT (Internet of Things), cloud computing and a distributed architecture to the garbage truck fleet management. With the new technology is possible to monitor the different containers around the city, and use historical information to predict some behaviors, also the app can provide the immediate location of the garbage truck. In addition, an arrival time forecasting method is designed and implemented. This paper is related with the proposal considering the monitoring and control of the fleet and the real-time information to change the arrival time in the different collection points.

Anagnostropoulos et al. (2015) propose the fleet estimation and workout. The solution is based in using sensors, ubiquitous mobile communications and IoT to optimizing the garbage truck fleet size, collection routes and prioritized waste pick-up.

One of the main problems in this topic is the uncontrolled dumping in open landfills. Amritha and Anilkumar (2016) analyze how a directed landfill of organic and biodegradable waste can be a good option to reduce the environmental risks and simultaneously using the same land for green productive purpose, reducing the pollution.

A solution of the problem of the route calculation for garbage removal is presented in (Brouko et al, 2017). In this case, the solution includes route calculation and collaboration among the different actors. This idea is important for the solution developed in this work.

Yusof et al (2017) present a smart garbage monitoring system in a bin acting in real-time. The contribution is the possibility to improve the efficiency of the solid waste disposal management by using sensors in special bins to notify when some level is reached. Kasliwal and Suryawanshi (2016) develop other similar idea, where microcontroller, ultrasonic sensor, GSM and IoT are combined in a monitor system.

A DSS for a municipal waste collection and transportation is presented by Hua et al. (2016), where real-time data through smart devices to calculate the best path for each vehicle in the trucks fleet is integrated. In other hand, Shafray and Kim (2017) show sustainable strategies for municipal solid waste management, this idea can be integrated with the proposal of Bylot et al. (2016) where the waste is generated and treated in a consumption perspective. Thus, the waste is converted in economic resources (Fudala et al, 2016).

Analyzing the literature is possible to identify different research topics, in some of these works there are suggestions to combine different topics because they are related. One of this research areas is the logistic required to transport the waste from the different locations through the collection to other locations where the organic waste can be re-used like landfill, incineration, compost plants, biofuel plants, farms, etc.

3 An approach for organic waste smart logistics

In this section the proposal of a smart organic waste management is presented. In the section 3.1 the problem is detailed with focus in the advantages of intelligent waste management and the change in the paradigm where the garbage has an economic power. The conceptual model, presenting the main actors in the system with their activities and different requirement is shown in the section 3.2. The solution architecture is presented in the section 3.3, while some initial results are discussed in the section 3.4.

3.1 Organic waste: the power of the garbage

The waste management is a growing up problem with many different aspects and different impact levels. The problem is worst now because of the proliferation of big cities and the inexistence of political actions in many countries around the world. However, a new vision is emerging where the waste has a value. The 3R (reduce, re-use, recycle) and other proposals are oriented to this new vision about the waste. In this work, it is considered only the organic waste because is the source of many problems related with the sustainability, and providing a solution for this would be a good starting point that can be extended in order to tackle the problems related to other kinds of garbage.

The organic waste is produced in every home, institutions, food markets, commerce and streets. In general, there is not a regulatory law to determine responsibilities and there is not a conscience in the society about the volume of garbage per day each person produces. The organic waste management is important because the consequences have a social, environmental and economic impact, with pollution on soils, air, and water and in transition with health consequence.

The organic waste is special because it can be used in a next value process, for example, used to animal feeding, compost, vermiculture, biofuels (replacing fossil fuels), biofertilizers, etc. and there is a value in the waste that can be part of the production process. Some benefits of a good organic waste management are organic matter in degraded soils (and then organic agriculture), reducing the synthetic fertilizers and the new jobs positions. This new idea is an economic power element, for example with the fossil fuel reduction and the dangerous situation of the natural resources.

In this context, the scenario has some waste generators and other organizations using the garbage to produce value. Usually, among them there is distance (inside the urban boundaries and/or outside the boundaries) and a coordination problem because they don´t know each other. Because of that, a transport service is required, being an actor in the urban logistics with new functionalities. The coordination among them is necessary and in this paper, a new DSS is proposed.

3.2 A conceptual model: Actors, process and the relationships

The problem under studio is the coordination among the actors involved in the process of smart logistics related with the organic waste management. The different actors and the relations among them are represented in the Figure 1. The model is a simplification of the reality showing only the main roles involved in the process. Naturally, the DSS has many requirements, and it is related with the four different roles.

The producer or generator is the source of garbage, it has the responsibility to separate the organic waste from the other kind of waste. The producer informs to the DSS about the quantities available of every kind of garbage, and the information is sent manually or using sensors in the different bins. In this work the focus is only in large organic waste generators like hospitals, educational buildings (schools, universities, etc.), food markets, supermarkets, restaurants and others. In other hand, the DSS informs to the generator the planning of the organic waste collection, which is important because the uncertainty can be reduced.

/In some cases, it is necessary to establish a negotiation process between the producer, receptors and transporters according to the available capacity and requirements. This process is triggered when the collection planning is not able to meet all needs or when a real-time service demand occurs. In this process, the coordination becomes explicit between the different actors, being the DSS a key element that allows integration between them, In addition, with the stored information it is possible to generate movement and load generation profiles, which will allow in the future to create proactive collection protocols.

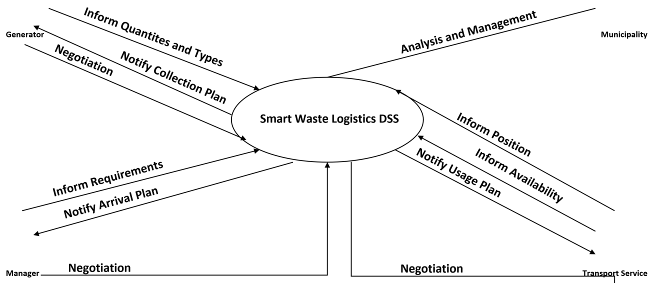

Figure 1: DSS Conceptual Model for organic waste smart logistics

One special kind of generator is the municipality itself through household waste collection. It this case, a separation process would be needed, and after it is completed the waste destination would depend on the service demand. If the waste is sent to the processing centers then the municipality would be considered as a regular producer but with higher volume of product; if it's sent to a specialized landfill, then this would allow the municipality to reclaim grounds.

The other actor relevant is the manager; this is the value generator from the garbage. Usually, this kind of actor is usually outside of city boundaries. Using the organic waste is possible to obtain energy (e.g. by incineration), biofuel, compost, etc. Alternatively, the waste can be used in a specialized landfill with only organic waste. This actor inform to the DSS the availability to process the garbage, and the system is responsible for informing the Manager that the trucks arrival planning. The manager can also participate in the negotiation process if he doesn't agree with the designed planning or because of the different needs originated by the other actors.

The municipality also performs this role of Manager but in a passive way, the surplus of the organic waste is destined to a sanitary specialized landfill only for the organic garbage and whose purpose is the recovery of land for its later use.

The relation among the generators and the managers moving the waste from the source to the destination is done through the transport service. The transport service can be outsourced or own, the goal is maximizing the own fleet. Each truck informs the availability of time and capacity, and the DSS informs the Usage Plan.

In addition, the truck informs the position with the GPS, which makes possible to monitor and control the fulfillment of the plans with the generators and receivers of the garbage.

The municipality is the other relevant actor, it can be generator and receiver, and the municipality needs to analyze how the process is doing and the benefits obtained. Also the municipality is responsible for the waste management policy in the city.

The DSS offers the coordination and integration between the different actors to planning the collection routes considering prioritized waste pickup, the truck fleet required, considering real-time data to change the plans dynamically, and the monitoring and control of the fleet. Furthermore, enables the municipality to conduct analyzes of the behavior of the different actors and their coordination. The next section details the main components of the proposed DSS.

3.3 DSS to the organic waste smart logistics

Considering the stakeholders defined in the previous section, the different the first conceptual components design of the DSS is presented. This version considers only the basic functions integrating different technologies. In the Figure 2 the main components are shown.

The first component is the Presentation Layer. Under this name, the components related to the presentation and interaction with the different users and other systems related. It is the top most level of the application.

For the problem under study, for each stakeholder there is a specialized component considering the requirements and activities to do in the system. For example, with the generators the information about the waste could be completing a form in the system or in automated way using IoT combined with specialized sensors in the bins, the stakeholders involved can receive the information about the collecting planning by means of messages, emails and/or using the DSS. In the transport stakeholder, the information is sent to the system using the platform directly in combination with the GPS system to inform the position during the service. The municipality and waste manager use the user interface in the system.

The second main component is the Logic Tier or Business Rules. In this level, the different elements of the systems are related to the application process and the coordination. These components make logical decisions, evaluations and perform

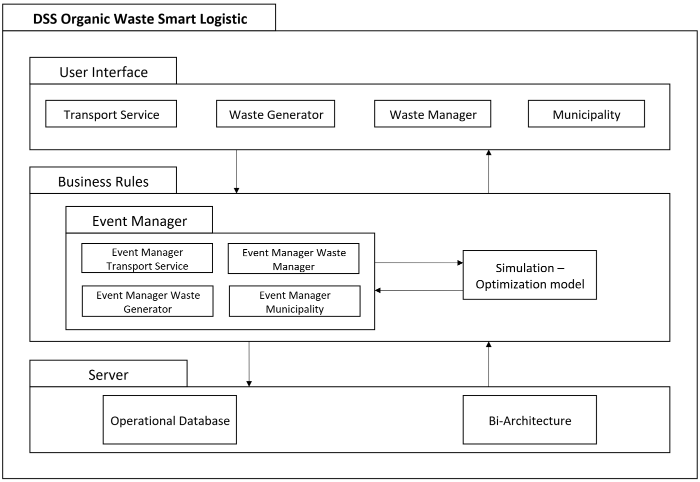

Figure 2: Conceptual Components in the DSS

different analysis. Also, it processes data between the surrounding layers. In this first approach, the main component in this level is the simulation-optimization model, taking the data from the generators and waste managers in combination with the transport service; this component produces the optimized garbage truck fleet and collection routes. In addition, with each change in the requirements, the component re-design the collection routes and it can the capacity to change the fleet to respond dynamically to the real-time information. Other components are related to the event management from the different stakeholders capturing and analyzing the changes in the original requirements or new requirements that can affect the planning.

In the next and last level we find the Data Tier. The function of this level is storing and retrieving the information. This level is in relation with the Application Tier sending data and receiving data in combination with requests.

The different elements of the architecture can be distributed between the different stakeholders. In the next version of this approach, the distribution of the components and its interactions will be under consideration

3.4 Desired results using the proposal

The organic waste management is a problem in every city around the world, and in most of the Latin-American countries, the normal process related with this kind of garbage is using landfills with a relative control with the consequences to the sustainability. With this proposal, there is a possibility to generate value using waste, in other words waste-to-value. Some of the desired results are The reduction in the uncertainty in each actors involved in the system and the ability to have a better reaction when something is out of the plan. Also, there is more flexibility, because there is information about when, how and what type of waste is being transported.

There is more information to develop new waste management policy. The municipality can redesign its policies considering this new information, thinking about the landfills location (e.g. specialized to only organic waste and then redesigning it) or the incineration plants.

The municipality and the garbage transport services enterprises should have better results, with an optimal trucks fleet according to the demand and optimized collection routes. The trucks should perform better and the usage is increased in time and capacity. Also, the urban logistic is affected with better routes and optimize fleet, especially if some restrictions are considered (e.g. to avoid the traffic jam in peak hours). In consequence, both the air pollution and the fuel oil consumption can be reduced.

Society should perceive less organic waste in the different sources of generation with the collection planning. Using IoT, sensors, and communication it is possible to have information in real-time, planning the waste collection when a point level is reached. Besides, it is possible to consider prioritized waste pickup.

Waste-to-value can be real, because the organic waste is not just garbage and can it be the input of a new process to add value and create new products like compost, energy or biofuel. Furthermore, there are new job positions related with this proposal, or a new conception from existing jobs. The transport is a key element linking the other actors.

The optimized garbage truck fleet and the optimization in the collection routes for each truck should be another important result, with the incorporation of real-time information, the routes can be changed to reflex the new requirement. This point is critical given that from a managerial point of view transport always takes a major role in the cost structure, and by taking care of this concept, system wide cost are optimized.

With this approach society should observe a reduction in the contamination in general, inside the city and in the landfills. With a better waste management, the pollution in air, soil and water is reduced. Moreover, this has an impact in the citizen satisfy level. This approach can be used in an educational program to the city, showing the benefits in the social, environmental and economic aspects. This potential benefits were developed in a round table with the different actors involved including the academy to model and design this approach.

According to the working table, the main contributions of the proposed DSS is the possibility to reduce uncertainty in the collection and delivery of waste, as well as having more certainty about the moving of it. Thus, facilitating the integration between different actors involving their processes in the decision making. However, for the acceptance and use of this platform, a technical training of the actors is required. Another critical point is the need to achieve the integration of different technologies and they heterogeneity, which must be respected considering the autonomy of the participants.

Currently a first proposal for the DSS has been awarded in an innovation and entrepreneurship contest with the co-participation of the Valparaíso City Hall (in

Chile). A conceptual test was analyzed in Brasil street (where the main buildings of educational institutions and markets are located) with the cooperation of the Facultad de Agronomía and Centro Biotecnológico. This concept test validated the main characteristics of the proposed system and the obtained results, laying the foundations to continue the development of this project to a larger scale.

4 Conclusions and Future Works

The organic waste is not a problem; it is a business opportunity and value added with the idea "waste-to-value". Furthermore, with a good organic waste management it is possible to have different benefits related with the sustainability and the use of natural resources.

The main result obtained with this proposal has been the possibility to work in a collaboratively in a round-table with the stakeholders involved in this process to value-added in the organic waste management. Because of that, the DSS for the smart logistics of organic waste collection emerges as a support to the collaboration and integration between the stakeholders. The DSS produce the optimized garbage truck fleet and collection routes for each truck, to move the organic waste from the generators to different plants and destination to produce other products like compost, energy or biofuel. Other destination can be specialized landfills controlled by the municipality.

This approach is the first step in a holistic intelligent waste management. Future works are required to consider the problem with its dimensions. The simulation-optimization model generates the optimized garbage truck fleet and collection routes, but only considering organic waste. It is necessary to increase the model including other kinds of waste, new garbage generators, and analyzing new restrictions. These restrictions are related to the hours (e.g. the collection routes are always out of rush hour); restrictions related to the type of trucks (i.e. different trucks for different kind of waste, or restrictions related with the circulation in the city), and other restrictions related to the urban logistics need to be considered.

From the municipality requirements, the approach can be extended considering the Business Intelligence. This extension permits the knowledge from the information in the system, and it is important for the analysis and evaluation of waste management policy. Evaluating the stakeholders' behavior to understand and discovery patterns and with this information re-design the simulation-optimization model. The information generated is key to have a better performance understanding and improving the process.

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