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Technologies for Sustainable Society

Optimizing Waste Management & Recycling Concerns through Domain Analysis

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Abstract

"There is nothing in which the birds differ more from man than in which they can build and yet leave a landscape as it was before."

- Neil LaBute

The focus of this study is put on the area of waste management and recycling. Through this study, the paper discusses how information technology (IT) can be incorporated within the focal area into making the environment more sustainable with the help of modern technologies and improved design while taken into consideration relevant factors such as social awareness. The paper aims to provide an in-depth approach into how this incorporation contributes to the overall sustainability of society. It then presents the assessment and results of the findings as well as the outcomes of the study.

Keywords: Environment, IT Solutions, Waste Management, Recycling, Society, Awareness, Sustainability, Technologies.

1 Introduction

Societies around the globe are expanding with an incredible pace. The world population is only getting larger and larger, thus making over-consumption, pollution, littering and other crucial contaminations of the environment an enormous problem for all the areas of our current society. A lot of companies, governmental bodies, and private persons have already realized that the current way of living and consuming must radically change. At the same time and with perhaps the same pace, IT is growing stronger than ever before. Almost every aspect of life today has to do with IT, from a digital timetable for buses to embedded systems in traffic lights. Therefore, it is highly relevant to further examine how IT can be applied as a solution to environmental problems in all levels of today's society.

1.1 Problem Statement

Sustainability is a broad concept that, in general, concerns with the reconciliation of social, environment and economy. Ideally, this can be achieved through proper utilization of available resources.

However, in the context of this research, the goal is to achieve sustainability by exploring ways to maintain the right balance between society and technology itself in the area of Waste Management and Recycling. Ultimately, the research attempts to find out the potential benefits this can have on the environment and overall society in terms of making it more sustainable.

The way in which the research approaches this subject will be bidirectional in terms of being both reactive and proactive towards the examined issues. The approach is proactive in a sense that the study emphasizes more on how technologies themselves, notably IT, can be utilized in the handling of waste material to benefit the environment in a more sustainable manner, which is distinctive from attempting to achieve sustainable IT through design or development of particular technologies. Although the proactive approach is what the paper aims for, its approach will also be reactive in the sense of suggesting how current waste management technologies can be adapted and utilized in a more environmental-friendly manner. Thus, the paper will also outline a design as a theoretical suggestion for a possible implementation. In addition, the paper also examines the social aspect of this subject in terms of social awareness towards the importance and impact of recycling. All in all, this research expects to answer the following research question;

- How can IT solutions be applied into Waste Management and Recycling to potentially help increase sustainability in environment and society?

1.2 Overview

The paper begins by introducing a traditional scenario (Section 2) that aims at showing the traditional process used in the examined problem domain. To help with understanding how the research is carried out in terms of what methods are used, where the data are gathered from, and what the available resources are, Research Method (Section 3) gives a detailed description on how the research is conducted step-by-step from beginning to end-result. This process is described using both model and textual representations. In order to discuss the relevance of different concepts adapted into the research, Related Research (Section 4) introduces these concepts and shows how they can be utilized to fit the scope of this research. Since data collection is a major part of this research, the collected data is gathered and presented in

Data Collection (Section 5), which contains all types of data from literature reviews, external case studies, field data such as interview answers as well as survey results. These data have been gathered from various respondents as mentioned in respective sections. The analysis results of these collected data is presented in Analysis and Discussion (Section 6). This analyzed data will guide the research to arrive at its conclusion, which is presented in Conclusion (Section 7).

2 Traditional Scenario

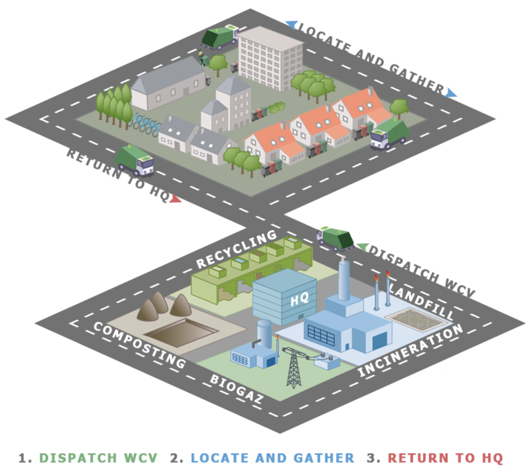

Figure 1: Traditional Scenario

Waste is collected from a broad variety of waste disposals in household areas periodically with a fixed schedule; for example, once per week, every Monday. This means that the waste collection vehicles (WCV) are dispatched to all pick-up locations regardless of the amount of waste each disposal has, until the vehicle is considered as having reached the limit of maximum waste it can carry. If needed, the driver can communicate with the headquarters to send in extra WCV's assuming that there are waste disposals left to be gathered. A couple of the bigger actors in the industry [28, 37] has better solutions when it comes to the identifying of waste disposals. For example by attaching a chip or tag on the bin, and also attaching an identifier on the WCV which, depending on the vehicle also can carry a weighing system.

Each tag is identified to a single bin, i.e a household. Meaning that the company will know exactly when and where the bin is emptied as the vehicle reports in to the main headquarters. In turn this means better customer information, better billing system and more efficient collection routes. Although these technologies are fairly common, they are yet to be integrated in the majority of the Swedish municipalities [22]. Since Sweden is the leading waste management and recycling country in the world [12], it can easily be said that the earlier remarks are true for the rest of the developed world as well; therefore, the traditional scenario below will only be based on the findings which can be referred as being the most common solution for waste management and recycling (Figure 1).

3 Research Method

This research will be conducted as an exploratory case study [10]. An exploratory case study is suitable for the purpose of identifying the existing 'problem domain' and possible solutions for improvement. This has its roots in an action research which proceeds in a spiral manner[8, 9]. In the same way, this study investigates the issue in an iterative manner. The collected information is formulated toward possible solutions. The iterative process allows the collected data to constantly be validated and defined.

3.1 Research Initiation

At the initiation of the study, a practical scenario (Section 2) of the problem domain is drawn out. The scenario has been grounded from social and practical perspectives, and how technologies can be applied for waste management and recycle at household areas. In the process of establishing a scenario, different stakeholders and their interests are also taken into consideration. In this way, the practical problem is framed [11]. Based upon the problem domain and the stakeholders' interest, this research is also going to specify the possible baseline of data sources. According to Yin, six main data sources have been determined, which are documentation, archival records, interviews, direct observations, participant observations, and other physical artifacts[10]. These are considered to identify the data sources.

The following conceptual model (Figure 2) illustrates how the initial baseline is set up.

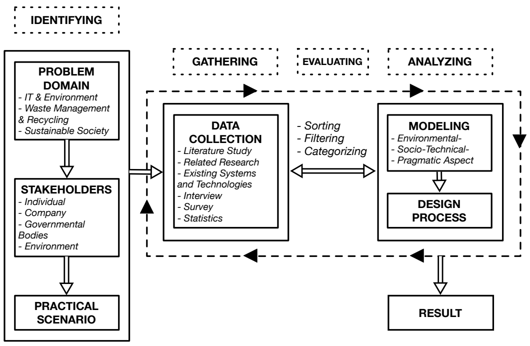

Figure 2: Conceptual Model

3.2 Research Findings

This section explains the data sources of the study and the process of data collection and data analysis. Several types of primarily collected data are analyzed and validated to find out the significant information for the study.

3.2.1 Literature Study

To gain a better understanding and a methodological approach of the existing solutions, the theoretical background of the research will be investigated. Based on the theoretical concept, the primarily focus is put on data collection and analysis of the general purpose of technologies for sustainable society that moves toward the designing of the prototype. This allows for the possibility of focusing on the empirical content of the study as well as applying the relevant data for this particular domain.Several search engines (e.g. Google Scholar, IEEE Xplore, ACM digital library, etc.) and relevant keywords will be used to find related study work.

3.2.2 Interview and Survey

During the research study, several interviews will be conducted to get insights into the individual experience. Interview will be conducted basically on two types of stakeholders, e.g. individual who are involved in recycling process, and companies such as Renova [28], Umeva [31], and Ragn-Sells [37] who are providing support in waste management and recycling process. The interview will be conducted based on "semi-structure" approach. Exploratory nature of the research influences the choice of this interview approach. This process also allows for the understanding of the user experience in a more expressed way. Unlike a questionnaire interview, in this case, semi-structured interview will enable relevant information to be found. In addition, a survey will be conducted as a part of data collection at the Gothenburg University and Chalmers University of Technology, Sweden. The reason for choosing these university students is easy availability and to see how aware students are at the higher level of academia.

3.3 Research Limitation

Due to a narrow time-frame, all phases in the research process have not been considered and given equal priorities. In addition, the scope of this paper is intentionally made limited to exclude the possibilities of discussing about broader and external aspects such as business model, cost, and economic perspective of waste management and recycling, etc. Another limitation is in terms of how the proposed design is carried out and how to truly evaluate the proposed design structure (Section 6.3) in a practical setting. The design structure is based on a small scale; hence, it will be a challenge to observe and evaluate the process model in a larger scale.

4 Related Research

The idea behind this research is formed based on various relevant concepts. These concepts have already been explored and researched with regards to this area as well as other areas. This section will briefly provide information about each of the concepts, but more importantly, it will discuss their relevance to this particular research in a sense of ideas and available technologies.

4.1 Waste Management & Recycling

Based on the data presented by Tanaka, "the earliest actions related to waste management were public hygiene measures, [but this has shifted to] environment hygiene measures to maintain urban functions and to preserve a living environment [as] waste disposal become quite a significant [factor] in [achieving] a sustainable society" [1]. In terms of integration with technologies, this usually deals with reducing waste through implementation and design of device and system.

As Gartland and Piasek explain in their paper about the design and implementation of an interactive waste disposal device, the concept of "Weigh Your Waste (WYW)" device is explained where it is able to digitally weigh the waste and present the result in the touch-screen through Wi-Fi[1] connection that will allow the user to monitor the status of their waste and calculate the recycle cost [2]. However, the main focus of WYW exclusively deals with sustainability through design. Nevertheless, this is worth looking into since this research also aims to suggest a possible design as one of its main aspects. However, it will not focus exclusively on the design aspect alone.

Another research By Saar and Thomas suggests an interesting use of Radio-Frequency Identification (RFID) in recycling and reusing as a product tag to track end-of-life products [3]. Based on this idea, the tag can contain relevant information about the product such as what kind of materials it is that can be read by the scanner at the waste disposal center. They can then be electronically sorted and filtered according to the embedded information. However, to be able to make this work, the waste disposal center need to support this feature and be able to read and process these RFID tags. This will be an additional modification that comes with introducing this idea into usage.

4.2 Fleet Management

The concept of Fleet Management[2] is a process of vehicle-tracking, which is already commonly used in various industries and companies where allocation of resources and transportation are of demand. This concept typically utilizes the GPS technology for real-time positioning that enables the control center, or user in this case, to locate and possibly control the dispatched vehicles. Since this concept is already widely in-use, it has been adapted and enhanced through many proposed solutions to improve its effectiveness. One of which is through the incorporation of Global System for Mobile Communications (GSM) and front-end intelligent and web-based management instead of relying on GPS alone. One of the advantage that the solution suggests is that "[GSM] can compensate the loss of GPS position." which will further increase the accuracy of the system [4]. This is the main reason for using the combination of these two technologies instead of having only either one by itself as in a traditional way. This conveys the possibility that existing technologies can be improved using available technologies.

Another alternative is proposed by Stojanovic et al. [5], which is called "MOWIS a service-oriented open software platform for location-based and context-aware mobile and Web applications" where information about the vehicle under monitoring can be searched, selected, viewed, and updated. Both mentioned alternatives [4, 5] present the used of the web-based management software/system, which can provide the control center with an overview of dispatched vehicles as well as routing that will make the process of monitoring the fleet more efficient.

For this research, similar ideas of fleet management concept are utilized in keeping tracks of the WCV's when they are dispatched to various pick-up locations. Based on the scenario presented in Figure 1, the company communication center not only can keep track of the WCV's but also of the waste disposals in the monitored areas as well. This information is also displayed in the WCV's enabling the driver to locate and identify the waste disposals in the pick-up locations.

A possible use of web system or application is also thought of for this research. This would serve a different purpose than those presented by the mentioned alternatives [4, 5]. The difference is that the web system will not be for monitoring the dispatched fleet, but rather to enable the information about waste collected to be uploaded/updated onto a website, preferably in real-time. This will provide some sort of statistics that can be viewed online. However, this is considered as an optional feature that will not be greatly emphasized in this research.

[1] A local area network that uses high frequency radio signals to transmit and receive data over distances using the Ethernet protocol.

[2] The management of a company's vehicle or fleet. Fleet management includes commercial motor vehicles such as cars, vans, and trucks.

5 Data Collection

The collection of data are gathered and furthermore explained for the means of establishing a conclusion of the research as a whole. In order to begin the process of domain analysis, the key domains examined by the study need to be defined. The three identified problem domains are product life cycle, technologies, and social awareness. These three domains are identified because of the research's goal to cover all waste management and recycling concerns addressed by the study, which starts from individual to social scales. This section presents the data relevant for these explored problem domains.

5.1 Product Life Cycle (PLC)

To build up and maintain a sustainable environment, a closed-loop PLC[3] is encouraged for a society [30]. Recycling materials is one of the main concern in a closed-loop product life [30]. This is inevitable that, individual and industry produce and use various kinds of materials. In the long run, all these materials become waste. Depending on the types of waste, some are possible to recycle, (i.e. household products) and some are not (i.e. batteries, chemical products) [30]. As shown in statistics gathered by Swedish Waste management (Trans. Avfall Sverige) in 2009 , Sweden's households generated around 511.2 kg for each person [12].

In Sweden, citizens, property owners, producers, contractors, and local authorities are responsible for the waste streams [12]. Usually waste is gathered in containers such as for recyclable/compostable waste, other residual waste are going to be incinerated for energy or very rarely, being thrown in landfills for the purpose of waiting for future measurements [19]. According to Swedish Waste Management (Trans. Avfall Sverige) 48.5 % of household waste undergoes the process of waste-to-energy [13]. In contrast, at Municipalities where household waste are handled in a better procedure, where around 97 % of household waste are currently being recovered [12]. Gathered information from various sources such as company websites and media shows that, most companies use WCV's for collecting waste [28, 31, 37].

[3]A life cycle that is closed by encouraging maintenance, manufacturing of products, reuse of components, and recycling of materials.

As mentioned in Section 2, they do not have any monitoring system to measure how much waste is produced in particular households or areas [28, 31, 37]. Therefore, both consumer and companies are fully unaware about the PLC in the sense that production of waste can determine how frequently individuals purchase products and turn them into waste.

The problematic areas in the PLC can be set up as followed:

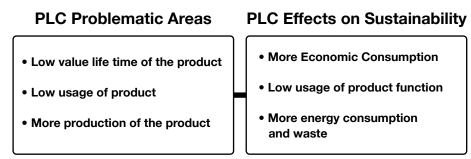

Figure 3: Problematic Areas and Effects

5.2 Technologies

The natural environment provides essential services that cannot be replaced by technologies [13]. However, using technologies can make a difference in maintaining sustainability in the environment for present and future [13]. The goal is to identify the existing technologies and usage of these technologies in waste management and recycling process specifically at household areas.

5.2.1 Waste Container

In most of the cases, very few households use any advanced or accommodating technologies in waste containers [28, 31, 37]. However, there exists incorporations of automated waste containers, but they seem to be very few and deal only with making the household more aware of throwing waste; for example, Germany, Berlin is testing a waste container which says 'thank you' when people throw waste in it [21].

Furthermore, there is hardly any technology used in waste containers that uses a communication link between the company communication center and the waste container itself. In an interview with Magnus Brömster, Head of the Household Department, for the waste management company Umeva, he says that, "[We only have] fixed date for gathering material (2 weeks in between), [and we currently have] nothing to predict dates". Therefore, they perform most of the tasks in a manual way.

Integrating new technologies in waste container can easily facilitate for better waste management. Such technologies can be used to achieve the followings;

- Monitoring of the location of the waste container position.
- Measurement of the waste container.
- Communication link between different domains (i.e. Company, WCV, and waste container)

To manage waste more effectively, some companies have looked for alternative solutions. As added by Magnus Brömster, "[We] looked at better alternatives to containers, mainly deep reservoirs (Trans. Djupbehållare)" [20].

5.2.2 Waste Collection Vehicle

Some automotive industries have developed various kinds of WCV's such as front loaders, rear loaders, grapple trucks, etc to facilitate waste management and recycling process. However, this study will not concern with the technologies that are used in automotive industry rather focus on the correlation between WCV, waste container and company communication center. The bigger companies dealing with waste management and recycling use different forms of GPS interfaces for mapping different areas as this allows them to easily find the best route to an area, but also to keep track of and monitor where to collect the waste. Some companies such as Renova and Ragn-Sells [28, 37] also use GPS to communicate between the communication center and WCV; this system is named 'smart collection' [21].

According to Magnus Brömster [20], when it comes to the metaphorical "technology scale" of Sweden, around 50 % has none or very little IT-based solutions incorporated in their companies. In fact, "this is the business with the least IT-based solutions if compared to other areas of municipal work" [20]. Regarding using technologies in WCV, Magnus Brömster also adds that "[We only use] standard GPS in the cars, nothing more, [but we also have a vision to] measure the amount of waste before containers are totally full." Traceability and On-board Weighing System [21] is a system that is used to keep track of the waste containers and manage waste production. In this system, each waste container uses a bar code or RFID labeling known as a 'Container ID' system that is embedded with the 'On-board Weighing' system in the WCV. 'Container ID' system is used to detect the waste container whereas 'on-board weighing' system is used to measure the waste weight [21]. According to Jon Nilsson-Djerf, technical adviser for Swedish Waste Management Association (Trans. Avfall Sverige) claims that, the total amount of WCV's in Sweden alone are between 1000 and 2500. Moreover, WCV's deal solely with household issues that are estimated to be around one thousand [22].

Any form of IT-technology in these WCV's are impossible to get a realistic number on; however, the trend is that there has been an increase when it comes to acquiring equipment in the WCV's that communicates with a communication center and stores relevant information. This data surrounds statistical information of how much has been gathered in a given area, in terms of weight. These WCV's are mostly very modern and use hybrid motors for a quieter start and less impact on the environment [24]. Swedish Waste Management Association (Trans. Avfall Sverige) estimates that weight-based systems are in operation in 25 municipalities in Sweden [22].

By observing the existing systems, the following improvements are expected:

- Mapping of waste containers in household areas.
- Communication between WCV and company communication center.

5.3 Social Awareness

To reach a sustainable environment, we are obligated to make sure that our means and ways does not affect future generations of living their lives [14]. This is not only true for humans alone, but for everything that is included in our environment. Pollution levels, global energy, and material resource usage need to drastically change with around 95 % for the world to be truly sustainable [29]. We have slowly start to realize that we are not the center of the creation and badly need to adopt another view, where the environment surrounds us, and not the opposite [17].

The European Parliament and the European Council took a decision autumn 2008 about a new framework for the handling of waste. [15] The rules are established in the Swedish legislation since December 2010. One of the more important points in this legislation was the Waste Hierarchy that prioritizes the handling of waste for a more sustainable environment and society.

The followings make up the waste hierarchy:

1. Minimization/Prevention[4]
2. Re-use[5]
3. Recycling / Composting[6]
4. Energy Recovery[7]
5. Landfill [8]

These above five steps can, through education, also make people more aware of what is happening after waste has been thrown. For example Swedish waste management companies [28, 31] invite schools to visit their facilities so that they, for themselves, can see how various kinds of waste are processed. This can in turn make them more aware of not throwing waste in the wrong waste container.

By conducting a survey (Figure 4) with twenty students at the IT-University of Gothenburg, one can easily see that a clear majority of students care for their environment, and also care about how they sort their waste. However, 37 % of the students did not know or had very little knowledge about what actually happens with the waste after it has been thrown away, and only 5 % said that they are well-informed about the process.

It is no coincidence that for a question as "What can be done to encourage people to recycle?" at least half of the students added suggestions to encourage an increase in social awareness, comments like: "Imply laws for awareness" or "Encouragement by pointing out how important it is to keep the environment healthy" was extremely normal answers.

[4]According to the Waste Framework Directive [15], this is the top priority to make people more aware of their social behavior. In combination with the step of re-use, this can change the consumption habits of our current society.

[5]Before throwing material, there might need to be structured instructions of considering re-use of products or in any other way favor the preservation of products [26, 33]

[6]Material that can be recycled or composted to be used as new products, soil etc. [15].

[7]Involving the extraction of energy by for example high temperature burning of material that cannot be recycled or material that can be recycled but has been thrown in the wrong waste container and is thereby burned [34].

[8]The least prioritized solution for waste handling is by landfill. [15] Even though it exists safe ways of covering such solutions, this is the least sustainable alternative of the waste hierarchy but sadly the most common method of dealing with waste around the world [27].

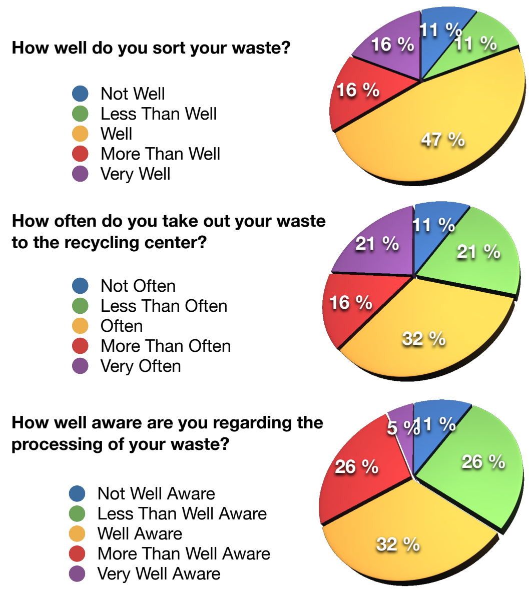

Figure 4: Social Awareness Survey Results

Another similar survey made by Avfall Sverige [25] confirms the previous survey by concluding that out of 730 individuals (326 Men and 405 Women) interviewed in various municipalities around Sweden, more than 70 % recycle and sort their waste regularly. Furthermore 49 % of 1000 individuals interviewed thought that by receiving more information on what they can do to reduce the amount of waste could help them in reducing their waste, 38 % answered that they would improve only if they get solid evidence that it is actually good for the environment and 13 % thought that introducing higher fees would enable them to be more aware.

6 Analysis and Discussion

The analyzed data is divided into three dominant areas from the problem domain, these are; environmental, sociotechnical and pragmatic aspects. The main purpose of doing so is to rationalize the relationship between IT and environment, as well as people (mainly stakeholders) and various existing technologies in waste management and recycling. The focus is brought on these aspects individually, and by not correlating them, the aspects remain thoroughly enhanced.

Thus, it enables for more solutions that suits not only one actor of the problem domain, but rather the whole scenario (Figure 1). This is done in order to explore potential solutions that might be used for the development of achieving a more sustainable environment and society. Such solutions are needed to find practical relevance in society by introducing a balance between social and environmental factors through the use of technologies.

6.1 Environmental Aspect

To maintain the sustainability and equilibrium of the environment, a PLC is a dominant area to explore. What people produce, use, consume often leaves behind some sort of ecological footprint[9]. This is an important factor to realize regarding environmental sustainability, and people have to make sure that what they leave behind has as less negative impact and effect on the environment as possible. In the findings presented in this paper (Section 5.1), improper product life-cycle is keyed out as a major constrain to achieve sustainability. In the 21st century and with the time being, people are more keen to enjoy luxury that leads all production to become more consumer-oriented. This luxury influences individuals to consume and use more.

In this process cycle, the increased usage of individuals demands industry, company and government bodies to produce more as well. However, the effect becomes visible when the excess amount of production influences the supply chain of production as well as increases the consumption of the products.
This means that consumer's demands cannot exceed the ecological system's capacity to regenerate.

In the beginning of the early 90's, EU set a goal that a person waste volume should be decreased to 300 kg/person each year whereas nowadays, waste volume is around 500 kg/person each year [32]. This difference in number is increasing day by day. One worrying information is "[only] with garbage in America [one could] form a line of field-up garbage trucks and reach moon" [18]. However, the process traditionally used (i.e. landfill) for recycling is also subject to question.

[9]A measure of human demand on the Earth's ecosystems. It compares human demand with the planet's ecological capacity to regenerate.

To increase the effectiveness in recycling process, technologies can be more effectively and properly utilized. The process can be applied from individual level to social and organizational level. A low-cost automated waste containers can be used in the household to increase human recycling behaviors.

6.2 Sociotechnical Aspect

As mentioned in Section 5.3, collaboration between technologies and people is an important sociotechnical aspect[10] to consider when it comes to introducing any form of sustainability into environment through the usage and help of technologies. In order to successfully utilize the technologies in improving the environment and making it more sustainable, this aspect should not be overlooked. Social awareness plays an important role in making this relation between IT and environment work. In terms of waste management and recycling, technologies has shown to help ease the process of waste collection and recycling as seen in Section 5.2.

However, if people are not aware or careless of this aspect, incorporation of technologies will not at all make much difference in this area.
Based on the data presented in Section 5.1, Figure 3, this deals largely with economic consumption since all products that people produce and consume will eventually turn into waste. Raising awareness in this area is, therefore, of great importance, which means that products have to be properly produced, used, and recycled by all actors involved in this process. As a result, this factor is dependent on the people as to how quickly used products can be discarded and turned into waste.

By influencing the social awareness on people to make them aware of this fact regarding consumption and waste management and recycling, this will help prolong the life cycle of products. Prolonged PLC means less waste will likely be produced. When less waste is produced, the chance of spamming the environment will also be reduced respectively.

[10]This aspect deals with interaction between people and technology such as human and computer.

Following the above discussion, there are various ways to raise awareness in individuals regarding waste management and recycling. One of the most common way is through education.

Educating people on the benefits of recycling can increase recycling behaviors in them. This combined with technologies results in a human-centered design as Zlatow and Kelliher have proposed, which aims at increasing recycling behaviors and “to educate consumers on the importance of purposeful and frequent recycling” while making recycling feel less of a burden [6]. The behaviors can also be influenced through social interaction between human and technologies. This is seen in Yamaji et al.’s development of ’Sociable Trash Box’ (STB), which can be referred to as human-dependent children-assisted trash collection robot [7]. Through this development, they make recycling behavior fun and engaging especially to children as the STB assists them in collecting trash within their environment. The presented information gives a glimpse of how technologies can be used to benefit the environment in promoting social awareness in people.

6.3 Pragmatic Aspect

After analyzing the collected information, the research moves toward designing a smart waste container (SWC). The prototype also gives a new direction in establishing the practical applicability of this research. However, this research will not cover the cost of production and business life-cycle of such a prototype, but rather explain how industry and society can benefit from the usage of this kind of waste handling solution. The intention is to explore conventional waste management and recycling behaviors from various stakeholders’ views and support all necessary utilities.

During this exploration, the findings gathered are resulted in quality attributes for the designing of the prototype, namely supportability, usability and extendability[16]. To have the ability of adding new functionality in the future with minimal or no effects in current design ’extendability’ is chosen as a quality attribute. Extensibility will also be allowed to design the internal structure based on the dependency inversion principle1 [16]. Supportability and usability is selected from basic user perspective to provide all services with ease-of-use and functionality of the system [16].

As shown in Figure 4, the SWC is structured into a number of discrete components integrated with multi-functional automation system. The SWC is combined with embedded components: battery, sensor chip etc. To power all this technology a solar powered battery will be used, the reason for this is to create an inexpensive solution for generating renewable electricity.

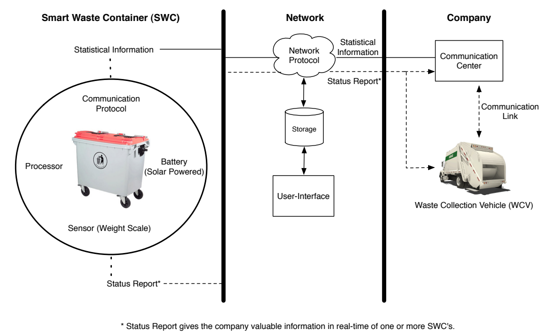

Figure 5: Process and Design Concept of the SWC

Other components are digital weigh scale, which will measure the weight. To monitor, log, and pass the weight information, wireless sensor network (WSN)[11] will be used.

The rationale behind choosing WSN is to forward several nodes of data packets to the base station(s)[35]. In that case, data packets contain weight and location in a form of message.

Two types of data are sent through the WSN:

- Statistical Information - Contains information such as SWC ID and other relevant data.
- Status Report -Provides real-time updates of the current status (i.e location, weight, etc.) of the SWC.

From an organizational perspective, information visualization and maintained communication linked between different domains (i.e company communication center, SWC, and WCV) are a concerned area.

[11]Consists of spatially distributed autonomous sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants.

The information is sent from the SWC via WSN. Both the company communication center and the WCV can monitor the current status in real-time through a user interface. This user interface is embedded with a priority-mode that displays the total percentage of waste depending on the status of SWC.

For example, if the priority mode is set to skip everything below 60 % then the WCV will be able to follow this through a color-scheme from red to green, where red means full and green means empty, and everything that is below 60 % will, therefore, be ignored (Figure 6). This priority mode might also be used for a certain area where multiple SWC's status reports are put together to form a network e.g. by calculating the total percentage of waste in a household.

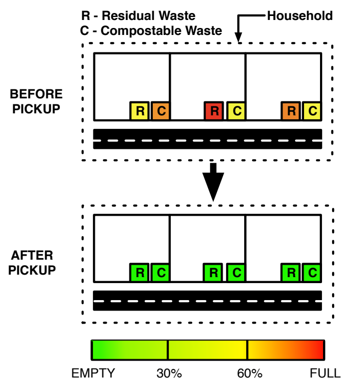

Figure 6: Real-Time Status Report Illustration

This means that WCV's can easily ignore such areas as long as the percentage does not exceed a certain level. If the total amount of waste in a household is 1500 kg, the company communication center can determine how many WCV's are required to be dispatched to that certain area. This system has a lot of advantages by not needing to rely on a fixed schedule for waste handling, but could instead measure, log, and monitor the process.

7 Conclusion & Future Study

Since this paper deals with the creation of IT-solutions, that have, to our knowledge not been used or tested before in a real-life scenario, it is difficult to know what impact such solutions will have.

The improved solutions show that the monitoring and statistics gathered will be greater than the traditional scenario (Figure 1). This is mainly because there exists no current way of gathering data and monitoring objects in waste management and recycling. This does not mean that incorporating technologies alone is sufficient to increase sustainability in society and environment as a whole, but rather points out that analyzing the social aspect of waste management is needed to take into consideration. This is necessary due to the fact that there exist other factors that are crucial to increase sustainability in our society. These are mainly individuals or households that also are the customers of such waste management and recycling companies. The actors involved must also be socially aware since they, directly or indirectly control the consistency in the level of recycling behavior. Hence, if the technology exists but no-one bothers to use the data gathered, how can these solutions then be used to its fully potential?

Increasing such behavior can greatly benefit the waste management and recycling process, which can increase the act of recycling itself through social awareness campaigns that could be arranged by the help of technology. For example in the form of providing statistical information regarding consumption for a household in a given area of e.g. Gothenburg on a website where people can see how much their area consume, daily, monthly etc. This might be a wake-up call for consumers since it displays facts that not many people know about but still care for. This system of monitoring and gathering statistical information might further evolve into including other solutions to potentially increase awareness.

For the future research of this study, the suggested designs (Figure 5, Figure 6) could be implemented in a real-world setting by enabling the study to examine the feasibility of this design to truly evaluate its effects in a more practical manner. When proper usage of technologies is combined with people's awareness about the importance of recycling, this can surely create a positive impact on the overall environment. This type of sustainability starts from a small scale and will essentially contribute to the sustainability of the whole society in a larger scale. Thus, to truly achieve sustainable society, the balance between technologies, environment, and people has to be maintained.

Furthermore, as this article is a rare example of articles dealing largely with the proactive solution in IT-technology. This article might be used as a "stepping-stone" for other future articles that can examine solutions which could potentially help increase sustainability in environment and society.

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