The adoption and implementation of IoT in waste management

A master thesis in Management of Technology

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The adoption and implementation of IoT in waste management

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by

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These are strange times that we are living in now. The past couple of years and hopefully not too many years to come will likely be remembered as the Covid-19 period. When I began my studies at TU Delft in 2018, I did not anticipate that I would be graduating while a world-wide pandemic was ongoing. While this period was somewhat chaotic at times, I was lucky to be able to keep busy juggling two jobs, working on this research project and spending time with family and friends.

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Executive summary

The fourth industrial revolution is upon us, and entire industries are seeking to reap the benefits resulting from the use of the technologies that the revolution brings. Waste management is one of those industries. The rapid growth of the human population causes more consumer goods to be produced every day. This underlines the importance of effective and efficient waste management.

The Internet of Things (IoT) has proven to be a useful tool to increase the efficiency of waste collection and while many waste management organizations are beginning to adopt these solutions, many are struggling to fully adopt and implement the technology. It is still unclear, due to lack of research, what factors are hindering the adoption and implementation of IoT technology in these organizations and how the process can be improved. The research scope of this study was three-sided: Industry specific, organizational, and technological. The focus was set on the waste management industry, and the intra-organizational barriers that hindered the adoption and implementation process of IoT-powered fullness sensors. The core problems at hand were identifying what the intra-organizational IoT adoption barriers are, what are the most influential barriers, what mitigation strategies can be employed to mitigate these barriers and how it can all be illustrated within an IoT adoption and implementation process framework.

The main research question formulated to answer these problems is: How can the adoption and implementation process of IoT-powered fullness sensors in waste management be improved? Four sub-research questions were formulated that held partial information which were needed to answer the main question.

The overarching structure of this research project follows the Design Science Research Methodology (DSRM). DSRM provides a commonly accepted approach which involves a rigorous six step activity process for creating and evaluating an IT artifact intended to solve organizational problems. This methodology was altered to fit this particular study, and thus followed five of the six steps. An analysis of literature was performed to identify the general intra-organizational innovation adoption barriers. An exploratory case study was conducted within a large waste management company in Iceland which recently decided to install IoT-

powered container fullness sensors to increase the efficiency of their processes. The case study revealed, through interviews, which of the identified barriers had the most significant effect on their adoption and implementation process. Expert interviews and desk research were used to formulate strategies that organizations could employ to mitigate the most prominent barriers identified. After all the interviews had been transcribed, coded, and categorized, data triangulation was used where data from multiple different interviewees was compared and analyzed. From the results of these research efforts, a framework explaining the IoT adoption and implementation process for waste management was then designed and developed. Expert interviews were again conducted to evaluate the framework and confirm the framework's theoretical validity, application and expected performance in terms of its set goals and objectives.

The results of this research are the identified general intra-organizational innovation adoption factors, the most influential factors affecting IoT adoption and implementation within waste management along with their proposed mitigation strategies as well as a designed IoT adoption and implementation process framework in which these strategies are incorporated. The general intra-organizational innovation adoption factors identified are: *Leaders' attitude towards change, Centralization, Complexity, Formalization, Interconnectedness, Organizational slack, Size, Culture, Degree of risk-taking, End user behavior, Strategic objectives* and *Uncertainty of business benefits.* The following are the three most influential barriers to IoT adoption and implementation within waste management and their proposed mitigation strategies: The first barrier is Uncertainty of business benefits and its proposed mitigation strategies are: *Gaining a Proof of Value (PoV)* and *Incremental scale-up*. The second barrier is Strategic objectives and its proposed mitigation strategies is: *Using information to gain a competitive advantage*. The proposed mitigation strategy for the third barrier, Degree of risk-taking, is *Renting with an option to buy*.

The applicability of the designed framework in a real-life setting is yet to be tested. Future research could involve using the framework and applying it in an actual implementation of IoT fullness sensors in a waste management organization.

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List of abbreviations

AI	Artificial Intelligence
BPMN	Business Process Model and Notation
DEMATEL	Decision Making Trial and Evaluation Laboratory
DOI	Diffusion of Innovation
DS	Design Science
DSRM	Design Science Research Methodology
ICT	Information and Communication Technologies
Industry 4.0	Fourth Industrial Revolution
IoT	Internet of Things
IS	Information Systems
IT	Information Technology
KPIs	Key Performance Indicators
LoRaWAN	Long Range Wide Area Network
MICMAC	Matriced'Impacts Croisés Multiplication Appliquéan Classement
MOT	Management of Technology
PoC	Proof of Concept
PoV	Proof of Value
RFID	Radio-Frequency Identification
SMEs	Small and Medium-sized Enterprises
TISM	Total Interpretative Structural Modeling
TOE	Technology, Organization and Environment
WMO	Waste Management Organization

1. Introduction

1.1 Background

Ever since the internet, and later the World Wide Web were introduced to the world our daily lives have been changing gradually. What started off as a new form of communication, information gathering and sharing, evolved into a disruptive technology, redefining how businesses and whole industries operate. The entertainment industry saw physical products like tapes and CDs turn into digital decoding and streaming services such as Spotify and Netflix took over the whole market (Tsiatsis, Karnouskos, Holler, Boyle, & Mulligan, 2019). Similar developments can also be seen in other industries, for instance in the retail and travel sectors where business transactions have moved online (Tsiatsis et al., 2019)

Now, radical changes are occurring with the emergence of the Fourth Industrial Revolution (Industry 4.0) where digital transformations in manufacturing and services are creating new opportunities for value creation. With Industry 4.0, new technologies and their applications in various fields are being researched and popularized. Among those technologies is the "Internet of Things" (IoT), a term originated from and is attributed to the Auto-ID Labs based on their work on Radio-Frequency Identification (RFID) infrastructures (Atzori, Iera, & Morabito, 2010; Wortmann & Flüchter, 2015). The technology is a relatively new communication paradigm that uses a network of connected physical objects or devices that are able to interact, collect and exchange data with one another (Mdukaza, Isong, Dladlu, & Abu-Mahfouz, 2018). These connected IoT devices are commonly called "smart", being able to retrieve, process and communicate data (Mdukaza et al., 2018). In that way, previously static information is turned into a dynamic mobile resource of potential value to organizations (Ng & Wakenshaw, 2017). As an example, in pragmatic terms, a bucket on the floor holds information on its contents, its contents color, volume and location. Normally this information is only available to those that can see inside the bucket. IoT however makes it possible for anyone else to see all information about that bucket (Ng & Wakenshaw, 2017).

The utilization of IoT has already proven beneficial in some industries, including waste management (Sarc et al., 2019). IoT has been used to increase operational efficiency of waste collection and management by using "smart bins/containers" where sensors are for example used for geographical mapping (Shyam, Manvi, & Bharti, 2017) and to measure container fullness levels (Kumar & Parimala, 2018). Resulting from these measurements, operational benefits can be realized with for example more efficient pickup routes and scheduling using routing optimization algorithms (Shyam et al., 2017).

1.2 Problem description

In recent years, IoT has been popularized in personal homes, offices, industries, vehicles and even in cities on a larger scale (Rose, Eldridge, & Chapin, 2015) thus leading to the development of smart homes, vehicles and cities. Municipalities are continuously increasing their use of information and communication technologies (ICT) and IoT plays a major role in constructing technological ecosystems which characterize smart cities (Mehmood et al., 2017). The goal of these smart cities is to become more attractive and sustainable, providing needed services with more ease (Mehmood et al., 2017). One of such required services in these ecosystems is smart waste management. Sustainable development practices and goals have become an integral part of our daily lives. These practices help reduce the effects of climate change while increasing the efficiency of resource management (Zhang et al., 2019). With the human population growing rapidly, annual waste generation is expected to increase by 70% from 2016 to 2050 (The World Bank, 2019). Piling on top of that, the United Nations predict that by that time, 66 percent of the human population will reside in urban areas (United Nations, 2014) which demonstrates the importance of efficient and effective waste management.

While some waste management organizations have already adopted IoT or are in the process of implementing IoT technology into their operations, there is a lack of research on the factors acting as barriers to IoT adoption and the adoption process (Zhang et al., 2019). Some organizations start off by piloting the technology to gain a Proof of Concept (PoC). By merely running the pilot and proving that the technology works does not guarantee a successful implementation and in fact, according to technical reports, around 70% of IoT pilot initiatives fail (Beecham research, 2020; Deloitte, 2019). This demonstrated the need to identify what is hindering this IoT adoption and implementation process, come up with strategies or methods that could be used to smoothen the process and then communicate the overall process. This information is useful from an academic perspective as the intra-organizational barriers within waste management have not been explicitly studied. Moreover, the resulting process can be useful for waste management organizations, but also other organizations that are experiencing the same barriers.

Hence the core problems at hand were *identifying what the intra-organizational IoT adoption barriers are, what are the most influential barriers, what mitigation strategies can be deployed to mitigate these barriers and how it can all be illustrated within an IoT adoption and implementation process framework.*

1.3 Research questions and scope

1.3.1 Research questions

The main research question was formulated to describe the main objective of the research. The sub-research questions hold partial information which were needed to answer the main question at hand. The following is the main research question:

How can the adoption and implementation process of IoT-powered fullness sensors in waste management be improved?

Answering this question required research into what internal factors are hindering the adoption and implementation of the IoT into waste management organizations. The first sub-question therefore focused on identifying what organizational-specific factors are generally acting as barriers to innovation adoption. By first identifying these factors, they could be used as a benchmark to see which are affecting IoT adoption and implementation in waste management. The significance of these barriers may vary, and it was important to identify the strength of each factor in order to pinpoint the biggest obstacles in the IoT adoption and implementation process within waste management, and thus that was the focus of sub-question two. Sub-question three focused on understanding how the adoption barriers can be mitigated. Presumably there are multiple intra-organizational factors that affect the adoption of IoT but to fully adopt and implement the technology, adoption barriers within waste management companies needed to be not only identified but also mitigated. The final question, sub-question four, entails design and development efforts. The main deliverable from this study was an IoT adoption and implementation framework for waste management. The question thus focused on identifying how an IoT adoption and implementation process in waste management looks like based on the research efforts and findings laid out in this report.

Thus, the following sub-questions were formulated:

1. What are the general intra-organizational innovation adoption barriers?
2. What are the most significant intra-organizational IoT adoption barriers within waste management?
3. How can the most significant intra-organizational IoT adoption barriers be mitigated?
4. What does an IoT adoption and implementation process in waste management look like?

1.3.2 Research scope

IoT is an overarching term that includes a broad spectrum of "things" that can be connected as well as their different applications. It is therefore important to address exactly is the main focus of this research and what is not. The research scope of this study is three-sided: Industry specific, organizational, and technological.

The waste management industry was the focus of this research as an opportunity was taken to do a case study within a waste management organization that is currently in the process of adopting and implementing IoT technology.

From the Organizational side, this study focused on the intra-organizational barriers to IoT adoption and implementation. It also identified what determinants are most influential in that process. This specific context of barriers was chosen due to having access to an organization where they can be examined in more detail. It was also chosen because the factors found within this context are likely more modifiable than those related to the technology itself or the external environment and thus more interesting in terms of mitigation strategies. Organizational practices, planning and decision-making were analyzed as they play a key role when designing strategies to lessen the influence of intra-organizational barriers to technology adoption. A framework illustrating the adoption and implementation process from an organizational perspective was then designed.

From a technological perspective, solely IoT container fullness sensors are considered in this study as it is a very logical fit to waste management in general. The technical specifications or design of the sensor system is not within the scope of this study, but focus remained on the influence the technology has in a waste management context. It also serves to mention that once IoT is implemented into waste management organizations, other industry 4.0 technologies are often fitted to augment the use of these sensors and bring about added capabilities. One such technology is Artificial intelligence (AI), but it was not addressed explicitly as a subject of this study.

2. Research Methodology

This chapter will describe the research structure, research methods used, the data collection and analysis that was needed for this study. A fitting research and data collection method was chosen to answer each of the sub-questions and subsequently the main research question of the study.

2.1 Research structure

The overarching structure of this research project follows the Design Science Research Methodology (DSRM) as portrayed by Peffers, Tuunanen, Rothenberger, & Chatterjee (2007). The method is based on Design Science (DS) research for Information Systems (IS) principles and guidelines provided by Hevner, March, Park, & Ram (2004) (Peffers et al., 2007). The DSRM provides a commonly accepted approach which involves a rigorous six step activity process for creating and evaluating an IT artifact intended to solve organizational problems (Peffers et al., 2007). An illustration of the original methodology can be found in Figure 1 – The DSRM, adapted from Peffers (2007).

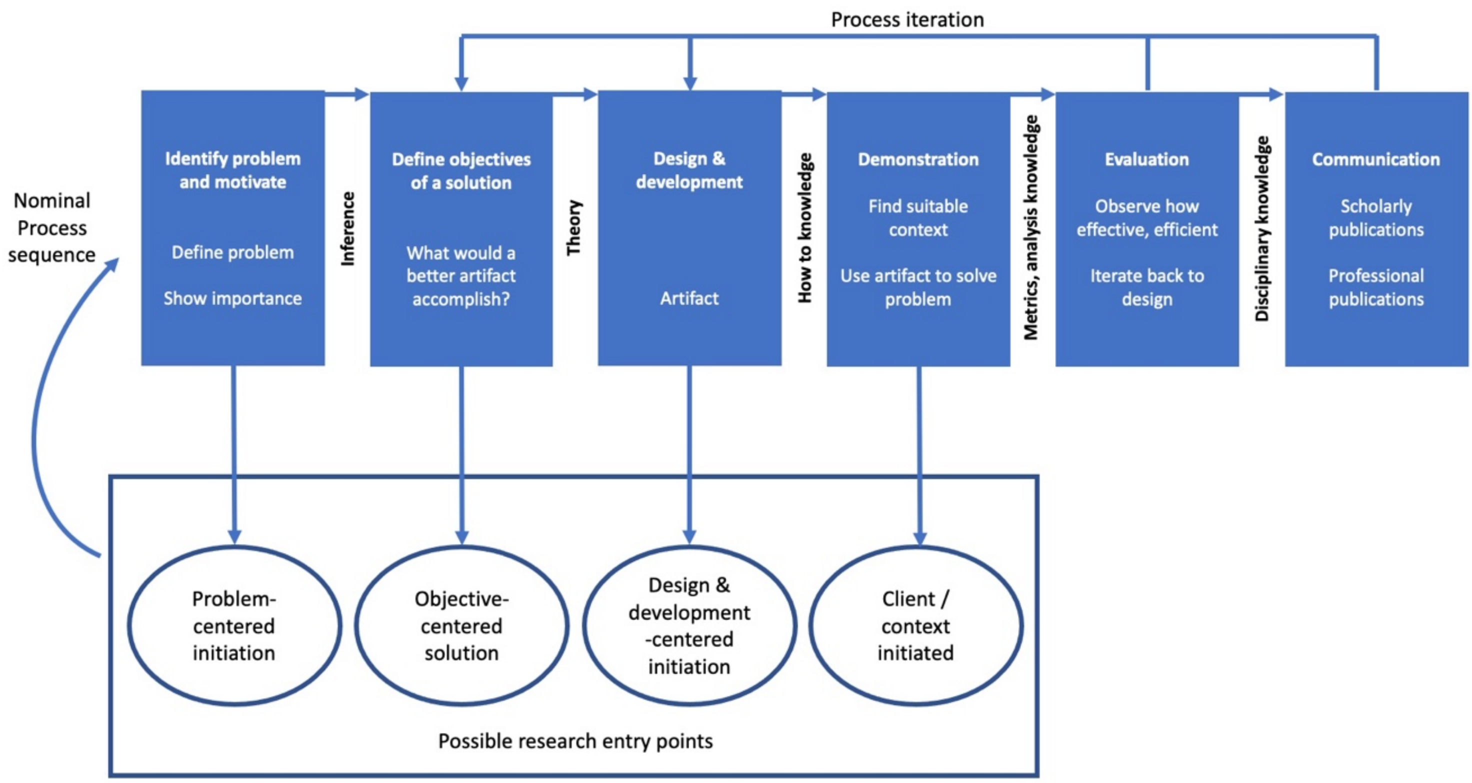

Figure 1 - The DSRM, adapted from Peffers et al. (2007)

The purpose of this research was to identify how the adoption and implementation of IoT technology within waste management can be improved, which demands a clear approach and procedure of activities and methods. The Design Science Research Methodology was chosen for this project as it provides all the necessary steps needed to design a framework in a sophisticated and purposeful manner. For this study, the DSRM was altered and tailored to fit this particular research. The framework designed in this study could not be implemented and tested in a real-life scenario due to the time restrictions of this research project. Demonstrating the designed framework was not feasible within the timeframe and thus the demonstration phase of the DSRM was not applicable for this study. Expert interviews were instead conducted to evaluate the theoretical validity of the designed framework. Figure 2 shows the adapted version of the DSRM describing the structure of this study.

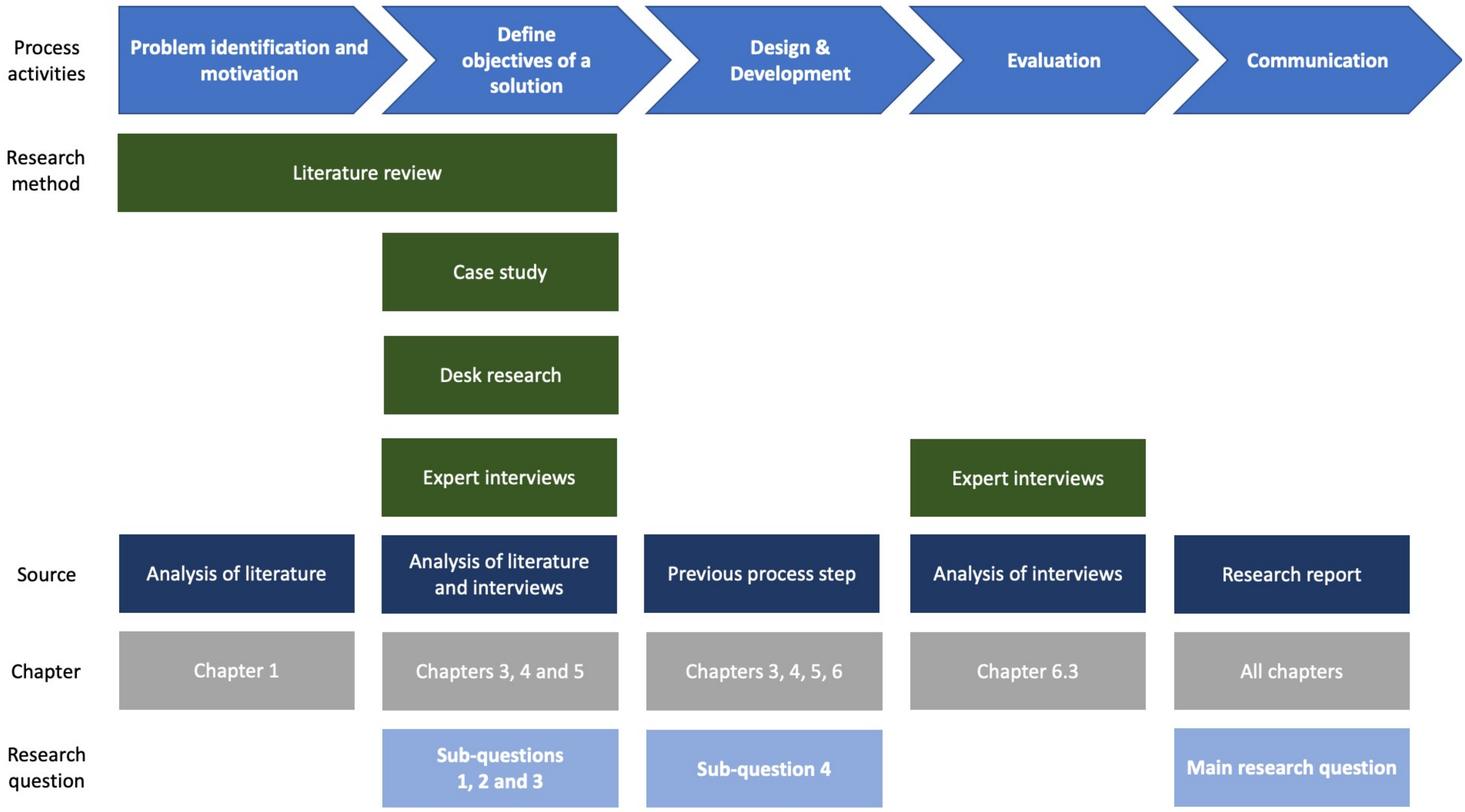

Figure 2 - Research structure, adapted from Peffers et al. (2007).

The first stage, *problem identification and motivation* can be found within chapter 1 - Introduction. This research project was initiated due to a case where a waste management organization was having trouble fully adopting and implementing IoT fullness sensors into their operations. This case prompted an examination of relevant literature, and later the realization that this organization was not the only one dealing with IoT implementation issues, as discussed in the introduction of this report. Furthermore, a gap in the literature was identified which further demonstrated the need for this research, both from an academic perspective as well as a practical one.

The second stage, *Define objectives of a solution,* represents chapters 3 – Literature review, 4 – IoT adoption barriers within waste management and 5 – Adoption barrier mitigation strategies. This stage of the research thus represents the main body of the research efforts of this study as it served as the foundation and main building blocks of the designed framework. In this stage, a clearer vision on what is possible and feasible to solve is obtained. When examining the relevant academic literature on innovation adoption and implementation, a trend was identified where scholars and practitioners focus on identifying and comparing the determinants of the adoption process using various methods. This was an important step in the research process of this study as it outlined a way to be able to identify the main barriers of IoT adoption and implementation within waste management.

A theoretical framework holding all the relevant intra-organizational barriers was first designed based on the existing literature. Case study interviews were then conducted within a waste management company to gain a deeper insight into the state of their IoT adoption and implementation efforts. During these interviews the theoretical framework was used to identify the factors acting as barriers in their process. This framework is introduced and described in more detail in section 4.1 - Organizational barriers to technology adoption framework. As a result, sub-questions 1 and 2 of this study were answered and the objectives of the designed framework were made clearer; to include steps that aim to mitigate the identified barriers. These steps entail strategies that can be employed by organizations to acquire the knowledge needed for a smoother and more successful IoT adoption and implementation. The strategies were formed based on information gathered by doing desk research and conducting interviews with IoT experts which made it possible to answer sub-question 3.

In the third stage, *Design & development,* the IoT adoption and implementation process framework was designed and created using the information and data gathered from the previous process step. In that way, the framework's overall functionality, activities and expected deliverables were designed and organized to form a coherent process for the IoT adoption and implementation process framework. After having designed the IoT adoption and implementation process framework and its evaluation in the next stage had been carried out and adjustments made, sub-question 4 was answered. This stage is presented in chapter 6 – The IoT adoption and implementation process framework for waste management.

The fourth stage, *Evaluation*, would typically entail an assessment of the framework's performance during its demonstration to determine how well it serves its intended purpose based on the solution's objectives in stage 2. The framework could however not be implemented in a real-life context during this research project due to its time restrictions. Demonstrating the framework and going through all its stages would take longer than the time allocated for a research project such as this one. As no demonstration was performed, in order to evaluate the framework designed in this study, expert interviews were conducted to assess its correctness and theoretical validity. Depending on the evaluation results, improvements can be made by iterating back to stage 3 or continue to the next stage of the DSRM and leave improvements to future projects. A confirmation of the framework's theoretical validity and expected performance in terms of its set goals and objectives was that way acquired. The evaluation is described in chapter 6.3 – Framework evaluation.

In the fifth stage, *Communication*, the identified problem, the framework and its utility, novelty of design as well as its rigor and effectiveness are communicated (Peffers et al., 2007) to the relevant audience, namely researchers and practitioners in the waste management industry. Recommendations for future research are also included in this stage for further improvements that can be made to the IoT adoption and implementation framework based on its limitations. The communication is made though this research report.

2.2 Research methods and data collection

Various methods and sources of information and data gathering were needed to answer all the sub-questions and the main research question. This section will introduce and argue for the research methods chosen for this study.

2.2.1 Literature review

The literature review served as a summary and a discussion of what research had been conducted relating to the research objectives of this study and identifying the most influential and prominent theories in this field. It therefore demonstrated the current status of knowledge in this particular field and showed where further investigations could be made in terms of filling up gaps of knowledge. The previous research conducted within the scope of interest for this study also provided useful points of investigation, providing guidance for some of the research approaches used in this study. This included the methodology used to identify the IoT adoption barriers and defining some of the questions used for the case study interviews.

2.2.2 Case study

There are numerous research methods that can be chosen for a thesis project such as this one. A case study, grounded theory, surveys, and experiments are all viable options. In this case, when examining the problem and expected deliverables, a case study was the most logical choice as it allowed a deeper analysis into the factors and barriers affecting the adoption and implementation process within waste management. Case studies are an appropriate approach when dealing with “how” or “why” research questions that focus on exploring or understanding something comprehensively (Schoch, 2019). According to Gerring (2004) a case study is when one studies a single unit in order to better understand a larger class of almost identical units. Case studies are performed when information is needed on a specific object, event or activity and is examined in a real-life context using various methods for the collection of data (Sekaran & Bougie, 2016).

A case study was fitting for this research project both due to its nature as a research method but also because an opportunity for such a study presented itself within a large waste management organization in Iceland. The unit of analysis in this study was this waste management company and its adoption and implementation of IoT technology. More specifically, the company’s IoT adoption barriers, waste collection processes, employees’ perceptions and opinions related to the IoT-powered fullness sensors were examined and evaluated which was made possible with the case study approach.

Semi-structured interviews were conducted within the company. A purposive sampling approach was taken where interviews were conducted with the head of services, head of scheduling, head of IT as well as two employees from the company’s control center. These participants were chosen by the author due to their knowledge on the company’s IoT adoption and implementation efforts, and experience from using the technology.

The case study interviews were conducted in two steps. In the first phase, semi-structured face-to-face interviews were conducted where participants were asked questions relevant to the organization’s problems of IoT adoption. The questions involved enquiring into changes within the organization after sensor installments, affected processes, reasons for seeking to adopt IoT, employees’ opinion on the technology and lastly the perceived barriers to adoption within the company. Nearing the end of these interviews, participants were handed a list of all the factors from the theoretical framework, introduced in section 4.1, and asked to indicate which of the factors they perceived to be present within the company and affecting the IoT adoption process. This gave an indication of what barriers were affecting the overall process but did not explain to what extent, which was the main focus of the second phase of interviews. The interview structure template for the first phase of interviews can be found in Appendix A – Interview structure templates.

The second step of the interviews was taken shortly after all the face-to-face interviews had been conducted. It involved having participants rate to what extent they agreed that a factor from the theoretical framework, was acting as a barrier in the company's IoT adoption and implementation process. This was done via Google forms where each barrier was described and then asking to what degree the employees perceived the factor in question to be acting as a barrier in the adoption and implementation process. A five-point scale from strongly disagree to strongly agree was used to indicate the level of significance for each factor. An example of this can be found in Appendix B – Barrier influence assessment example.

2.2.3 Expert interviews

The experts chosen for this study are individuals working for a progressive telecommunication company founded in 2017 and is based in Hafnarfjordur, Iceland. The company specializes in the installment and maintenance of various telecommunications but is currently the market leader for IoT solutions in Iceland. Among their clientele are the municipality of Reykjavik and the waste management organization studied in this research project. Even though the company is relatively young, two of the interviewed experts have been working with IoT since before its establishment while the other two have been involved with the technology for the last two years.

Semi structured face-to-face interviews with four IoT experts were conducted to gain an insight into their views on the most effective barriers affecting IoT adoption processes in waste management. More importantly, these experts were asked about viable strategies that can be used to mitigate these barriers based on their experience of practice in this field and working with the waste management organization. For the mitigation strategies, this approach was chosen as a combination with desk research as the academic literature on these kinds of strategies is limited. The interview question template for these interviews can be found in Appendix A – Interview structure templates.

Aside from the mitigation strategies, three expert interviews were also used to evaluate the IoT adoption and implementation process framework designed in this study. The framework was introduced, and each step explained in detail including its fundamental basis and design, and the incorporation of the adoption barrier mitigation strategies. The experts were then "walked" through the process and asked to take a critical look at the framework. They were subsequently asked to identify aspects that stuck out at each stage that needed altering or more consideration for the framework to represent a realistic and functional process. It was deemed more effective to conduct these interviews separately instead of in the form of an expert panel to get individual opinions and reduce the chances of conformity. These interviews were conducted using the Zoom video teleconferencing software due to the increased spread of COVID-19.

2.2.4 Desk research

While the expert interviews provided some very interesting and useful information on relevant strategies that can be employed, desk research was also needed for some of the barriers. As the academic literature on countering some of the barriers in question is scarce, grey literature was also used as a source of information. These mostly included IoT analysis reports from private consultancy firms and privately published research reports within the field of IoT.

2.3 Data analysis

When analyzing the interview data, the first step taken was transcribing the interviews themselves, the next step was data reduction through interview coding and categorization. This process was carried out manually using Microsoft Word's basic functions as recommended by Saldana (2015) for those not familiar with using specialized coding programs. A deductive coding approach was taken as explained by Saldana (2015), where most codes and categories were defined before the coding process started while others emerged in the process. The predefined codes and categories were chosen according to the sub-research question it helped to answer. As an example, all responses and explanations that helped give an insight into the second sub-question "What are the most significant intra-organizational IoT adoption barriers within waste management?", were assigned predefined codes that had the names of the intra-organizational factors from the theoretical framework. In this example, these codes were then assigned to the category "Barriers". This process was particularly useful when analyzing how many interviewees mentioned each barrier during interviews in this study. Table 1 – Interview coding example one, shows an example of this.

Table 1 - Interview coding example one

Category	Interviewee	Interview texts	Codes
Barriers	A	"Culture, we have some cultural difficulties or challenges..."	Culture
Barriers	A	"Strategic objectives, this is also a big thing that needs to be carefully planned when we take the technology into our hands, how do we use it, not just internally but also when presenting it to our customers."	Strategic objectives
Barriers	B	"Centralization, it has been so that the distribution of power within the company is lacking."	Centralization

Some codes were however derived from the interview transcripts and represented something that could be useful to answer the sub-research questions. An example of this is when the expert interviewees were asked about mitigation strategies for the most influential barriers identified in the case study. Here, the codes emerged based on the respondents' answers as there were no predefined codes for the mitigation strategies that the experts came up with. The category in this case was created for all the barrier mitigation strategies and then a sub-category describing which barrier the strategy aimed to mitigate. Codes were that way categorized and sub-categorized according to themes that emerged in the transcripts. An example of this can be seen in Table 2 – Interview coding example two.

Table 2 - Interview coding example two

Category	Subcategory	Expert	Interview texts	Codes
Barrier mitigation strategy	Uncertainty of business benefits	A	"It is a bit the responsibility of those who are coming up with the solutions, new solutions and other things, to show that they work. It can sometimes be more of a challenge when there are maybe only a few of such projects or if the concept is new, then it can be harder. The threshold can drop if you can point to [another waste management company] in this case, and say 'see they have done this and this is how much they have saved'. Then all of a sudden you have facts on the table because we always call for facts to actually make decisions." "It's just a question of when, if you get your hands on something like this, it should be made 'smart', and we need to do it in steps, even if it takes 2 years or 5 years."	Use cases Incremental scale-up
Barrier mitigation strategy	Uncertainty of business benefits	B	"[...] like regarding business benefit. It's what we rely in our suppliers who have larger projects going on, that they can demonstrate that these business cases have been going well. I think it's something that companies need to see and often maybe even	Use cases

			see for themselves if they can, what can I say, if they can get to know other companies' processes, how the implementation was done by others, I think that says much more than us describing how this happens."	

After all interviews had been conducted, transcribed, and coded, data triangulation was used where data from multiple different interviewees was compared and analyzed. This was done to alleviate the inevitable researcher bias often associated with interviews (Sekaran & Bougie, 2016) and enhanced the credibility of the results, especially for both the first and second sub-question of this study. The coding tables can be found in Appendix D – Interview analysis.

3. Literature review

This chapter will introduce the relevant literature found using strings of keywords associated with the problem at hand, namely *IoT, adoption, adoption barriers, intra-organizational, waste management, implementation, innovation, process*, *strategies,* and *mitigation* to name a few. These were used in conjunction with one another as well as using relevant synonyms for each keyword. In this chapter, the Internet of Things and its relevance to waste management will first be discussed and the operational benefits resulting from using the technology within the industry. Research and theories on technology adoption factors will then be discussed before narrowing our scope to IoT adoption factors. Lastly, IoT adoption factors in waste management and innovation adoption processes will be discussed.

3.1 IoT in waste management

As cities are gradually becoming "smarter", smart waste management has gained interest among researchers with some focusing on the system architecture (Al-Masri, Diabate, Jain, Lam, & Nathala, 2018; Bharadwaj, Rego, & Chowdhury, 2017; Likotiko, Nyambo, & Mwangoka, 2017), while others focus on the technological system itself (Chen, Wang, Huang, Huang, & Tsai, 2018; Hong et al., 2014; Mahajan, Kokane, Shewale, Shinde, & Ingale, 2017).

Although smart cities, system architectures and the use of technological solutions in smart waste management solutions are the focal points of most research today (Zhang et al., 2019), limited attention is paid to the adoption and implementation process of these solutions. It is however important to understand why waste management organizations are seeking to digitalize their processes by using IoT technology and so the operational benefits from utilizing IoT in waste management will be briefly discussed.

Operational benefits of IoT fullness sensors in waste management

Operational benefits of IoT-based fullness sensors have been researched to some extent (Chen et al., 2018). At its core, the benefits that organizations can gain by using IoT are derived from readily available and automatically collected information (Brous, Janssen, & Herder, 2020). The use of IoT can result in improved strategic planning due to improved forecasting, improved planning of pickups, cost reductions due to increased operational efficiencies, improved effectiveness and efficiency of provided services and improved reputation of the organization (Brous et al., 2020).

Gutierrez, Jensen, Henius, & Riaz (2015) designed a smart waste collection system in 2015 and conducted a case study in which the system was tested using a simulation with open data from the city of Copenhagen. The test was performed in three scenarios to compare traditional waste pickups to dynamic ones where the designed system was used. The authors concluded that picking up cans when they were completely full was more efficient in terms of overflowing trash and time elapsed after a can became full, but higher daily costs were incurred due to three times as many kilometers driven (Gutierrez et al., 2015). It is thus important for waste management organizations, specifically their managers and leaders to plan carefully how the technology will be used, what operational benefits they seek and how they can be realized.

In 2017, Shyam et al. (2017) concluded that the traditional waste management method, where every bin/container is emptied, is less efficient and more costly than solely emptying those that have reached a certain capacity, especially when using a route-optimization algorithm. Misra, Das, Chakrabortty, & Das (2018) did a cost-benefit analysis of using fullness sensors where equipment costs, time savings, salaries and driving distance were taken into consideration. Similar research was conducted by Bakhshi & Ahmed (2018) where only fuel and time costs were assessed. Both studies showed that waste management costs can be lowered by using IoT technology. This shows that operational benefits can be gained from using IoT within waste management and it is not a matter of "if" but "when" the technology will be considered essential within the industry.

3.2 Organizational technology adoption factors

When examining the literature on technology adoption determinants from an organizational perspective it becomes evident that many authors base their work on or expand on two prominent technology adoption theories. These theories are Rogers' Diffusion of innovation (DOI) theory from 1995 and the Technology, Organization and Environment (TOE) framework developed by Tornatzky and Fleischer in 1990 (Oliveira & Martins, 2011). These theories and associated frameworks proved useful as a baseline for identifying internal adoption factors within waste management.

In his book, Rogers (1983) used "innovation" and "technology" as synonyms and claims the innovation does not need to be something recently developed, but something an organization has recently implemented or adopted. Rogers' theory states that the following two characteristics of an innovation need to be evaluated by the potential adoptee before implementing the technology. Firstly, the relative advantage of the innovation and its compatibility with the firm's current infrastructure are deemed as the most significant factors. Secondly, the complexity and trialability of the innovation will need to be evaluated (Prause, 2019). The DOI framework is divided into three categories of independent variables affecting organizational innovativeness, namely: Leaders' characteristics, internal characteristics of organizational structure and external characteristics (Rogers, 1983). The category Leaders' characteristics contains the factor *Attitude towards change*. Although this factor does not describe the internal structure of the organization, it is a factor found *within* the organization as it describes the organization's leadership. The other organizational factors found in the DOI framework by Rogers (1983) are: Centralization, Complexity, Formalization, Inter-connectedness, Organizational slack and Size. While this framework does include many organizational characteristics that certainly can influence the adoption of innovations into organizations, other organizational determinants of adoption, not related to its structure, are missing.

According to Oliveira & Martins (2011) the TOE framework defines three contextual aspects which affect an organization's technology adoption and implementation process: Technological context, Organizational context and the Environmental context. The Technological context contains the factors Availability and Characteristics. These factors describe the technologies available to the firm, both internally as well as externally. This category also includes the firm's current practices and equipment within the company (Oliveira & Martins, 2011). The more applicable context, Organizational, holds the descriptive factors that define the firm, namely Formal and informal structures, Communication processes, Firm size and Slack (Oliveira & Martins, 2011). The Environmental factors are Industry characteristics and market structure, Technology support infrastructure and Government regulations which all set the organization's arena (Oliveira & Martins, 2011).

When developing an Information and Communications Technology (ICT) adoption framework, Govender & Pretorius (2015) identified multiple internal, external and technological factors that influence the adoption of ICT within an organization. By conducting a literature review, they gathered all the relevant factors and designed a framework intended to aid manager with ICT adoption decision-making. The organizational factors identified were 15 in total. Most of these factors were the same as presented in the DOI and TOE frameworks, thus very much related to the structure of organizations. There were however factors identified which describe the nature, behavior, and management of organizations which were not included in the previously discussed frameworks. These factors are: *Culture, Degree of risk-taking, End user behavior, Strategic objectives* and *Uncertainty of business benefits.* (Govender & Pretorius, 2015). The internal factors identified proved useful as a benchmark when identifying the factors inhibiting the adoption and implementation process within waste management.

Alshamaila, Papagiannidis, & Li (2013) studied the adoption process of cloud computing into small and medium-sized enterprises (SMEs) in England. This study was based on the multi-perspective TOE framework mentioned earlier in this section. In total, 15 companies were studied. Interviews were conducted to gain a deeper insight into each company's adoption process and the TOE factors evaluated for each company and a comparison on their effects was made (Alshamaila et al., 2013). To avoid bias, participants also had the chance to discuss the factors that they deemed to be of importance in the process, although not necessarily a part of the TOE framework. Geo-restriction was the only critical factor identified which was not included in the original TOE framework (Alshamaila et al., 2013). The intra-organizational factors found to be significant in the adoption process of cloud computing were: Relative advantage, Uncertainty, Compatibility, Size, Management support and Innovativeness (Alshamaila et al., 2013).

3.3 IoT adoption factors

Omoyiola (2019) did a literature review on research that had been conducted on the factors that affect the adoption of IoT within companies. The foundation of Omoyiola's research was a framework designed by Oliveira, Thomas, & Espadanal (2014) where the DOI and TOE frameworks were merged together, covering the frameworks' independent and mutual IoT adoption factors. In this merged framework, ten factors were identified (Oliveira et al., 2014), of which Omoyiola focused on seven of those factors. Only two of the identified factors proved to be intra-organizational, namely *Top management support* and *Firm size*. The study provided a useful ideology, to merge frameworks together for added coverage in the research.

A model designed by Lobo, Vasconcellos, & Guedes (2018) was constructed from factors found in the literature with a focus on the technology contextual factors. The model was then used in two case studies conducted by the same authors. Two companies operating in different domains were chosen for the case studies based on the fact that they had recently, or were in the process of integrating IoT technology. The authors tested the model by conducting interviews with representatives from each company and gaining insight into the respective relevance of each factor for each company in the adoption process. Subsequently, a comparative analysis of the two case studies was made and the authors concluded that all factors in the model were relevant to either company in their implementation process with a varying degree of effect depending on the companies' values, context and industry (Lobo et al., 2018). This research shows that adoption determinants are context-based and affect organizations differently as they are subjective to each company based on how they perceive the influence of each factor.

IoT adoption factors in waste management

Sharma et al. (2020) sought to identify IoT adoption barriers and their strength to influence waste management within smart cities. The barriers were identified through a systematic literature review and then verified by experts. A total of 15 determinants were identified and their intensity analyzed using three different methods, namely the hybrid TISM, Fuzzy MICMAC and the DEMATEL method (Sharma et al., 2020). The research findings suggested that the lack of regulations, policy and directions, internet connectivity, and lack of standardization were the key IoT adoption barriers for waste management within smart cities (Sharma et al., 2020). The factors examined are mostly external and technical, likely due to the research context of smart cities. There was only one factor specifically related to the intra-organizational context which was Limited skilled workforce (Sharma et al., 2020).

In their journal article, Zhang et al., (2019) sought to identify barriers to smart waste management in China with a focus on circular economy by using a mixed-method approach. The authors first identified six initial barriers by conducting desk research. These barriers were then used in interviews with 14 experienced practitioners from different industries that all had experience from using IoT. The interviewees were asked to review the list of barriers and add ones they felt was missing. These interviews resulted in 12 important barriers being identified in total. Among these 12 barriers there were four intra-organizational barriers of interest for this study. Those are the *lack of innovation capacity*, *difficulties in technology and their applications*, *costs and financial challenges* and lack of *leadership commitment*. In the quantitative phase of the research the authors used the fuzzy Decision-Making Trial and Evaluation Laboratory (DEMATEL) method to visualize the causal relationships and the degree of influence between barriers. Three different stakeholders, a technology provider, a technology user, and a government agency were then surveyed on these barriers and the most effective barriers analyzed from each perspective. The perspective of interest for this study is from the technology user which identified the *lack of innovation capacity* as the most significant barrier to IoT implementation. The authors state that there is a need for both quantitative and qualitative research in this field of study and while this study identified some intra-organizational barriers, it was not its main focus. It can further be argued that the intra-organizational factors identified in this study are the same as in other technology studies, although their phrasing is different. Furthermore, it can be argued that the lack of innovation capacity is a factor that constitutes multiple organizational factors, the factors that this study will focus on.

No other research was found that specifically focused on IoT adoption and implementation barriers within waste management, which establishes the need for such research and to identify the intra-organizational barriers of IoT adoption and implementation within waste management organizations.

3.4 Innovation adoption processes

Rogers (1983) posits that the adoption of a technology within organizations occurs in stages and that the decision to adopt is ultimately made based on the adopter's perception of the innovation (Rogers, 1983). These stages are divided among two main parts, *Initiation*, and *Implementation*. The initiation describes all the information gathering and planning needed for the innovation adoption before a decision to adopt is made (Rogers, 1983). The implementation describes all the actions and decisions that need to be made within the organization for putting the innovation in regular use (Rogers, 1983). The adoption process occurs in five stages, *Agenda-setting, Matching, Redefining/restructuring, Clarifying and Routinizing* (Rogers, 1983). In agenda-setting, individuals within the organization identify a problem and look for an innovation that can solve it (Rogers, 1983). In the matching stage the organization evaluates the feasibility of the innovation in terms of solving the organizational problem (Rogers, 1983). In the redefining / re-structuring stage the innovation or the organization's structure is altered to accommodate the organization's needs from the innovation (Rogers, 1983). In the clarifying stage, the innovation is becoming embedded into the organization and its use and meaning becomes clearer to the organization's members. The routinizing stage is the final stage in the innovation process where the innovation has become fully integrated into regular tasks and processes handled within the organization (Rogers, 1983). Figure 3 shows how the stages are connected and how the implementation of a technology occurs after the decision to adopt has been made.

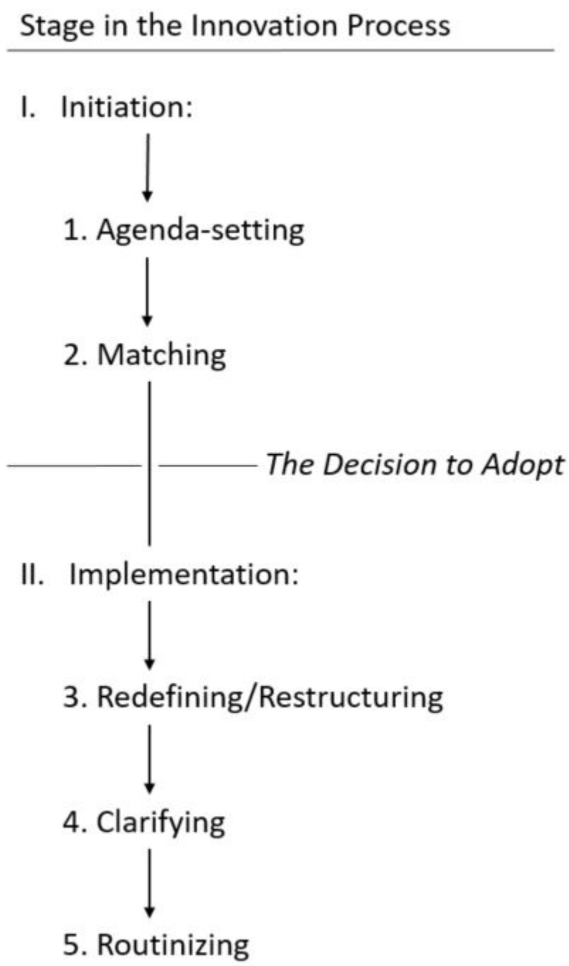

Figure 3 -The innovation adoption process within Organizations, adapted from Rogers (1983).

Frambach & Schillewaert (2002) reviewed the literature on organizational innovation adoption processes as well as their inhibitors and stimulators. These findings were discussed and integrated within a framework. Their findings suggest that little is known about what factors are affective each stage of the adoption process and that most studies focus on the factors affecting the adoption decision itself (Frambach & Schillewaert, 2002). A conceptual framework is presented which attempts to explain direct and indirect effects of factors inhibiting the innovation adoption process within organizations. The process itself differs from the one commonly used by Rogers (1983) as they posit that the innovation adoption process on an individual level should be examined as well (Frambach & Schillewaert, 2002). Their logical reasoning for this approach is that to adopt an innovation on an organizational level, affecting organizational processes, the end-users will have to comply with its usage. This line of reasoning shows that although a value-creating technology is brought into an organization it will still have to be accepted by the respective members of the organization for a successful adoption and implementation. During the case study conducted in this research it was therefore important to gather information on the IoT acceptance of relevant employees' and assess if that is indeed a barrier in their process.

3.5 Knowledge gap

When examining the previously discussed literature on internal adoption barriers, various factors are identified, and different frameworks are used as benchmarks or adapted to identify adoption barriers within organizations. The most prominent frameworks in this field do include internal or organizational factors affecting the adoption of a technology. It is however uncertain what *intra-organizational* factors affect the adoption of *IoT technology* within *waste management.* According to Alshamaila et al. (2013), the business domain of the adopting organization was consistently found to affect the technology adoption process within companies. No frameworks solely focusing on factors within the organizational context were found in the literature and only two articles were found that focused on IoT adoption barriers, both internal and external. One research focused on the context of smart cities while the other focused on a circular economy involving multiple stakeholders but neither in the context of waste management. Furthermore, no scientific articles were found that explicitly discuss appropriate strategies that can be employed to mitigate organizational barriers. Some scholars have attempted to describe the general innovation process within organizations. They however don't quite encapsulate what is needed at each stage, especially for IoT technology.

4. IoT adoption barriers within waste management

In this chapter, the theoretical framework used in the case study to identify the barriers to IoT adoption will first be introduced. The case study will then be discussed as well as its findings.

4.1 Organizational barriers to technology adoption framework

This section will introduce the theoretical framework which was used as a benchmark for identifying the internal adoption barriers within waste management. These factors were used during interviews in the case study of the waste management organization. Figure 4 shows an overview of the factors that were used in this research to identify the influential barriers affecting the adoption of IoT into waste management.

In order to cast a “wide net” and include most of the significant intra-organizational determinants, a new framework with a focus on internal factors was developed. This new framework was used to identify the relevant factors associated with IoT adoption within waste management. As mentioned in section 3.2, the two most prominent frameworks focusing on innovation adoption within organizations are the DOI and TOE frameworks. These frameworks contain identical internal factors and thus the DOI framework was chosen to serve as a starting point for the new framework. The other framework that was used and previously mentioned in section 3.2, is the ICT adoption framework designed by Govender & Pretorius (2015) due to its large number of organizational adoption barriers, and the fact that they do not only focus on the organizational structure. The duplicate factors found in the latter framework were excluded as well as multiple factors that can be described as a single factor. An example of this is Budget and Resources, which are combined into a single factor, Organizational slack, in the DOI framework by Rogers.

The included internal factors from the DOI framework by Rogers (1983) are: Leaders' attitude towards change, Centralization, Complexity, Formalization, Interconnectedness, Organizational slack and Size. *Leaders' attitude towards change* simply describes the organization's leaders' views on needed changes within the company to accommodate innovations or facilitate innovative thinking. *Centralization* is the degree to which power and control is distributed within the company and more concentration of power usually means less innovation within companies (Rogers, 1983). *Complexity* indicates the level of knowledge and expertise that an organization's employees possess, usually measured by occupational specialties and formal training. Complexity encourages innovation perception and innovative thinking (Rogers, 1983). *Formalization* is the degree to which formal rules and procedures are emphasized within the working environment of an organization. High formalization tends to inhibit innovations within organizations (Rogers, 1983). *Interconnectedness* is a factor describing the social communication networks within the company and the more interconnected the organization is, the more innovative it tends to be (Rogers, 1983). Organizational slack indicates the available resources within the firm and is positively related to innovativeness (Rogers, 1983). The *size* of a company has consistently been found to have positive relations to its innovativeness and is a variable that is easily measured (Rogers, 1983).

The remaining relevant factors are from the earlier discussed ICT framework by Govender & Pretorius (2015) which are: *Culture*, *Degree of risk-taking*, *End user behavior*, *Strategic objectives* and *Uncertainty of business benefits*. *Culture* describes the behavior, norms and values within the organization which can affect the adoption of innovation (Govender & Pretorius, 2015). *Degree of risk-taking* indicates the level of risk the organization is willing to take when associated with an innovation (Govender & Pretorius, 2015). *End user behavior* describes the attitude, experience and knowledge of employees on the innovation (Govender & Pretorius, 2015). *Strategic objectives* indicate the organization's strategic objectives and its position in relation to its competitors. Organizations that have aggressive market strategies are more likely to adopt innovations (Govender & Pretorius, 2015). *Uncertainty of business benefits* describes how organizations perceive the benefits from the innovation in terms of improved productivity, efficiency or response times where uncertainty negatively affects the intention to adopt (Govender & Pretorius, 2015).

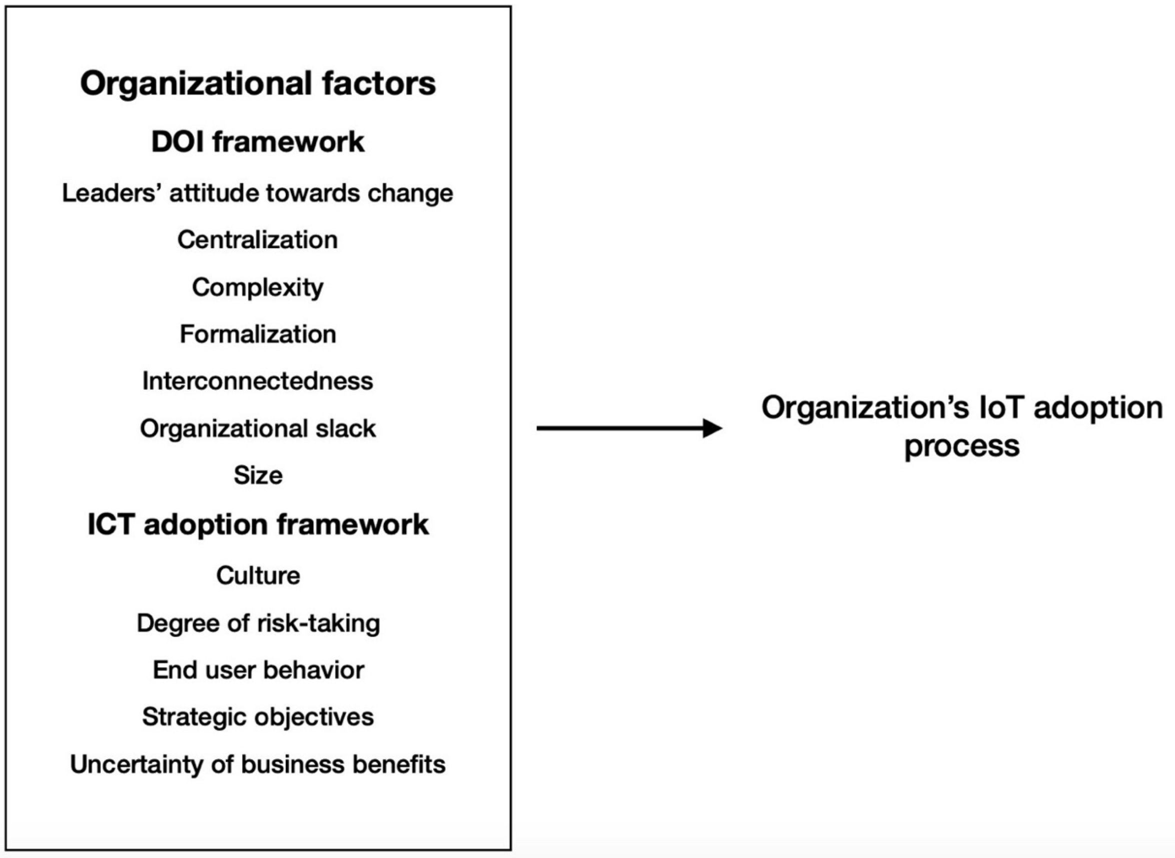

Figure 4 - Organizational factors affecting innovation adoption. Adapted from Rogers (1983) & Govender & Pretorius (2015)

4.2 An exploratory case study within waste management

4.2.1 Case study background

One of Iceland's largest waste management organizations operates as a contractor for municipalities providing waste collection and disposal services all around Iceland. Its headquarters are located in Hafnafjordur, near Reykjavik and the company currently has offices and disposal sites all around Iceland and around 240 employees.

This organization is in the starting stages of adopting and implementing IoT to become "smart" and reaping the technology's operational benefits. They are currently in the piloting phase of the adoption and implementation process, trying to gain a Proof of Concept (PoC). They as of now, have 15 fullness sensors installed in the south of Iceland in a suburban area near Selfoss and 10 fullness sensors are in the capital area near Reykjavik. The sensors were installed in collaboration with a third-party technology provider, also based in Iceland, in August of 2020. The waste management organization is currently using Sensoneo for their IoT fullness sensors, a cloud-based platform system specifically designed and well established for monitoring waste containers which even includes a route optimization feature based on data from sensors (Sensoneo, 2021). The sensors are connected using the LoRaWAN network standard which is maintained by the company's technology provider. The technical specification of the overall IoT system is therefore not one of the waste management company's main concerns in the current stage of their adoption process.

The organization is still contemplating how they can use the data from these sensors to improve their operations. Since the installments, no major changes have been made regarding pickup routing, scheduling, or other processes. Furthermore, the organization does not know how the technology is perceived among their employees, how it will affect them in the workplace or what is needed to fully implement the technology. As indicated by a representative of the organization's top management, there are still unidentified barriers within the company that need to be identified and dealt with.

When conducting this case study, the main objective was to identify the intra-organizational barriers to IoT adoption. However, knowledge on how the organization operates, its processes, motivations for wanting to adopt IoT and employees' opinion on the technology was also deemed important. Understanding the “whole picture” was therefore essential to visualize their adoption process and especially relevant for the proposed mitigation strategies discussed in the next chapter of this report.

4.2.2 Motivations for adopting IoT and employees’ opinion on the technology

During the case study interviews, respondents were explicitly asked what the organization was hoping to gain by using the IoT sensors they had begun to adopt and implement in the Proof of Concept. The primary motivations varied to some extent, but one consistent motivation was identified within all the interviews which was *less driving*. The summary of these results can be seen in Table 3 and the overall analysis in Appendix D – Interview analysis.

Table 3 - Summary of motivation analysis

Motivation	# of times mentioned
Less driving	4
Improved services	3
Lower carbon emissions	3
Container pickup optimization	2
Lower costs	2
Improved company image	2
Fuller containers	1
Improved efficiency	1
Customer demands	1
No manual checks on container status	1
Less maintenance	1

For the IoT adoption and implementation process to be successful, employees will need to embrace the new technology (Frambach & Schillewaert, 2002). The interviewees were thus asked for their opinion on the technology which then gave an indication of whether employees’ experience of the technology was positive or negative. All the employees’ opinions were positive regarding the use of the technology, and some believed that this was the future, thus worthy of the pursuit. The employees’ IoT sensor opinion analysis can be found in Appendix D – Interview analysis.

A part of the exploration in this case was fully understanding the organization’s process they wanted to improve by using the sensors. This process was illustrated based on information gathered from the interviews. The interview analysis on the waste collection process of this organization can be found in Appendix D – Interview analysis while the process itself can be found in Appendix E – Waste management organization's waste collection process.

4.2.3 Intra-organizational barrier results

During the first phase of the employee interviews each respondent was handed a list of all the innovation adoption factors from the theoretical framework, discussed in section 4.1, along with a description of each factor. The interviewees were then asked to identify which factors they believed were influencing the IoT adoption and implementation process within the company. An analysis of the interviews indicated that all the factors were perceived as barriers in the adoption process, to some extent. That is, all the factors were identified and some more often than others. Although each factor's perceived influence was not determined at that time, it gave an indication of what factors the employees thought to be influencing the adoption and implementation process within the company. In some cases, the employees expressed their concerns related to the factor mentioned which allowed for a deeper insight into how the employees felt about these factors based on their experience from working within the company and with the technology. The factor analysis table produced from these interviews can be found in Appendix D – interview analysis.

The most frequently identified factors during the first phase of face-to-face interviews were: *Strategic objectives* (5) which was identified by all the interviewed employees and *Degree of risk-taking* (4), identified in four interviews. All other factors except for *End-user behavior* (2), *Leaders' attitude towards change* (1) and *Size* (1) were identified three times. Table 4 shows the summarization of all the factors mentioned in the first phase of interviews with the company's employees.

Table 4 - Factors identified during interviews

Barrier	# of interviewees that mentioned or marked
Strategic objectives	5
Degree of risk-taking	4

Centralization	3
Complexity	3
Formalization	3
Interconnectedness	3
Organizational slack	3
Culture	3
Uncertainty of business benefits	3
End user behavior	2
Leaders' attitude towards change	1
Size	1

During the second phase of the interviews, the respondents were asked to what extent they agreed that each factor was acting as a barrier in the IoT adoption and implementation process within the company. This was done using a five-point nominal scale from "strongly disagree" to "strongly agree". The results of how each factor was perceived as a barrier on the aforementioned scale can be seen in Table 5 – Barrier influence summarization and in Appendix C - Barrier influence assessment results. The influence assessment results suggest that the factors that are most influential in the adoption of the container sensors into the company and thus acting as the most prominent barriers in that process are: *Uncertainty of business benefit, strategic objectives, and the degree of risk-taking*. A summarization of the perceived level of influence of each factor for all the respondents can be seen in the following table.

Table 5 - Barrier influence summarization

Barrier	Inter-viewee A	Inter-viewee B	Inter-viewee C	Inter-viewee D	Inter-viewee E	Barrier influence Total
Uncertainty of business benefits	4	4	5	4	3	**20**
Degree of risk-taking	2	2	4	4	4	**16**
Strategic objectives	1	2	5	4	4	**16**
Complexity	4	2	1	2	5	14
Centralization	3	2	3	2	3	13
Organizational slack	4	2	2	1	4	13
Leaders' attitude towards change	1	1	3	3	4	12
Interconnectedness	1	2	1	3	4	11
Size	3	1	1	2	4	11
Culture	2	3	1	2	3	11
End user behavior	2	2	1	3	3	11
Formalization	2	1	1	2	4	10

These results can also be seen in the following bar chart in Figure 5.

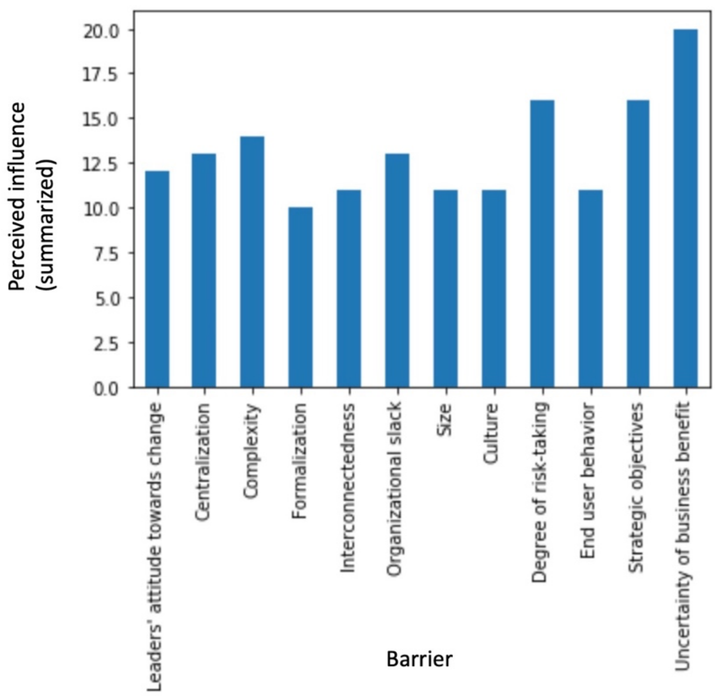

Figure 5 – Barrier influence summarization

Reading into the results, it is interesting to see, although not surprising, that all the factors from the theoretical framework were perceived to influence the adoption of IoT in waste management to some extent. This shows the complexity of such adoption and implementation processes, especially when the innovation in question requires altering organizational processes, strategies or even its structure.

It can be argued that the most effective factors identified in this case are more of a managerial nature than the other factors used. At their core, they describe decision-making made within the organization. As an example, employed market strategies and the level of risk an organization is willing to take are essentially made by the organization's top management. It can also be argued that the uncertainty of business benefits stems from decision-making, or a lack thereof, by not making explicit what is expected from using IoT and planning how to capture value from the data.

5. Adoption barrier mitigation strategies

This chapter will first introduce an important step that organizations need to make when adopting IoT sensors, to assign a technology champion or a dedicated unit within the organization that is responsible for the IoT sensors. Doing so can support the adoption barrier mitigation strategies and accelerate the overall IoT sensor adoption and implementation process. The viable strategies that organizations can use for the most significant barriers, identified earlier in the study will then be introduced and discussed. These steps and strategies were formulated based on existing academic and grey literature as well as recommendations made by IoT experts gathered through interviews. The analysis of these interviews can be found in Appendix D – Interview analysis.

The importance of a technology champion

Organizations often view IoT adoption and implementation as a technology project rather than an operation transformation. IoT adoption and implementation "projects" are thus often led by the organization's IT department. In reality, capturing value from IoT requires a cross-functional team to change employees' behavior and processes (Chui, Collins, & Patel, 2021). Assigning a dedicated technology champion or a dedicated unit within the company to oversee and lead the adoption and implementation of a technology can accelerate the overall process (Premkumar & Roberts, 1999). This is particularly important in the later stages of the process where the technology is integrated into the existing systems and infrastructure of the organization (Ghobakhloo, 2018). It has been shown that such dedicated units can improve the technology strategy-making and identify resources that can be used to demonstrate the feasibility of technologies (Howell & Boies, 2004). This also applies to IoT as one of the interviewed experts pointed out:

> "Making things "smart" is about collecting data that you intend to use to some extent. Perhaps what is missing is that companies don't have someone responsible for it, whether it is to use the data or put it in the process of making use of the information obtained from making things "smart"."

Furthermore, this unit also responsible for securing overall organizational support for the technology while handling the communications with the organization's top management and keep them updated on the progress (Howell & Boies, 2004).

When in the process of adopting a new technology, uncertainties and problems may rise which impede or even terminate the entire adoption and implementation process. Although it is important to identify the general and most significant factors that influence the adoption and implementation of IoT in waste management, the knowledge will be of limited practical use if they are not mitigated. In the following sections, the most influential barriers identified are discussed as well as their corresponding mitigation strategies.

5.1 Uncertainty of business benefits

The largest barrier identified in this research is the uncertainty of business benefits. In this study, Uncertainty of business benefits describes how organizations perceive the benefits from the innovation in terms of improved productivity, efficiency or response times where uncertainty negatively affects the intention to adopt (Govender & Pretorius, 2015). There is no universal way or procedure on how to realize the business benefits or value from innovations. There are however certain steps that can be taken to increase the probability of recognizing the value of innovations such as IoT.

5.1.1 Gaining a Proof of Value (PoV)

Before making the decision to adopt a new technology it is important to assess the value it will bring to the organization. Many technology implementations are technology-driven, especially when an interesting new technology is brought to market. This can lead organizations to prematurely adopting IoT without defining the value that the technology is supposed to capture and deliver. To increase the probability of a successful IoT adoption and implementation, the process should be value-led (Ericsson, 2015).

How organizations go about identifying the value of IoT varies based on what they want to achieve by using the technology, to what extent they have analyzed its intended application and the information they have readily available. Using Key Performance Indicators (KPIs) for this purpose has proven a successful benchmark for identifying and monitoring IoT-related progress (Rymaszewska, Helo, & Gunasekaran, 2017). In the case of waste management, KPIs such as environmental ones can be used by monitoring how many kilometers are driven for the waste pickups. The same example can be used for cost savings on driven kilometers.

Another viable option is to look use cases. Successful cases of IoT adoption and implementation can be analyzed to determine how value is being captured and delivered. This is sometimes the “proof” that an organization’s top management needs for deciding to move forward in the process. This possibility was addressed by one of the interviewed experts:

> “...like regarding business benefit. It’s what we rely in our suppliers who have larger projects going on, that they can demonstrate that these business cases have been going well. I think it's something that companies need to see and often maybe even see for themselves if they can, what can I say, if they can get to know other companies’ processes, how the implementation was done by others, I think that says much more than us describing how this happens.

5.1.2 Incremental scale-up

Although often depicted as a sequential process, technology implementation can be difficult, and iterations of steps are often needed. Simply carefully planning such a process goes a long way but is not always sufficient to ensure a successful adoption and implementation. Organizations, such as the one from the case study, have thus begun to initiate a Proof of Concept by piloting such technologies and test the waters. In that way, small steps are taken, and a limited number of resources are used to minimize the risk involved with fully integrating the technology right away. By initiating such pilots, organizations can verify that the IoT system works as expected but that alone does not guarantee that benefits are being realized right off the bat.

An implementation strategy of starting small and incrementing is needed for an adoption and implementation process. The scale-up calls for a detailed plan which is designed after piloting the IoT sensors, thus after having acquired a Proof of Concept and everything works as expected. As one expert pointed out:

> “[...] maybe try to make an agreement with them to implement things slow and steady so it’s not too much at once…It's just a question of when, if you get your hands on something like this, it should be made ‘smart’, and we need to do it in steps, even if it takes 2 years or 5 years.”

This plan involves decisions on how the installments are made. A certain starting point is decided based where or how the scale-up should take place. An organization can for example focus on covering a certain neighborhood with the long-term plan of covering its zip code. Another scale up example is by focusing on a specific type of container and then gradually expanding the IoT sensor network. By utilizing this strategy, organizations can over time increase the probability of capturing value from the sensors and deliver it to the organization. In the case of value not being realized in the scale-up process, organizations still have the option to abort. This way, incurred costs are lower than in the case of full deployment and reaching the same conclusion. Approaching the implementation in this manner can limit the financial risks involved and is thus also an applicable strategy for Degree of risk-taking.

5.2 Strategic objectives

Strategic objectives describe an indication of the organization’s strategic objectives and its position in relation to its competitors. Organizations that have aggressive market strategies are more likely to adopt innovations (Govender & Pretorius, 2015).

Using information to gain a competitive advantage

Generally, a competitive advantage can be gained by either performing a service at a lower cost than or by performing the service in a different way than rivals in the market (Porter & Millar, 1985). Once the value that can be gained from utilizing IoT sensors has been established and thus a Proof of Value acquired, strategic planning can take place by exploiting the information that the sensors capture. By doing so, the organization can determine how it intends to gain a competitive advantage.

As discussed previously in this study, the benefits from using container sensors are obtained using the information they make readily available. These benefits can take many forms and it is important that organizations pinpoint what they want to improve and how they want to capture value from using IoT. For example, increased efficiency and effectiveness of processes and operations can be realized through dynamic routing, resulting in cost reductions (Misra et al., 2018; Shyam et al., 2017). On the other hand, the main objective for adopting IoT may be more focused on the customer, being able to share data with consumers or striving for improved efficiency and effectiveness of services provided (Brous et al., 2020). Even though these two strategies are not mutually exclusive, in the case of a customer-oriented approach, the benefits will have to be communicated either directly or indirectly to the customer. This involves forming a solid business strategy based on what aspect of the organization's operations should be improved and capitalized on, followed by a market strategy based on the cost reduction or differentiation. When adopting data capturing technologies like IoT, the overall business model may even need to be modified (Parida, Sjödin, & Reim, 2019) based on the opportunities that present themselves. An effective digital transformation should be backed and led by the organization's business strategy (Lauritzen, Lee, Lehnich, & Liang, 2020) which in turn shapes the marketing strategy of the organization.

5.3 Degree of risk-taking

The degree of risk-taking indicates how much risk an organization is willing to take when associated with an innovation. How much risk an organization is willing to take when exploring the adoption and implementation of IoT is subjective to its top management. When adopting and implementing a relatively new and radical technology as IoT, risk is an understandable barrier. When adopting a new technology, research has shown that lowering the risks associated with the technology stimulates both its adoption and implementation (Frambach & Schillewaert, 2002). The previously mentioned strategy of incremental scale-up has the potential to minimize the risk involved with adopting and implementing IoT. There is however another well-established approach that can be taken which is renting instead of buying.

Renting with an option to buy

The last mitigation strategy proposed in this study implies a partnership or at least a close relationship with an organization's IoT technology provider. An agreement can be made where the sensors are rented with an option to buy once the benefits from their use have manifested. This approach is sometimes used and even deemed necessary in some cases of high technology markets (Frambach & Schillewaert, 2002). One expert described this approach as:

> “[…] then we could just make a one-year or two-year deal. For example, a two-year project, these are x many sensors and x many platforms needed, this is an investment, and we could just lease the equipment. You just pay rent, and this would not be high costs per month. Then you could rent the sensors and we would just install them, and it would entail a certain start-up cost… And then we would add together the rent for this equipment, which had to be charged for this large-scale pilot project, and credit that amount and sell the sensors.”

By utilizing this simple, yet effective strategy, a part of the risk associated with IoT-fullness sensors is thus transferred to the supplier. This can increase the prospect of a successful IoT adoption and implementation.

6. The IoT adoption and implementation process framework for waste management

This chapter will present and discuss the IoT adoption and implementation process framework designed based on the previous research efforts carried out in this study. The chapter will discuss the foundation of the framework, how it was designed and developed, before describing how the framework works by going through its process stages. Lastly, the evaluation of the framework will be described, and the evaluation results discussed.

6.1 Framework design and development

When designing the intra-organizational IoT adoption framework for waste management, the organizational innovation adoption process introduced by Rogers (1983) was used as a foundation. An adoption process generally describes different stages that an adopter passes through in a sequential order before fully adopting and implementing an innovation. Rogers (1983, p. 20), defines the innovation adoption process as “the process through which an individual (or other decision-making unit) passes from first knowledge of an innovation, to forming an attitude toward the innovation, to a decision to adopt or reject, to implementation of the new idea, and to confirmation of this decision”. It is important to note that the organization can reject the innovation at any stage of the process. Figure 3 shows an overview of Roger's organizational technology adoption process described earlier in this report.

Rogers' process provides a solid foundation as it describes a general flow of activities carried out by organizations, either explicitly or implicitly. Here, this process has however been modified so that it fits the context of IoT-powered fullness sensors and waste management. The activities that are marked in red are those that have been modified more than solely substituting "innovation" out for "IoT sensors". The barrier mitigation strategies proposed in the previous chapter were incorporated into this process, enriching the activities with more detail than those originally proposed by Rogers. The framework therefore demonstrates the sequence of stages that need to be passed to navigate the intra-organizational barriers identified in this study.

Aside from the added activities, the framework shows the expected deliverables from each stage. These deliverables are prerequisites for being able to move on to the next stage in the adoption and implementation process. The key stakeholders that are normally responsible for the tasks and deliverables from each stage are also included in the process. This demonstrates the responsibilities of the individuals or units within each stage of the framework but also the need for an alignment of different organizational units. The designed IoT adoption and implementation process framework is depicted in Figure 6.

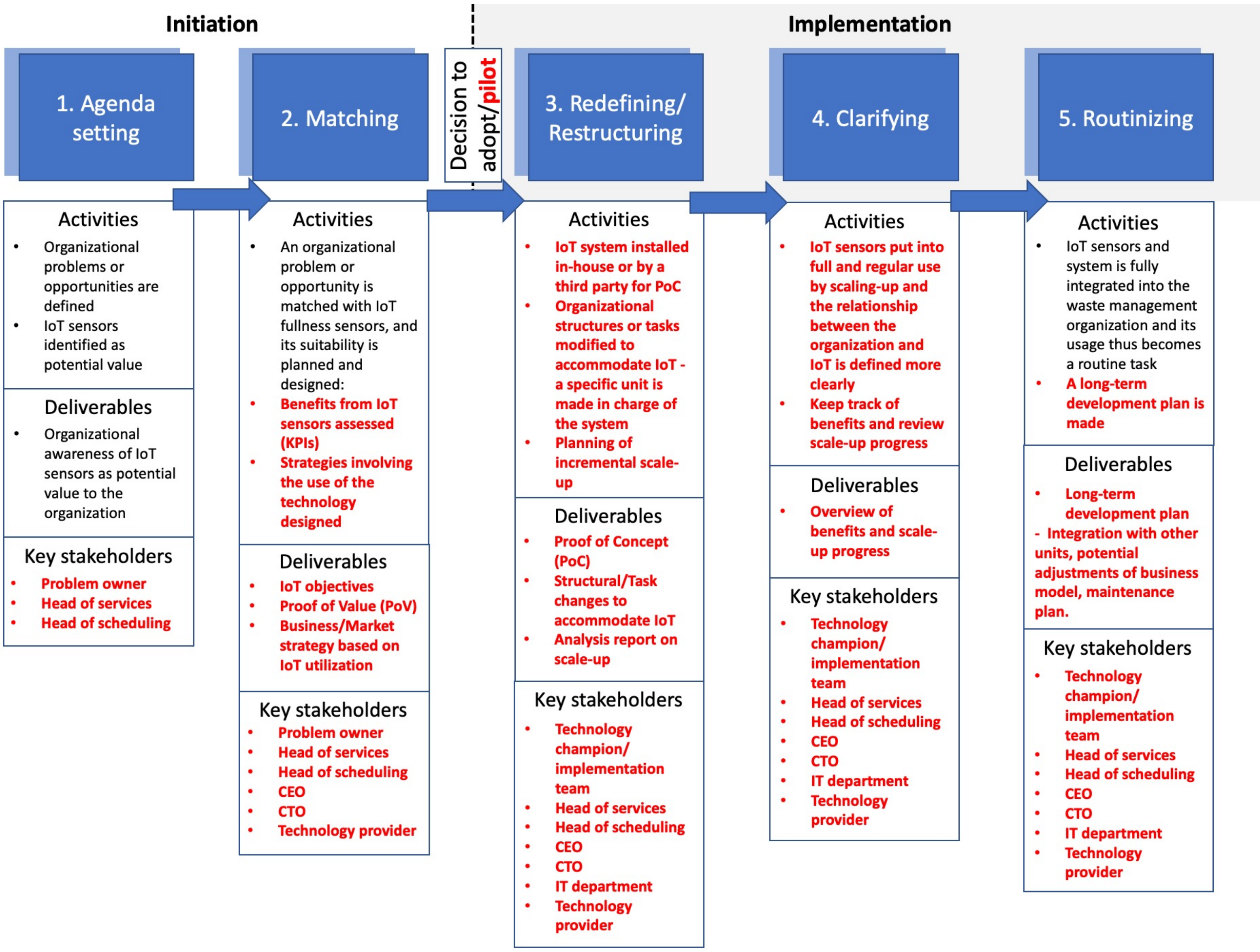

Figure 6 - IoT adoption and implementation process framework, adapted from Rogers (1983).

6.2 Framework stages

Agenda setting

The agenda setting is the first stage of the process and marks the initiation. In the initiation, all relevant information on IoT sensors is gathered and assessed and plans involving the use of these sensors are made.

In the agenda setting a problem owner identifies a problem or an opportunity within the organization. IoT-powered fullness sensors are then explored as a potential solution to the identified organizational problem or solution. This can however also happen in a reversed sequence where the knowledge of IoT-powered fullness sensors prompts the problem owner to seek out organizational problems or opportunities where they can be used. The problem owner then involves the head of scheduling and the head of services as they are introduced to this potential matchmaking and the decision is made to analyze this potential further.

Matching

In the matching stage, the organizational problem or opportunity is defined more clearly and the utility of the IoT sensors rigorously assessed to determine if they can indeed solve the problem or be used to exploit the identified opportunity. If a match between the IoT sensors and the organizational problem or opportunity can be identified, the organization's CEO and CTO as well as a technology provider (IoT expert) are brought in as the benefits resulting from the use of these sensors are made clearer using KPIs or case studies. Business and market strategies involving the use of the sensor are then formed. These business and market strategies can take many forms but do however focus on capturing and delivering value by utilizing the information gathered from the IoT sensors. An example of a business strategy would be to improve the efficiency of waste pickups by only emptying containers when they are nearing their threshold, resulting in less driving and less costs. Based on this, a sound market strategy would be promoting the company as more efficient and eco-friendlier than their competitors.

Redefining / restructuring

At this stage of the process the decision to adopt or pilot the technology has been made. The IT department is brought into the loop as the organization begins installations of the IoT sensors and the system for a Proof of Concept. This is either handled in-house or by the technology provider. After a certain period, a Proof of Concept is obtained, thus proving that the sensors work as expected. An employee or an organizational unit is substituted for the problem owner and put in charge of leading the project, thus handling the IoT sensors as well as the system. In some cases, this unit will have to be formed specifically. Planning of an incremental scale-up, where more sensors are installed gradually over time, is made and kept as a progress report by the technology champion.

Clarifying

In the clarifying stage, the IoT sensors are put into full and regular use as the value of the IoT sensors is becoming clearer. The use of the IoT sensors is gradually becoming a routine task within the company. Benefits gained from the sensors are continuously monitored (for example using KPIs) and the scale-up report is being maintained to be able to review the scale-up progress.

Routinizing

In the final stage, the use of IoT sensors is considered routine within the organization. A long-term development plan is made for the use of the sensors which can include the integration of the information from the sensors into other units of the organization, potential adjustments to the business strategy or even the business model of the organization and a plan for maintaining the sensors and the system.

6.3 Framework evaluation

According to the DSRM that this study follows, the evaluation of a produced article, in this case the IoT adoption process framework, typically occurs after its demonstration. The purpose of the evaluation is to assess if the framework indeed serves its purpose, that is, determine how well it supports a solution to the problems it was designed and created to solve (Peffers et al., 2007). Like emphasized earlier in this report, demonstrating this framework in a real-life setting was not feasible due to the amount of time it would take a waste management organization to go through all its stages. It was thus not possible within the timeframe of this research project.

Even though an evaluation of the frameworks functionality and validity based on a performed demonstration was not possible, a more theoretical approach was taken where expert interviews were conducted to assess the frameworks conceptual functionality and validity. The experts chosen for the evaluation are all employees at a company that provides organizations IoT solutions and consultancy. The choice was made based on the experts' technical experience but also, and more importantly, their experience of implementing and integrating IoT into organizations. The experts' positions within the company are Executive manager, Head of sales and an IoT software specialist. Two of these experts have been working with IoT since before the organization was founded in 2017 while the third, the IoT software specialist, has over two years of experience in this particular field.

Three expert interviews were conducted to evaluate the IoT adoption and implementation process framework designed in this study. For each interviewee, the framework design was explained in detail, its theoretical basis, added and improved activities, deliverables and key stakeholders based on the barrier mitigation strategies identified in the study. The overall functionality of the framework was then explained. Going through the whole framework, at each stage in the process the experts were asked if any modifications were needed for the activities, expected deliverables or key stakeholders to confirm that the framework indeed depicts a realistic and purposeful process. The feedback from the experts can be found in Table 6 – Expert evaluation feedback.

Evaluation results

Based on the experts' evaluations there was one stage that needed modifying for the framework to fully explain the needed actions from organizations in such a process. The change was to include the IT department of organizations sooner in the adoption and implementation process and should thus be involved right after the Proof of Concept initiation. Based on the IoT software specialist's experience, the sooner the IT department is included in the process after initiating the PoC, the more successful the implementation will be. This especially applies to the integration of the technology into the organization's departments later in the process.

Table 6 - Expert evaluation feedback

Expert	Feedback from expert evaluation
Executive manager -IoT service company in Iceland	"No, I think you have done a very good job here. You can really visualize the process. This describes exactly what needs to be done. Like now for instance, in our relationship with [the WMO], we are still in between stages 2 and 3. We are still there. We haven't moved to the next stage. They haven't used what they have. The stakeholders are key, that you have the right people and the right departments." "You have listed the right way to go about this. We showed up like cowboys before and said "shouldn't we run proof of concept" without having analyzed the problem. But now they have opened up the discussion, and they are really performing a self-assessment. Doing their own analysis of needs. What needs to be done. Which is of course the right way to do it."

	"It's no problem to just install a bunch of sensors and not wonder what you're going to use them for. What you're going to do with them." "IoT adoption and implementation is often so badly planned, and at first thought of as a PR stunt, rather that something valuable. We have been noticing this. It's very common that cities start the implementation process before elections. But then nothing is planned. Who was supposed to implement this and oversee this? No one. They just decided to adopt this very fancy system, but no one was assigned the responsibility of implementing it. If you don't have the right stakeholders, and no one within the organization is assigned the responsibility, then nothing happens. You have the whole scale, not just the executives. You need to reach from top to bottom to get everyone involved if you want to do this properly." "What's tricky with proof of concept is that you choose bits and pieces but can't fully show the system and functionalities as a whole. If the data points are few and somehow all over the place. Like now, [the WMO] have about 20 censors. They have some of them in Grímsnes and Grafningi and a few in large, shared waste containers. You could never make a routing plan, there aren't enough variables, and you would never benefit from that." "You did a really nice job. This is so clear. It's amazing to see this presented like this. To see this listed up like this in black and white. You could apply this to all companies. This is the approach to implement new technology, IoT or not, just any new technology into any company that is set in their ways. Which is very tricky like we have discussed. It's very tricky and has always been tricky. Just imagine how it was 30 years ago when computers first came to the offices, you needed to completely change how you went about your work."
Head of sales - IoT service company in Iceland	"I think this is fantastically done. This is just exactly how it's supposed to be done. I'm just very impressed that you managed to get this out of this work. This is great. Just great. In my mind, I of course started to fit a problem to this process and started to think about it while you were talking. And this is amazing. Here you have, in fact, the process that they can use to make decisions, implement, evaluate the benefits, do proof of concept, scale up, and all the key players are involved at the right place." "You address how to implement a new work culture that needs to take place in the process. I have nothing to add to this. And nothing to criticize. I think you address everything that matters. This is simply the model they can use to go in the direction where they are clearly thinking of going now."
IoT software specialist - IoT service	"What went through my mind is if the IT department should be a part of stage 3, after proof of concept. My experience so far is that if they are present in the process sooner, then it's more likely that the project will be a success sooner. Like our systems offers integration to a 3rd party. It differs between companies how they make use of the data, if they are using the systems that are offered, or use the data in the systems that are

company in Iceland	already there. The plan is that if the IT department is present sooner in the process, then that might help with the success.”

The expert made no other remarks on changes needed to the process framework but did however give comments on its expected functionality and design. Firstly, the process was judged to be clear, and it can even be pinpointed where the waste management organization is currently positioned in the process. The Executive manager further stated that the framework describes exactly what organizations need to do when adopting and implementing IoT technology, especially regarding the needs analysis -what to achieve by using the sensors, from the Matching stage and the involvement of the key stakeholders. The Executive manager and the Head of sales also point out that this framework is what organizations that are adopting and implementing IoT need as a “roadmap” to go through all the important steps in the process, performing the necessary activities, acquiring the right deliverables, and including the right stakeholders. It thus “addresses how to implement the right work culture that needs to take place” for IoT adoption and implementation, as the Head of sales put it.

Based on the evaluation results, it was decided to include the IT department as a key stakeholder in stage 3 of the IoT adoption and implementation process framework, as recommended by the experts. The real-life functionality of the framework will have to be demonstrated in future research and then further improvements can be made based on the demonstration’s evaluation.

7. Discussion

This chapter discusses the implications of this study’s findings, both from practical and academic perspectives. The limitations of the research will then be addressed.

7.1 Implications

One of the objectives of this study was to gather the relevant organizational innovation adoption barriers that generally affect an adoption and implementation process within organizations. By examining the literature, a total of 12 intra-organizational factors were identified in the academic literature. The presence of these factors in a waste management and IoT context was then studied through the case study conducted. The results suggest that all the intra-organizational factors were affecting the IoT adoption and implementation process to some extent. These findings thus contribute to filling the knowledge gap on what intra-organizational factors affect IoT adoption and implementation and what factors are most influential within in a waste management context.

The case study interview results further suggest that the three main barriers to IoT adoption and implementation within waste management are *Uncertainty of business benefits*, *Strategic objectives*, and *Degree of risk-taking*. These are all factors that were found within in the ICT adoption barrier framework proposed by (Govender & Pretorius, 2015). These factors were however not included in the DOI framework by Rogers (1983) nor the TOE framework by Tornatzky and Fleischer (Oliveira & Martins, 2011). It thus poses the question of whether one of the most frequently used innovation adoption frameworks in this field of study, namely the DOI and TOE frameworks will need to be modified in terms of organizational factors when used for industry 4.0 research.

As no previous research was identified that focuses on the IoT adoption and implementation process within organizations, this study can potentially have some implications for future research. The designed IoT adoption and implementation process framework for waste management has the potential to help other scholars design a more general framework where the designed framework from this study can be used as a building block or a starting point in their research.

As discussed in the literature review of this report, Frambach & Schillewaert (2002) stated that the knowledge on what factors affect each stage of an adoption process is limited. It can be seen by using the IoT adoption and implementation framework where the waste management organization from the case study is currently positioned in the process. They have already initiated a PoC but cannot move forward and are thus stuck in the Redefining/Restructuring stage. It can be argued that the reason for not being able to move on in the process is because they have not completed all the necessary activities from the previous stage. Those activities include acquiring a Proof of Value, by carefully assessing the benefits that can be realized from the use of IoT sensor data, developing a business strategy and a corresponding market strategy. By visualizing their current position in the process, one can identify as to where each influential factor identified in this study is affecting the process.

Both Uncertainty of business benefits and Strategic objectives are barriers experienced due to the skipped activities in the previous stage of the process, while the degree of risk-taking is most likely a factor that is derived from the uncertainty of not addressing the first two. This implicit finding can potentially contribute to research that aims to pinpoint which factors are affecting which stage of IoT adoption processes.

A more practical implication of this study is that managers within the waste management industry can use the designed IoT adoption and implementation process framework as a tool to guide them through the overall process. It can either be used in its entirety depending on the problems their organization is experiencing or partly used by ensuring that certain steps have been taken, certain deliverables acquired, or key stakeholders included.

The strategies outlined in this study can provide waste management managers, or even managers in other industries some ideas on how to mitigate the most effective barriers identified in this research. As discussed in the introduction of this report, many organizations, not just within waste management, are experiencing difficulties when adopting and implementing IoT. It is therefore likely that other organizations are experiencing or will experience the same barriers as those identified within waste management.

7.2 Limitations

This study, like most, is not without its limitations. Due to the nature of case studies, the generalizability of the study is questionable. This especially applies to the most significant factors identified. To gain a deeper and more reliable insight into the factors affecting IoT adoption within waste management the study would have needed to include more use cases on waste management organizations currently in the process of adopting and implementing IoT technology. This unfortunately was not feasible both due to time restrictions and the fact that finding other waste management organizations in the same situation as the one from this study is not an easy task. The main purpose of exploratory case studies is however to shed a light on some phenomena and statistical generalizations and sampling used for other methods are not normally expected (Yin, 2018).

During the interviews all the interviewees identified Strategic objectives as a barrier to the integration of these sensors. Four respondents identified the Degree of risk-taking, while the factor that the employees identified as to having the most effect, Uncertainty of business benefit, was only identified by three respondents during the interviews. This raises the question of why uncertainty of benefits was not identified by the other two interviewees during the first phase of the interviews while being perceived as the most influential barrier in the second. One can argue that respondents felt more under pressure during the face-to-face interviews than when they made their assessment through Google Forms. This demonstrates the inaccuracy of the qualitative research methods chosen, although deemed as the most logical choice based on the research objectives.

Due to the chosen scope of the study, only organizational factors were considered which introduces certain limitations. This study focused on the organizational actions and changes that are needed in an IoT adoption and implementation process. It would have been ideal to include all typical categories, adding technological and external factors which can also inhibit the adoption process one way or another, but narrowing the scope down to a manageable size was appropriate for a master's thesis such as this one. Furthermore, due to the nature of the chosen industry, waste management, it is uncertain that the final deliverable of this study, the IoT adoption and implementation process framework is useful in other sectors as is it designed based on the factors identified within this particular use case and its context.

Another limitation is the number of people that were qualified to participate in the case study itself as only five individuals within the company had experience working with or knowledge on the IoT technology and the processes it aims to improve. This is also a limitation regarding the reliability of the resulting factors identified.

The IoT adoption and implementation process framework was designed based on a thorough process, as described in section 2.1. While the evaluation of such an artifact is normally performed after its demonstration, the framework was not demonstrated in a real-life scenario. This was unfortunately not possible as demonstrating the framework in real-life would take longer than the time expected for this research project. The expert evaluation performed in this study is thus based on its theoretical performance in such a real-life setting and its theoretical validity based on the experts' experience in this field. The expert evaluations alone do not ensure its correctness or applicability for describing an actual adoption and implementation scenario, but they do enhance the credibility of the designed framework to a certain extent.

8. Conclusion

This chapter summarizes the overall research. The sub-research questions and the main research question of this study will then be answered. Recommendations for future research will then be addressed followed by a personal reflection on the project and its relation to the Management of Technology program.

The aim of this study was to improve the adoption and implementation process of IoT technology in waste management, focusing on the organizational context, by designing and developing a framework. With this in mind, the first step was to identify what factors are hindering this process. To do so, the literature was examined to gather the relevant factors. A case study was then conducted within waste management to assess which factors are the most influential barriers in the adoption and implementation process. Mitigation strategies intended to alleviate these barriers were then formed using expert interviews and desk research. These findings were finally integrated into a framework which describes the stages of IoT adoption and implementation in waste management.

To answer the main research question of this study it was broken down into smaller, more manageable questions which were answered following a coherent research process, namely the DSRM, discussed in section 2.1 of this report.

Sub-question 1: What are the general intra-organizational innovation adoption barriers?

Answering this question required looking into and analyzing academic literature on the factors influencing the adoption of innovation within organizations. Prominent innovation adoption frameworks were identified, including the widely used DOI framework by Rogers (1983). As Rogers' framework contains a limited number of factors in the organizational context, another framework, designed by Govender & Pretorius (2015) which holds various and a more extensive collection of organizational factors was also used. No other intra-organizational factors were found that were not covered by these two frameworks. A theoretical framework was thus created by integrating these two frameworks into one. The factors identified were: *Leaders' attitude towards change, Centralization, Complexity, Formalization, Interconnectedness, Organizational slack, Size, Culture, Degree of risk-taking, End user behavior, Strategic objectives and Uncertainty of business benefits.* Identifying these factors was necessary to answer the next sub-question of this study.

Sub-question 2: What are the most significant intra-organizational IoT adoption barriers within waste management?

To answer the second sub-question of this study an exploratory case study was executed in one of Iceland's largest waste management organizations. This organization was at that time, experiencing difficulties with fully adopting and implementing IoT-powered fullness sensors for waste level monitoring in their containers. 25 sensors had already been installed as a part of a Proof of Concept, but no changes had been made in terms of tasks or processes. In this case study, five employees involved in the adoption and implementation process or using the IoT system were interviewed. These interviews provided insight into the organization's experienced problems, and their motivations for adopting IoT. The main purpose of these interviews was to identify what factors from the theoretical framework discussed in the previous step were affecting their process of adoption and implementation of IoT. By doing so, this step served the purpose of identifying the core problems that needed to be addressed in the IoT adoption and implementation process framework and define its objectives.

During the interviews, employees were tasked with mentioning or marking down the factors they believed to be hindering the process. They were then later asked to indicate on a 5-point scale to what extent they agreed that the barrier was influencing the process based on their perception. The most influential barriers identified during these interviews, and thus the answers to the second sub-question were: *Uncertainty of business benefits, Degree of risk-taking* and *Strategic objectives*.

Sub-question 3: How can these adoption barriers be mitigated?

After having gained a deeper understanding on the waste management organization's problem through the case study, exploring how these identified barriers can be mitigated was the next step taken. The objectives of the designed framework were that way made clear. To identify the appropriate strategies that can be used to mitigate the most effective barriers

(Uncertainty of business benefits, Degree of risk-taking and Strategic objectives), a combination of desk research and expert interviews was used. The desk research entailed an exploration of academic and grey literature. The use of technical reports from private consultancy firms and IoT analysts was deemed necessary as the academic literature was limited in terms of recommended solutions to these problems.

Expert interviews were conducted with IoT professionals that are employed at one of Iceland's leading IoT organizations. The purpose was to gather information on applicable strategies, based on their experience, to lower the significant barriers identified within waste management. There were no clear-cut or universal strategies identified that can be employed to solve each barrier. A more practical approach was therefore taken and there were certain strategies and steps pinpointed that can be utilized to potentially decrease the effects of said barriers. In some cases, it was argued that the strategies proposed influence more than one barrier.

The first barrier is Uncertainty of business benefits and its proposed mitigation strategies are: *Gaining a Proof of Value (PoV)* and *Incremental scale-up*. The second barrier is Strategic objectives and its proposed mitigation strategies is: *Using information to gain a competitive advantage*. The proposed mitigation strategy for the third barrier, Degree of risk-taking, is *Renting with an option to buy*.

Sub-question 4: What does an IoT adoption and implementation process in waste management look like?

Based on all the research efforts carried out in this project, the literature review, case study, desk research and expert interviews as well as the results from each, an IoT adoption and implementation framework was designed in the context of waste management. The framework was then evaluated through expert interviews. In this evaluation, feedback regarding improvements on the framework was received and used to adjust its design. After the confirmation of the framework's theoretical validity and expected performance in terms of its set goals and objectives, the IoT adoption and implementation process framework answers sub-question 4. This framework can be found in Figure 6 in chapter 6.

Main research question: How can the adoption and implementation process of IoT-powered fullness sensors in waste management be improved?

By going through the process depicted in the IoT adoption and implementation process framework, performing its suggested activities, attaining its specified deliverables, and including all the relevant stakeholders, waste management organizations can improve their IoT adoption and implementation initiatives.

8.1 Recommendations for future research

The motivation for this research was to identify the intra-organizational barriers to IoT adoption within the context of waste management and establish guidelines to lessen the influence of the most effective barriers in the adoption process. The deliverable from this research project is an IoT adoption process framework for waste management organizations wanting to exploit the benefits that can be gained from using IoT fullness sensors. Although the main objectives of this study have been reached, the overall research in this field is far from over. Based on the limitations of this study, covered in the previous chapter, recommendations for future research were formed.

The applicability of the designed framework in a real-life setting is yet to be tested. Future research could involve using the framework and applying it in an actual implementation of IoT fullness sensors in a waste management organization. That way, the demonstration stage of the DSRM would be finalized and an evaluation on the framework's effectiveness could take place based on the outcomes from the demonstration instead of expert interviews.

To enhance the generalizability of the study, more use cases are needed from the waste management industry where IoT adoption and implementation barriers are identified. This would enhance the credibility of this study's findings. Based on the outcome of those case studies, the IoT adoption and implementation process framework could subsequently be improved or altered.

Due to the chosen scope of this research, the intra-organizational barriers were only considered. Future research could also include barriers external to the organization as well as barriers stemming from the technology itself. By doing so, a more extensive framework can be designed based on all the factors that influence the adoption and implementation of IoT in waste management or even other industries.

From a more practical perspective, future research can include testing the barrier mitigation strategies identified and formulated in this study, both in the context of waste management but also in other industries experiencing similar barriers as identified in waste management.

Another research opportunity identified during this study was the lack of academic literature on not only the process of IoT adoption and implementation in general but also what factors impact each step of the IoT adoption and implementation process. This also applies to strategies or methods that can be employed in each step.

8.2 Personal reflection

The last couple of months, while working on this research project, have been very interesting to say the least. Much like the barriers identified in this study, I too had to face multiple obstacles of my own. Many of these challenges had to do with the social environment that had evolved due to the Covid-19 global pandemic. Everything was moving much slower than before but that is something that takes time to get used to. For instance, interviews got postponed, data gathering related to the research got delayed. Face-to-face meetings moved online and that also applied to some of my later expert interviews as well. During this time, it was important to adapt to the situation and even though time was of the essence, patience was crucial.

Looking back at everything that I learned during this research I am most grateful for all the interesting interviews, both with the waste management employees as well as the IoT experts. The interviews themselves and the chats before and after were very insightful. I also got a chance to sit in on meetings between representatives from the waste management organization and their technology provider, introduce my research to both parties and listen to their discussions on what steps will need to be taken to continue with the implementation of the IoT sensors. The barriers identified in this research were therefore not confined to this report but also served as a topic of discussion during those implementation meetings.

Before this research project started, I was familiar with IoT technology from some of my courses at TU Delft. I was however surprised to learn the full extent of the technology's capabilities and its use in various industries, especially when integrated with AI. Even though the technical solution and architecture of IoT in waste management was not within the scope of this study, I would sometimes find myself losing track of time while glancing through technical implementation articles to gain a deeper understanding of how waste management operations will become in the near future.

8.3 Relevance to the Management of Technology (MOT) program

This research project and thesis is a partial fulfillment and the final step to graduate from the MOT program. The program aims to shape individuals with a technology-oriented background into technology managers by introducing and teaching them the social, ethical, and economical aspects of innovations. That way, the gap between engineering knowledge and that of other disciplines is bridged as these different aspects are essentially what separates technology managers and leaders from technical engineers. A good grasp on these different technological perspectives enables these individuals to look at technology as a company resource but not just a tool.

It is evident, as this study shows, that IoT is by no means just a plug and play technology and that its adoption and implementation require careful planning and effective strategies. The problem as well as its solution as defined in this thesis are multi-faceted and require technical, social, managerial, and business perspectives. By combining all the knowledge I acquired through the program's courses, namely Business Process Management and Technologies, Emerging and Breakthrough Technologies, Leadership and Technology Management, Technology, Strategy and Entrepreneurship and I and C Service Design, I was able to analyze a technical problem from an organizational perspective, come up with solution-oriented strategies to mitigate the problem and integrate them into a process framework.

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Appendix

A. Interview structure templates

This section includes the interview templates used for both the case study interviews as well as the expert interviews conducted in this study.

Case study interview structure

Phase 1

Introduction

1. What is your position and responsibility within the company?

Waste collection process

1. How would you describe your tasks related to scheduling or container pickups?

2. How would you describe the current waste collection process for the connected containers?
    a. What business processes and tasks are needed?

    b. Has the process changed after installing the fullness sensors?

How can the utilization of IoT-powered fullness sensors improve the waste collection process?

1. 1.What operational benefits was the company hoping to gain from using these sensors?
    a. Did that work?
        i. Why / Why not?
2. What operational benefits do you think can be gained from the technology in its current state of implementation?

3. Are there specific containers which control the frequency of all container pickups on the Selfoss route?
    a. (If yes) Which container are filling up fastest?

4. Do you think that operational benefits can be gained from placing extra container/s in the Selfoss route?
    a. Why / Why not?

What are the internal adoption factors within the company?
(Each participant is handed a sheet containing the initial factors from the theoretical framework along with descriptions of those factors)

1. What factors (if any) do you think are affecting the IoT adoption process within the company?

2. Are there any factors affecting the adoption process which are not included in the presented list?
    a. (if yes) Which factors?

Phase 2 - Influence assessment of each barrier (Conducted through Google Forms)

Expert interview Structure

Introduction

2. What is your position and responsibility within the company?
3. How long have you been working with IoT?

Internal implementation barriers within waste management

1. In your experience, when integrating IoT into organizations what are the most common intra-organizational barriers?
2. Are the integration factors that can be identified within organizations industry-specific?
3. In your opinion, what are the intra-organizational factors influencing IoT integration within [name of waste management company from case study]?

Most significant barriers within waste management

1. What do you believe are the most significant barriers affecting IoT integration within waste management?
    a. Why (specifics)?

Adoption barrier mitigation

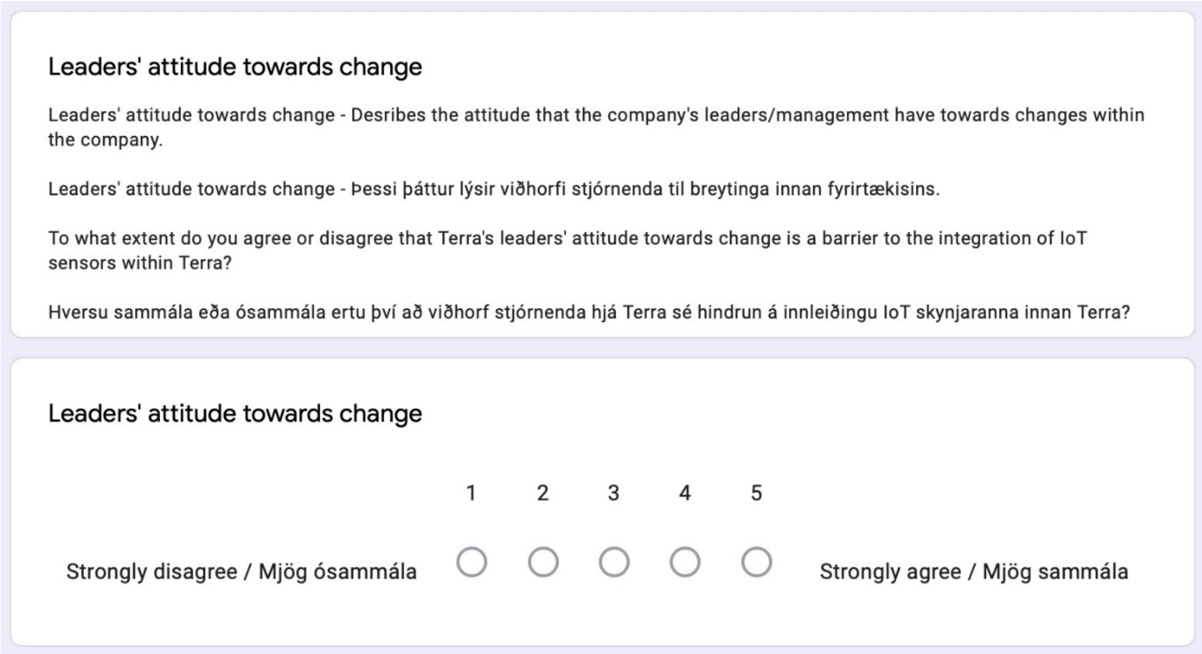
1. Are there any specific procedures that you follow when integration problems arise?

(Discussion on the most significant barriers found within the case study waste management company)

2. How would you go about mitigating these barriers?

B. Barrier influence assessment example

This section gives an example of an assessment question and the five-point nominal scale influence assessment that were used to determine the influence of each barrier in the case study interviews.


Leaders' attitude towards change

Leaders' attitude towards change - Desribes the attitude that the company's leaders/management have towards changes within the company.

Leaders' attitude towards change - Þessi þáttur lýsir viðhorfi stjórnenda til breytinga innan fyrirtækisins.

To what extent do you agree or disagree that Terra's leaders' attitude towards change is a barrier to the integration of IoT sensors within Terra?

Hversu sammála eða ósammála ertu því að viðhorf stjórnenda hjá Terra sé hindrun á innleiðingu IoT skynjaranna innan Terra?

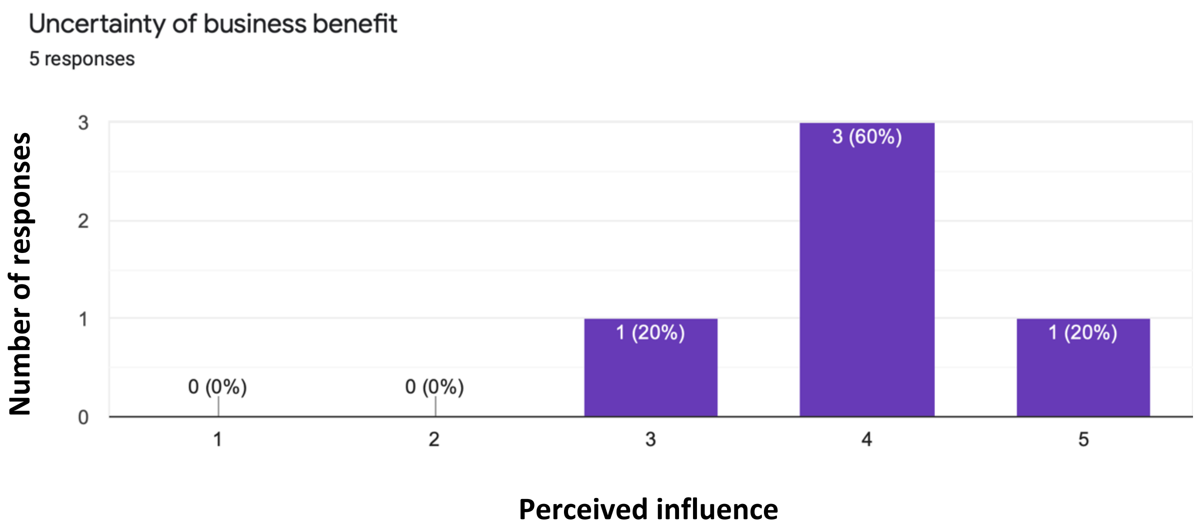
Leaders' attitude towards change

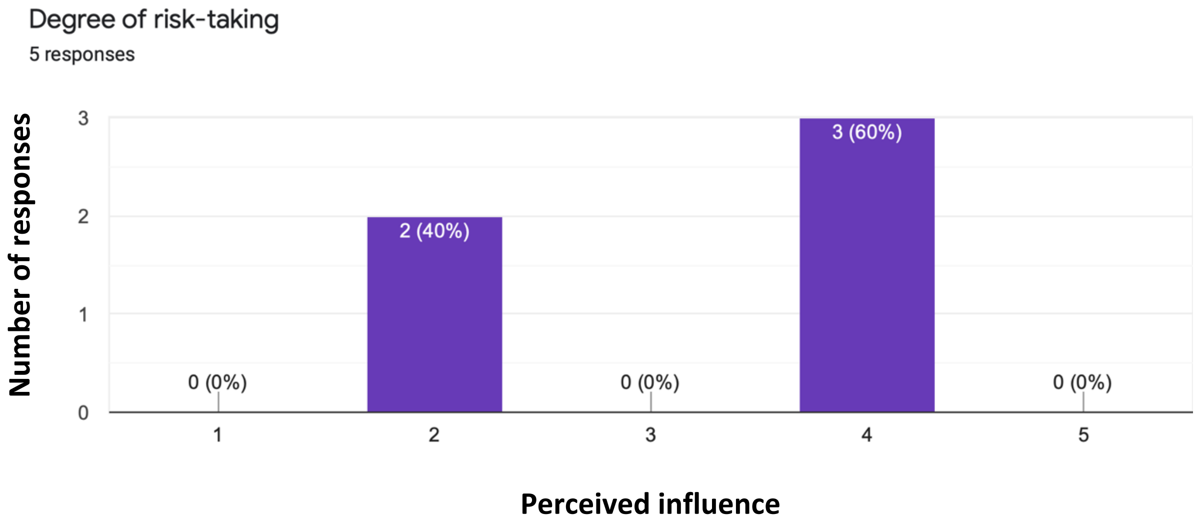
	1	2	3	4	5	
Strongly disagree / Mjög ósammála	○	○	○	○	○	Strongly agree / Mjög sammála

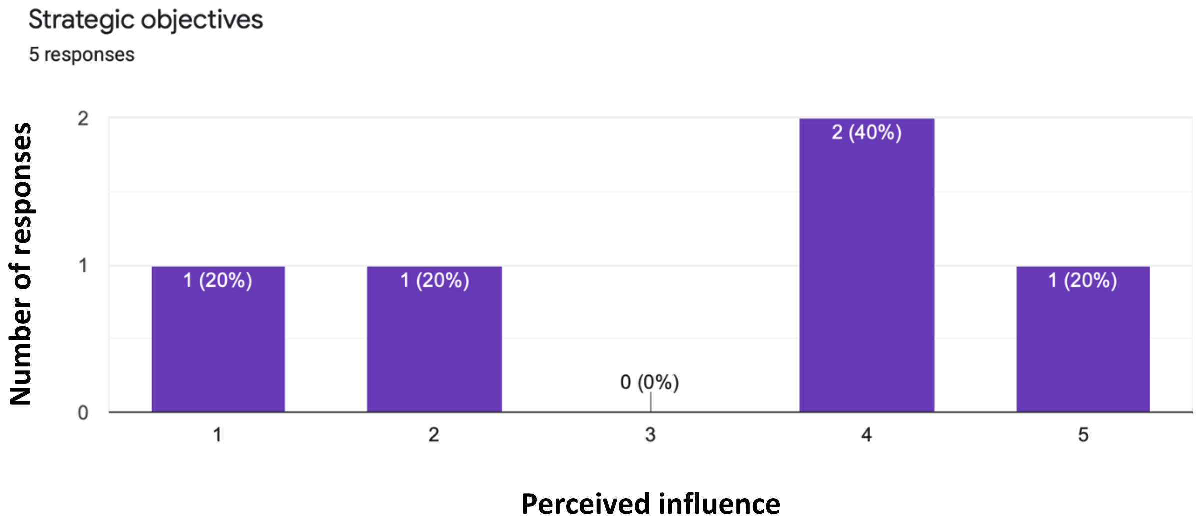
Figure 7 – Influence assessment, question sample

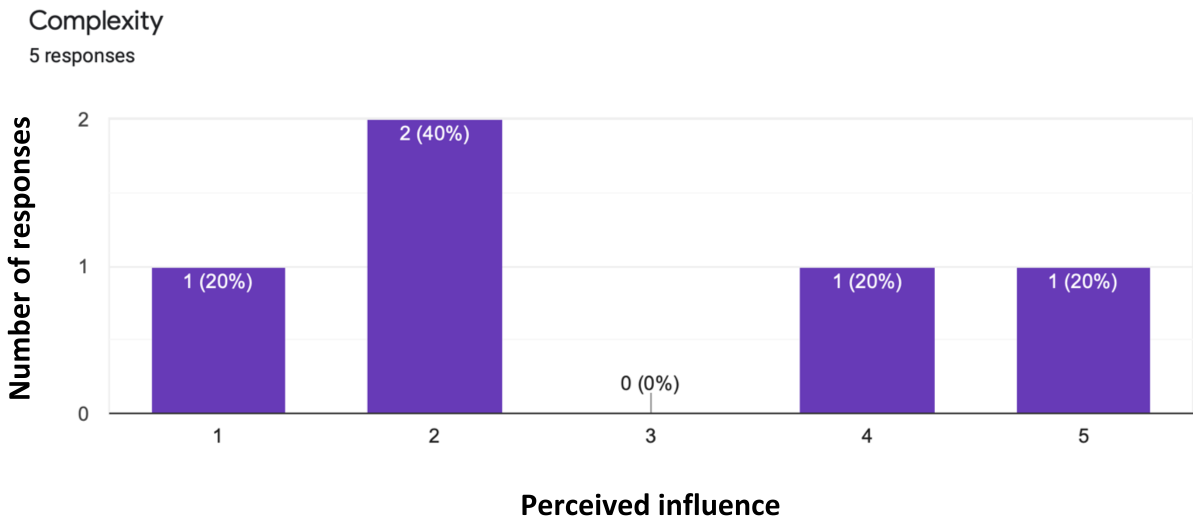
C. Barrier influence assessment results

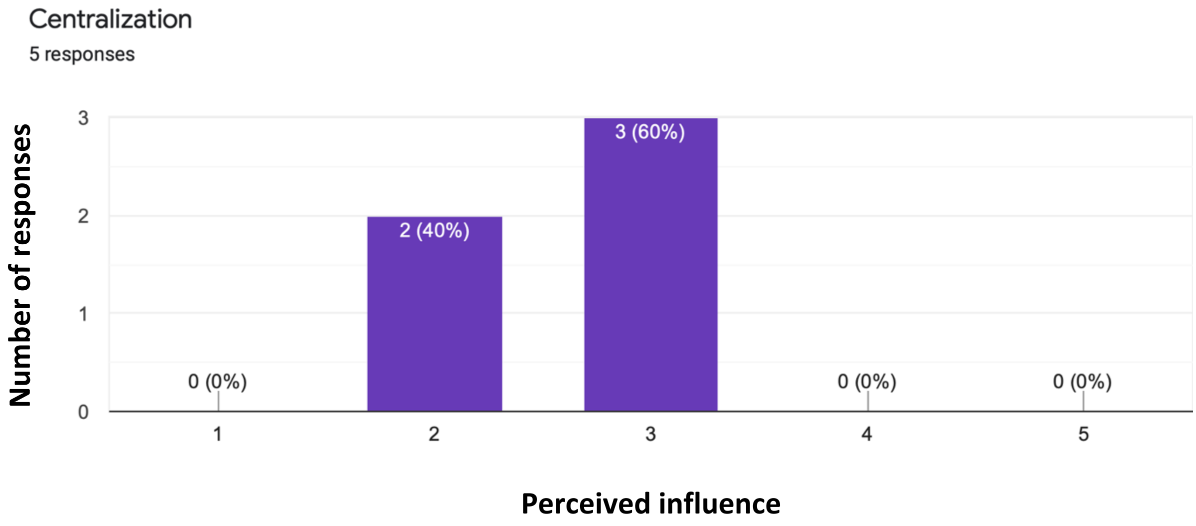
This section shows how the waste management employees perceive the influence from each barrier in the IoT adoption and implementation process. The scale used is the 5-point nominal scale from Appendix B.



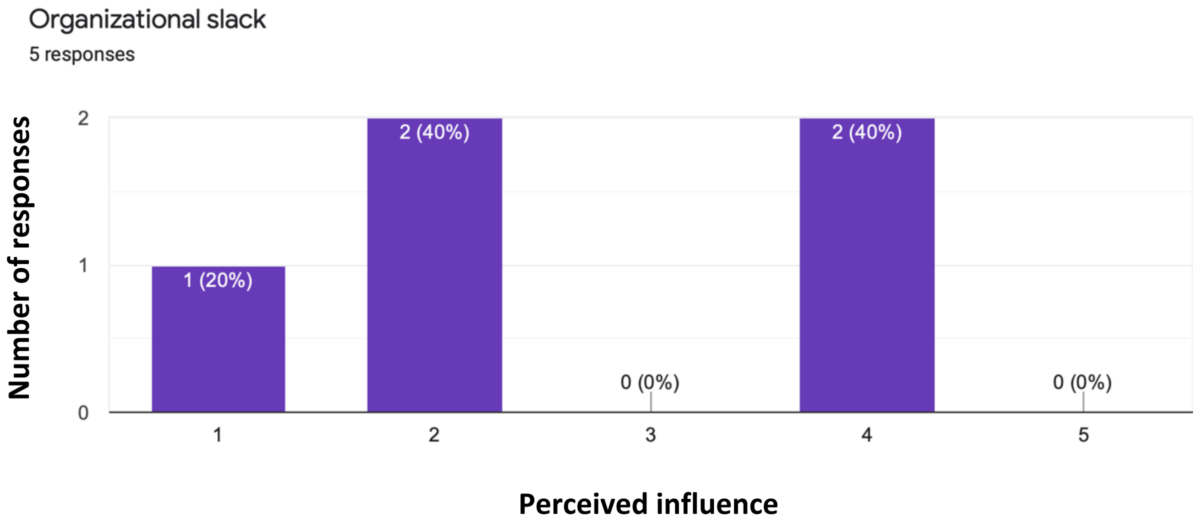

Degree of risk-taking
5 responses
Number of responses
3
2
1
0
0 (0%)
2 (40%)
0 (0%)
3 (60%)
0 (0%)
1
2
3
4
5
Perceived influence


Strategic objectives
5 responses
Number of responses
2
1
0
1 (20%)
1 (20%)
0 (0%)
2 (40%)
1 (20%)
1
2
3
4
5
Perceived influence

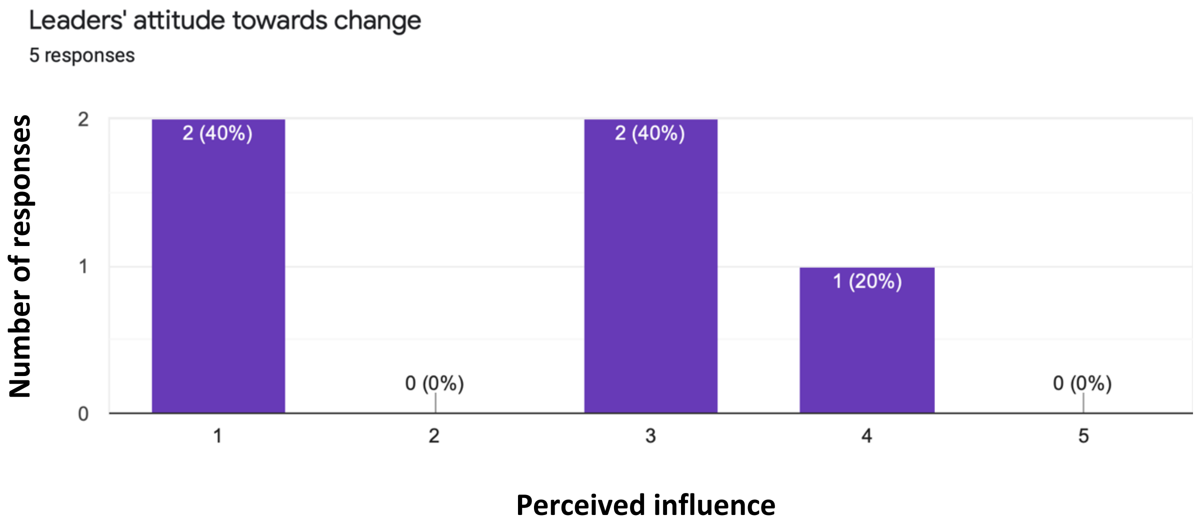

Complexity
5 responses
Number of responses
2
1
0
1 (20%)
2 (40%)
0 (0%)
1 (20%)
1 (20%)
1
2
3
4
5
Perceived influence



Centralization
5 responses
Number of responses
3
2
1
0
3 (60%)
2 (40%)
0 (0%)
0 (0%)
0 (0%)
1
2
3
4
5
Perceived influence

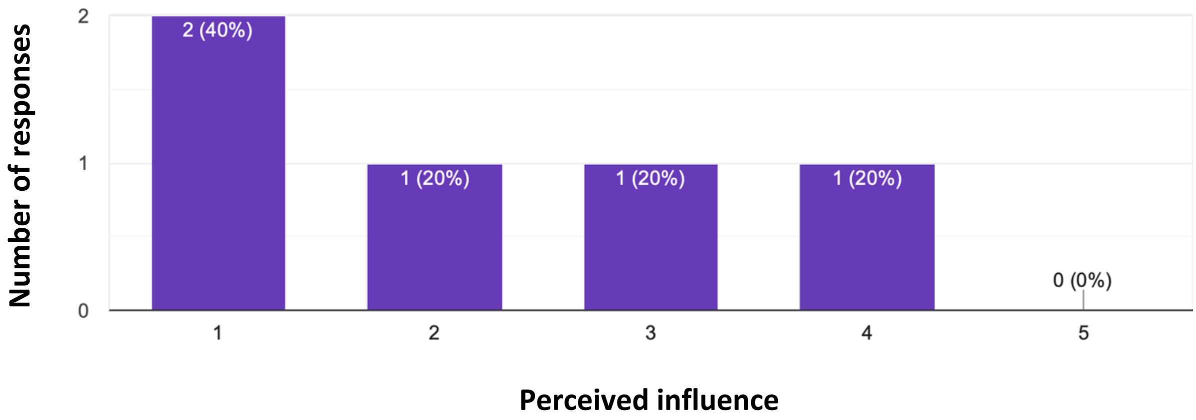


Organizational slack
5 responses
Number of responses
2
1
0
2 (40%)
2 (40%)
1 (20%)
0 (0%)
0 (0%)
1
2
3
4
5
Perceived influence

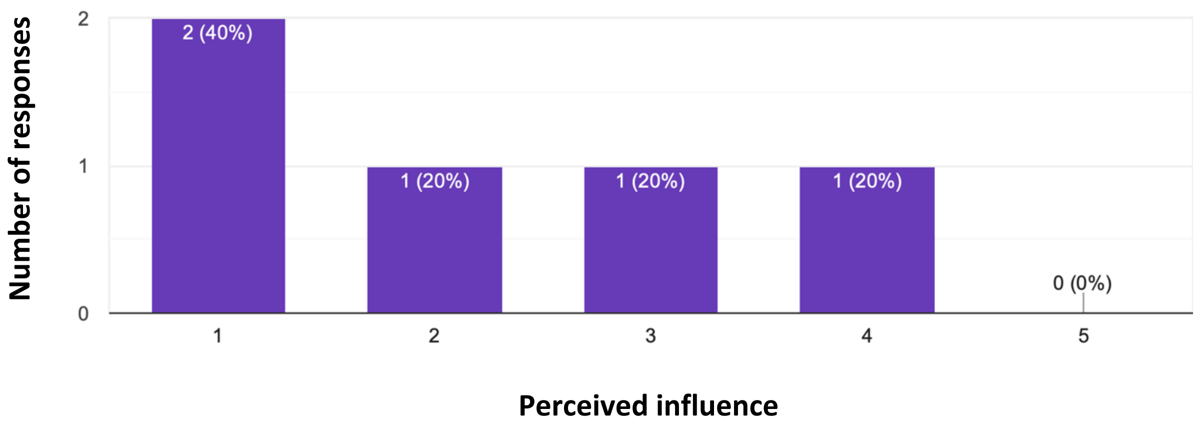


Leaders' attitude towards change
5 responses
Number of responses
2
1
0
2 (40%)
2 (40%)
1 (20%)
0 (0%)
0 (0%)
1
2
3
4
5
Perceived influence

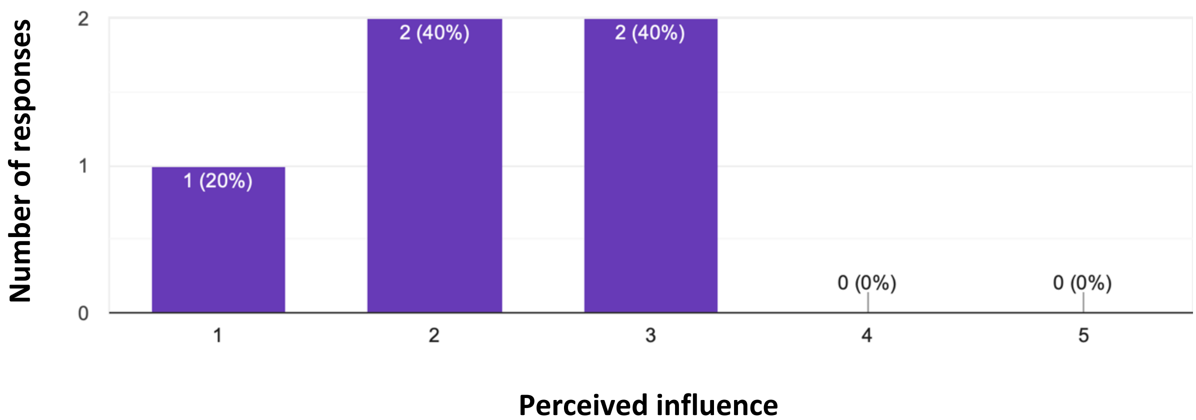
Interconnectedness
5 responses

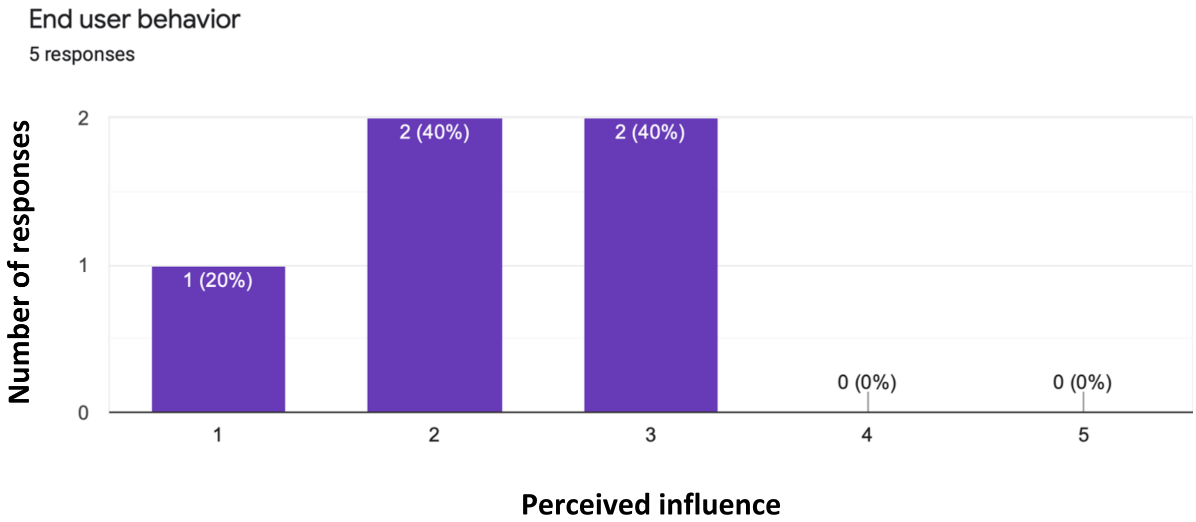


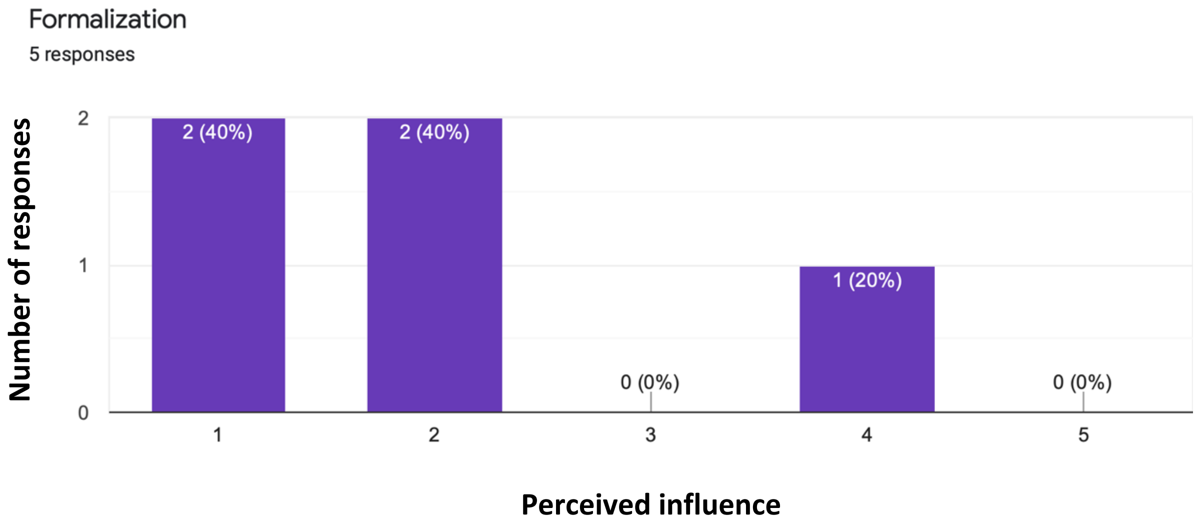
Size
5 responses



Culture
5 responses







D. Interview analysis

Table 7 shows the motivation for adoption analysis from the case study interviews.

Table 7 - Motivation for adoption analysis

Category	**Interview texts**	**Codes**
Motivations for adoption	**Interviewee A:** "It is of course container pickup optimization. To be able to be more proactive when providing the services, be there before everything is overflowing. Lower operating costs for the route and fleet department, less driving. Also, the [company] image, it will improve if we are there on	• Container pickup optimization • Improved services (proactive) • Lower costs • Less driving • Improved company image

	time to pick up containers before they are full…”	
Motivations for adoption	**Interviewee B:** “That would be fewer kilometers driven, more weight in the containers, better utilization. That would be the main benefit, of course also the fact that even though customers trust us to have the right frequency, this way the customer can trust that we are not coming to collect half-empty container as people fear when we offer regular services, that we are coming unnecessarily and there is an increased demand for that, so I foresee that this will be useful to us in the future.”	• Less driving • Fuller containers • More efficiency • Improved services • Customer demands (not picking up empty containers)
Motivations for adoption	**Interviewee C:** “It will have a bigger part to play regarding the automation in terms of driving and management. They cannot be stand-alone for long. When more sensors are installed, more autonomy will be needed. It will reduce carbon footprint, costs and increase customer service.” “Better utilization of the car fleet. Reduction of operating costs, driving, fuel, repairs, and etc. The commercial factor, i.e., the service part, is also big. We would not be emptying half-empty containers, we would also not have to worry about full containers, but they are emptied when needed. The focus is on companies and larger containers rather than homes. The image will also be	• Container pickup optimization • Lower costs • Less maintenance • Improved services • Lower carbon emissions • Less driving • Improved company image

	that the company is technologically advanced and is looking at the latest solutions and is taking part in the technological revolution that is taking place.”	
Motivations for adoption	**Interviewee D:** “I think it was for lower carbon emissions, not having to manually check the status of containers. That’s so old-fashioned.”	• Lower carbon emissions • No manual checks on container status
Motivations for adoption	**Interviewee E:** “Less driving and carbon emissions.”	• Less driving • Lower carbon emissions

Table 8 shows the case study interview analysis for determining if employees’ opinion on IoT technology was positive or negative.

Table 8 - Employee opinion on IoT sensors

Category	**Interview texts**	**Codes**
Employee opinion	**Interviewee A:** „So I think this is a very useful tool in situations like this.”	• Useful tool • Positive opinion
Employee opinion	**Interviewee B:** “I really like this. I have a good opinion on this (IoT).”	• Positive opinion
Employee opinion	**Interviewee C:** “I really like this (IoT).”	• Positive opinion
Employee opinion	**Interviewee D:** “I am super happy with this (IoT).”	• Positive opinion
Employee opinion	**Interviewee E:** “This is the future, I like it, no question about it.”	• This is the future • Positive opinion

Table 9 – Waste collection process analysis

Category	Subcategory: Actors	Subcategory: Activity	Interview texts	Codes
Current process	Route and fleet managers	Pickup route and schedule creation	**Interviewee A:** "I would say based on employees' experience, data they have and how waste is sorted, a route is created."	• Pickup route and schedule creation • Experience • Data
Current process	Head of scheduling	Pickup route and schedule creation	**Interviewee B:** "[The head of scheduling] has been making the schedule. There can be for example a schedule for every two weeks and then we need to change it due to pickup needs where containers are filling up faster than we anticipated and then the pickup frequency is changed and we are looking at once a week or every two weeks (for Selfoss)[…] We have a pretty solid route here in the capital and we are emptying containers approximately every two days."	• Pickup route and schedule creation • Head of scheduling • Selfoss • Weekly pickups • Pickups every two weeks • Reykjavík • Pickups every two days
Current process	Route and fleet managers	Pickup route and schedule creation	**Interviewee C:** "In the beginning, route and fleet managers create the pickup route and schedule."	• Pickup route and schedule creation

Current process	-	Pickup route and schedule creation	**Interviewee D:** "Then a schedule is created for the whole year or for the contract period..."	• Pickup route and schedule creation • Contract period
Current process	Route and fleet managers	Pickup route and schedule creation	**Interviewee E:** "... and we created our own schedule for this contract." „We saw which containers were full and which were not full and created a route based on that as well as the population in the area." "In the south we have sensors in a couple of places and we monitor them to determine when pickups are needed but during the summer months we need to go every week."	• Pickup route and schedule creation • Route and fleet managers • Population • Monitoring pickup needs • Weekly pickups
Current process	Head of scheduling Driver	Send pickup schedule and route to driver Receive schedule	**Interviewee B:** "Head of scheduling creates the initial schedule which is then displayed for the drivers and "then becomes a routine where it is displayed for him (the driver) which containers to pick up and on which day."	• Head of scheduling • Send schedule • Driver

Current process	Route and fleet managers	Monitor and confirm tasks (completion)	**Interviewee B:** “They (route and fleet managers) need to monitor, confirm and process all requests for trucks and at the end of the day, check if all tasks (pickups) have been completed…”	• Route and fleet managers • Monitor • Confirm task completion
Current process	Driver	Pickups	**Interviewee B:** “When the truck embarks the driver takes the whole route and picks up everything.”	• Driver • Drive route and pickup containers
Current process	Customer	Send notification	**Interviewee C:** “Containers are also picked up based on notifications from customers.”	• Customers • Notification

Table 9 above describes the interview analysis used to draw a BPMN of the waste management organization’s waste collection process for their IoT-connected containers. This BPMN illustration can be found in Appendix E.

Table 10 describes the case study interview analysis for the IoT adoption factors identified during the first phase of interviews. These barriers were often explicitly stated to be present within the company and sometimes a description of how these factors were affecting the IoT process was given. In other cases, the factors were simply marked down on a provided paper holding all the factors from the theoretical framework.

Table 10 - IoT adoption barriers mentioned or marked during case study interviews

Category	Interviewee	Interview texts	Codes
Barriers	A	"Culture, we have some cultural difficulties or challenges..."	Culture
Barriers	A	"Strategic objectives, this is also a big thing that needs to be carefully planned when we take the technology into our hands, how do we use it, not just internally but also when presenting it to our customers."	Strategic objectives
Barriers	A	"End user behavior, yes it's there..."	End user behavior
Barriers	A	"Complexity, we need to consider when we are integrating a technology not to focus to much on this place (HQ) but look at the whole organization."	Complexity
Barriers	A	"Centralization, although it is much better now than it was before…"	Centralization
Barriers	B	"Centralization, it has been so that the distribution of	Centralization

		power within the company is lacking.”	
Barriers	B	“Formalization, we have been very diligent in coming up with innovations but stagnated somewhere and that might be because of this.”	Formalization
Barriers	B	“Interconnectedness, there is a need for more communication channels within the company.”	Interconnectedness
Barriers	B	“The finances have been acting as a barrier to further progress”	Organizational slack
	B	“Culture, you don’t get a chance to bring up new ideas and they are often shot down, the company culture is stuck somewhere.”	Culture
Barriers	B	“We have been relatively careful regarding innovations and such, we were always at the forefront, but we have been completely surpassed in various areas.”	Degree of risk-taking

Barriers	B	“Strategic objectives, I feel like they (leaders) have been more focusing on innovations for the customers while we in the control center were using pencils and paper.”	Strategic objectives
Barriers	C	“I think they all have an effect but to a various degree.”	Leaders’ attitude towards change
Barriers	C	-	Centralization
Barriers	C	-	Complexity
Barriers	C	-	Formalization
Barriers	C	-	Interconnectedness
Barriers	C	-	Organizational slack
Barriers	C	-	Size
Barriers	C	-	Culture
Barriers	C	-	Degree of risk-taking
Barriers	C	-	End user behavior
Barriers	C	-	Strategic objectives
Barriers	C	-	Uncertainty of business benefit
Barriers	D	“Formalization, it is a bit like that. This is how it has always been done, this is how it should be, this	Formalization

		works, we shouldn't change it."	
Barriers	D	"Degree of risk-taking I would say, although it has changed a little bit with new staff (coming in)."	Degree of risk-taking
Barriers	D	"Strategic objectives."	Strategic objectives
Barriers	D	"Uncertainty of business benefit, I think that plays a part. Costs are incurred by installing the sensors you see, and I think the big question is should we pay for this or the customer who is renting the container…"	Uncertainty of business benefit
Barriers	E	(Marking on the paper sheet where the barriers are listed) "The ones that I mark in red are the once that could be present."	Complexity
Barriers	E	-Marked	Interconnectedness
Barriers	E	-Marked	Organizational slack
Barriers	E	-Marked	Degree of risk-taking
Barriers	E	-Marked	Strategic objectives

Barriers	E	-Marked	Uncertainty of business benefit

Table 11 describes the expert interview analysis for the IoT adoption barrier mitigation strategies proposed by the IoT experts.

Table 11 - Expert interview strategy analysis

Category	**Subcategory**	**Expert**	**Interview quote**	**Codes**
Barrier mitigation strategy	Uncertainty of business benefits	A	"It is a bit the responsibility of those who are coming up with the solutions, new solutions and other things, to show that they work. It can sometimes be more of a challenge when there are maybe only a few of such projects or if the concept is new, then it can be harder. The threshold can drop if you can point to [another waste management company] in this case, and say 'see they have done this and this is how much they have saved'. Then all of a sudden you have facts on the table because we always call for facts to actually make decisions." "It's just a question of when, if you get your hands on something like this, it should be made 'smart', and we need to do it in steps, even if it takes 2 years or 5 years."	Use cases Incremental scale-up
Barrier mitigation strategy	Uncertainty of business benefits	B	"...like regarding business benefit. It's what we rely in our suppliers who have larger projects going on,	Use cases

			that they can demonstrate that these business cases have been going well. I think it's something that companies need to see and often maybe even see for themselves if they can, what can I say, if they can get to know other companies' processes, how the implementation was done by others, I think that says much more than us describing how this happens."	
Barrier mitigation strategy	Uncertainty of business benefits	C	"...maybe try to make an agreement with them to implement things slow and steady so it's not too much at once." ". If we were to make a three-year plan or something and cover places far away from the service centers and try at the same time to, you know, save time, and cars, and slowly implement this at some point."	Incremental scale-up
Barrier mitigation strategies	Uncertainty of business benefits	D	"Of course, what we have tried to do to overcome this is this proof of concept. Which we have been working on with [the WMO] at the lowest possible cost for them so that the risk is kept to a minimum. However, the disadvantage is that we do not have the capacity to demonstrate the benefits of the system. Then you would need to have more sensors, but we cannot lend 1000 sensors for some x time	Proof of Concept

			to do this, so this has become a catch 22.“	
Barrier mitigation strategy	Degree of risk-taking	A	“.. then we could just make a one-year or two-year deal. For example, a two year project, these are x many sensors and x many platform needed, this is an investment and we could just lease the equipment. So you just pay rent, and this would not be high costs per month. Then you could rent the sensors and we would install them and it would entail a certain start-up cost. Then after two years or after the contract period with a manageable investment in a real proof of concept on some scale and then we would add together the rent for this equipment, that had to be charged for this large scale pilot project, and credit that amount and sell the sensors.”	Renting with an option to buy
Barrier mitigation strategy	Degree of risk-taking	B	“..and offer ways so you do not necessarily have to invest. It is possible to rent equipment, there are various things you can do without taking the biggest steps.”	Renting sensors
Barrier mitigation strategy	Generic – Need for a technology champion	B	“Making things ‘smart’ is about collecting data that you intend to use to some extent. Perhaps what is missing is that companies don’t have someone	Technology champion

			responsible for it, whether it is to use the data or put it in the process of making use of the information obtained from making things "smart"."	
Barrier mitigation strategy	Generic – Need for a technology champion	C	"I think there needs to be a person at [the WMO] who would be keeping track of what they already have implemented, who would be monitoring the system."	Technology champion

E. Waste management organization's waste collection process

Figure 8 shows the waste collection process of the waste management organization from the case study in a BPMN format.

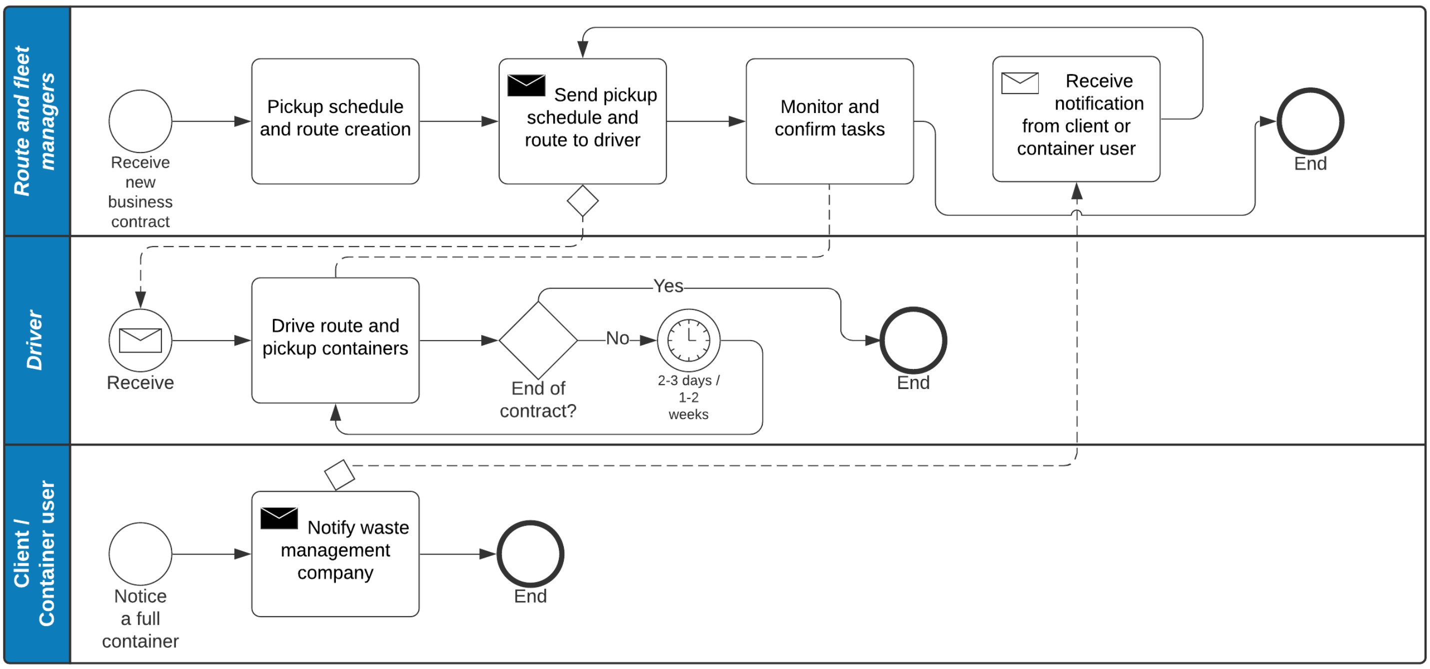


Figure 8 – Waste management organization's waste collection process