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Digitalizing Waste Collection in Tinn Municipality – A Case Study

Digitalisering av avfallsinnhentingen i Tinn kommune – En case-studie

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Preface

This thesis addresses how modern technology can be used to digitalize and improve the waste management process in a small, rural municipality. The project is written in collaboration with Sensorita and is the final thesis of the master's program Entrepreneurship and Innovation with specialization in digital business transformation.

Different educational backgrounds and interests have contributed to different knowledge and necessary competence in the preparation of this thesis. This has contributed to rewarding discussions and reflections needed. We would like to thank Emil Skar for the countless Zoom discussions and supporting us from day one. The cooperation with Sensorita has been exceptionally good and extremely important for the progress of the project work. Through the work on this case study, we have gained valuable experiences that will become important in our work life. We hope this thesis can inspire Tinn and other municipalities to invest more in digitalization and increase their knowledge in this field.

We would like to thank our co-supervisor, Kristian Sørby Omberg, who has provided solid support throughout the assignment and provided good feedback. The completion of the thesis is also due to our main supervisor, Odd Ivar Lekang, who has given constructive criticism and feedback, which we are very thankful for. In addition, we would like to thank our informants who have contributed with important information and insights used throughout the assignment. Finally, we would like to thank friends and family who have supported us through the process of writing our thesis. They have set aside several hours to read through the assignment and provided feedback that has been essential for the end result.

Executive summary

Municipal waste is an ever-growing problem in the modern world. According to The World Bank, 2,01 billion tons of municipal waste is generated annually. They expect global waste generation to reach 3,40 billion tons by 2050, which is more than twice the expected population growth for the same period (The World Bank, n.d.). This expected growth in waste generation will lead to increased pressure on waste collection, making the process of waste management even more important than before.

In Norway, 20% of the waste is generated by private households (SSB, 2020). Collection of waste from private households in Norway is done based on static routes, where waste is collected regardless of how full the containers are. By using sensor technology, one can monitor waste levels in the containers and adjust the collection routes accordingly. Studies conducted in other European cities have shown that a cost and emissions reduction by 30–60% can be achieved by implementing sensor technology (ISWA, 2019).

Together with Sensorita, the thesis aims to digitalize waste collection in the municipality of Tinn, Norway. Using Tinn as a case study, the goal is to create a contextualized data model for waste management which can be used by several municipalities. The objective is to improve the current waste management process by using sensor technology. The Sensorita System contains three components. A hardware, software, and a sensor. The sensor is located on the back of the truck and collects data from wastebins using radar technology. The contracting process in a small, rural municipality with a limited economic budget will also be studied.

The key objective is to look at the existing process within waste collection and evaluate whether it can be improved based on several criteria through digitalization. The criteria in focus are costs, efficiency, and environmental friendliness. The project team aims to initiate the digitalization process of Tinn municipality and provide valuable knowledge for Sensorita to further build and grow upon.

Tinn municipality has budgeted a total renovation cost of NOK 2 900 000 in 2021 (Tinn Municipality, 2020). This is a total of NOK 16 233 500 when adjusted for prices and wage increases from 2022–2027. A total of 32 524 kilometers are driven annually to collect

municipal waste in Tinn, and there are a total of 3 133 municipal clients. This amounts to an estimated cost of NOK 1 036 and 10.38 kilometers driven per municipal customer. Total project costs and investments are estimated to be NOK 6 425 583 from 2022–2027. Three scenarios are presented when considering total savings potential. The realistic scenario includes an 20% reduction in costs and driving distance today. This reduces the cost by NOK 808 and annual driving by 8.30 kilometers per municipal customer. Considering these costs, an estimated savings potential of 22.0% can be achieved when compared to what Tinn municipality has budgeted. This is close to the rest of the digital waste collection market and what Sensorita´s competitors claim. The results are meant to illustrate potential effects by transitioning to a digital waste collection system.

More dynamic driving routes can lead to time savings as the sensors use machine learning to learn and grow independently, leaving human intervention excluded from the learning process. Sensors can cause more efficient time use by emptying bins that are actually full. To make sure that cost reductions are realistic, it is pivotal that the waste collection system is implemented correctly. This will require additional resources in the form of IT support, increased monitoring of the new process, and adjustments to the new workflow for the employees.

The reduction of climate gas emissions is difficult to determine based on the data provided. As is the case with the cost reduction, it is highly likely that the digital waste collection system will contribute to reducing emissions. A reduction will then come in the form of being able to empty more bins and collect more waste on the dynamic routes compared to the static routes. This means fewer stops and unnecessary trips to bins that have not reached their capacity.

The project group recommends that Sensorita starts by doing more pilot projects in order to gather more data and experience to build a solid foundation for further development of the machine learning algorithm. This can strengthen their position in a potential tender. Sensorita should look at how AI can be used to design driving routes and automate the waste plan. They should look at the possibility of analyzing weight as this is something many of their competitors already offer. In relation to the current situation, Sensorita should focus on collecting more data, verifying the technology they are using, document savings, and learning from the process.

Sammendrag

Kommunalt avfall er et voksende problem i dagens samfunn. Ifølge The World Bank blir 2,01 milliarder tonn søppel generert årlig. De forventer at den globale avfallsproduksjonen vil nå 3,40 milliarder tonn innen 2050, noe som er mer enn det dobbelte av forventet befolkningsvekst for samme periode (The World Bank, n.d.). Den forventede veksten i avfallsproduksjon vil føre til et økt fokus på avfallsinnsamling. Dette gjør avfallshåndteringsporsessen enda viktigere enn før.

I Norge blir 20% av søppelet produsert av private husholdninger (SSB, 2020). Avfallsinnhentingen fra husholdningene er basert på statiske ruter. Det vil si at søppel hentes uavhengig av hvor fulle søppelkassene er. Sensor teknologi gjør det mulig å observere hvor mye søppel en søppelkasse inneholder, og på den måten kan man hente søppel etter behov. Studier gjennomført i andre europeiske byer har vist at 30–60% av kostnader og utslipp kan reduseres dersom sensorteknologi benyttes i avfallsinnhenting (ISWA, 2019).

I samarbeid med Sensorita er målet å digitalisere avfallsinnhentingen i Tinn Kommune. Hensikten med oppgaven er å lage en kontekstualisert modell for avfallshåndtering som kan implementeres i flere kommuner. Hensikten er å forbedre dagens prosess ved bruk av sensorteknologi. Systemet til Sensorita består av tre komponenter. En hardware, software og en sensor. Sensoren plasseres bak på søppelbilen og samler inn data ved bruk av radarteknologi. Oppgaven vil også se nærmere på anbudsprosessen i en mindre distriktskommune med begrenset økonomi.

Hovedfokuset er å evaluere eksisterende prosess for avfallshåndtering for å se om den kan forbedres basert på ulike kriterier gjennom digitalisering. Kriteriene som er i fokus er kostnader, effektivitet og miljøvennlighet. Målet til prosjektgruppen er å sette i gang en digitaliseringsprosess i Tinn Kommune, og gi verdifull erfaring og innsikt til Sensorita slik at de kan fortsette å utvikle seg som selskap.

Tinn Kommune har satt av kr 2 900 000 til renovasjon i 2021 (Tinn Municipality, 2020). Etter kostnadene er regulert etter pris og lønnsjusteringer utgjør dette kr 16 233 500 fra 2022-2027. Det er totalt 3 133 innbyggere i Tinn og søppelbilene kjører totalt 32 524 km i året. Dette

resulterer i 10,38 km og en estimert kostnad på kr 1 036 pr innbygger. Total prosjekt- og investeringskostnad er estimert til å være kr 6 425 583 fra 2022-2027. For å se på potensiell kostnadsbesparelse brukes tre ulike senarioer. Det realistiske senarioet antar at kostnader og kjørelengde kan reduseres med 20%. Dette resulterer i redusert kjøredistanse på 8,30 km og kostnad på kr 808 pr husholdning i året. Ved sammenligning av budsjetterte kostander i kommunen, kan de potensielt spare 22% på kostnader og kjørelengde. Dette stemmer overens med hva konkurrentene til Sensorita hevder de kan spare. Resultatene er kun ment for å illustrere et poeng og gi et bilde av mulige kostnadsbesparelser ved å benytte en digital løsning i avfallshåndteringen.

Mer dynamiske kjøreruter kan føre til en reduksjon i kostnader ved at maskinlæringsalgoritmen lærer og utvikler seg basert på innsamlet data. Dette kan med tiden erstatte mennesker i forskjellige prosesser. Bruk av sensorer kan føre til mer effektiv bruk av tid ved at fokuset blir rettet mot søppelkasser som er fulle i stedet for halvfulle. For at en kostnadsreduksjon skal være realistisk er det svært viktig at systemet blir implementert korrekt. Det vil mest sannsynlig kreve ressurser i form av IT support, nøye oppføling fra ledelsen, økt overvåkning av ny prosess og justeringer i arbeidshverdagen for arbeiderne.

Beregning av klimagassutslipp ble vanskelig basert på data prosjektgruppen har hatt tilgjengelig. Det antas imidlertid, som med kostandene, at et digitalt avfallshåndteringssystem vil bidra til å redusere klimagassutslipp. Dette på bakgrunn av at dynamiske kjøreruter kan bidra til mer effektiv bruk av kjøretid når søppelkasser tømmes. Det vil si at det forventes færre stopp og unødvendige turer til søppelkasser som ikke trenger å tømmes.

Prosjektgruppen anbefaler at Sensorita fortsetter med pilotprosjekter slik at de får et solid datagrunnlag for videre utvikling av maskinlæringsalgoritmen og for å tilnærme seg verdifulle erfaringer. Dette kan styrke deres posisjon i et potensielt anbud. Sensorita burde også se på hvordan AI kan brukes til å utvikle kjøreruter og automatisere avfallsinnhentingsplanen. I tillegg vi vil det være en fordel å se på utviklingsmuligheter ved sensorene, som blant annet å analysere vekt. Dette er en funksjon flere av deres konkurrenter tilbyr. I forhold til dagens situasjon burde fokuset til Sensorita ligge på å samle inn data, verifisere teknologien de benytter, dokumentere kostnadsbesparelser og lære av prosessene.

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1 Introduction

Municipal waste is an ever-growing problem in the modern world. According to The World Bank, 2,01 billion tons of municipal waste is generated annually (The World Bank, n.d.). They expect global waste generation to reach 3,40 billion tons by 2050, which is more than twice the expected population growth for the same period (The World Bank, n.d.). This expected growth in waste generation will lead to increased pressure on waste collection, making the process of waste management even more important than before.

In Norway, 20% of the waste is generated by private households (SSB, 2020). Collection of waste from private households in Norway is done based on static routes, where waste is collected regardless of how full the containers are. By using sensor technology, it is possible to monitor waste levels in the containers and adjust the collection routes accordingly. Studies conducted in other European cities have shown that a cost and emissions reduction by 30–60% can be achieved by implementing sensor technology (ISWA, 2019).

1.1 Background

1.1.1 Waste management and waste collection in Norway

In 2019, the Norwegian Environment Agency presented a five-year plan regarding waste management. This plan includes the current status and further plans for waste management and waste reduction.

Each municipality in Norway can choose how they want to handle municipal waste, as long as they follow the pollution control act from 1981 (Miljødirektoratet, 2019). This can be organized through a local waste management agency, a subject department, a municipal company, or through an international cooperation. However, the Norwegian government has certain criteria which the municipality must fulfill regarding waste management. One criterion is that all waste management must be financed through a waste fee following the full cost principle. This means the municipalities must set a waste fee that covers the total costs of waste management, based on the waste levels in each municipality (Heflebower, n.d.). The municipalities are not able to subsidize nor make any profits from handling their waste.

Separate budgets for industrial waste management and municipal waste management are required by law (Miljødirektoratet, 2019).

How waste collection and waste management are handled varies from different municipalities. They can handle waste management themselves through an intermunicipal company, use an independent waste management company, a public enterprise, or a combination of the alternatives. Recent bankruptcies of private waste management companies have sparked a debate of whether waste management should be exposed to competition or handled by the municipality themselves. Data from 2016 shows 71 intermunicipal companies handled waste in 94% of Norwegian municipalities, covering 78% of the Norwegian population (Miljødirektoratet, 2019).

Tinn municipality follows a static collection route. Residents are given a waste collection calendar showing what waste is collected on which day. Due to the amount of tourism in the municipality, Tinn has one calendar for residents and one calendar for cabin owners in the area (Tinn Kommune, 2020). A set route covering the entire municipality is followed Monday through Friday. Waste management is partly handled directly by Tinn and through an independent renovation company (Sortere.no, 2020).

1.1.2 Problem statement

Together with Sensorita, the project team aims to digitalize waste collection in the municipality of Tinn, Norway. Using Tinn as a case study, the thesis aims to create a contextualized data model for waste management that several municipalities can use. The goal is to improve the current process. The thesis also looks at the contracting process in a small, rural, municipality with a limited economic budget, and how the size of the municipality, geography and budget will affect the digitalization process.

The team has created a zero hypothesis that will be explored in the discussion, based on the results. The project group assume that Sensorita´s product will reduce costs and climate gas emissions compared to the current solution. Based on this, the following problem statements have been created:

- *How to create a contextualized data model for process improvement in waste management?*
- *What are the most important criteria to measure the effects of such a model?*
- *How is innovation weighted in a contracting process in small, rural municipalities?*

The first two parts is the main focus of the thesis as they form the basis of the model. Nevertheless, it is necessary to understand how a company that delivers an innovative product, such as Sensorita, can stand out in a tender. Concerning tenders, it is limited to only look at how innovation is emphasized, as this is where Sensorita stands out.

1.1.3 Goals and objectives

The key objective of this project is to look at the existing process within waste collection and assess whether it can be improved based on several criteria through digitalization. The criteria in focus are costs, efficiency, and environmental impact. With this thesis, the project team aims to initiate the digitalization process of Tinn municipality and provide valuable knowledge for Sensorita to further build and grow upon. Another goal is to see how smaller municipalities consider innovation and sustainability when choosing a digital system for waste collection. To achieve the main objectives, the project team has divided the process into sub-goals.

Theory and key concepts will provide a theoretical framework for understanding the project. This includes key concepts such as digitalization, industry 4.0, IoT and machine learning. Innovation and the tender process regarding public procurements in Norway will also be explored. The chapter also includes an assessment of relevant methodology that will be an important part when evaluating the existing waste management model and developing the contextualized model for waste management presented in chapter 4.

The technical review will give an introduction of the technicalities of Sensorita's product. Tinn municipality is analyzed based on population, budget, and geography. Several popular technologies used in the sector is also presented. An analysis of Sensorita's biggest competitors is conducted to gain better insight into their market position.

The model foundation builds upon many of the key concepts introduced in chapter 2. The presented as-is process is based on information provided directly by the municipal manager in

Tinn. Along with this, a second model including a digital waste collection system is given to look at the differences and potential improvements as a result of implementing a digital alternative. The effect of the contextualized model is evaluated through a return-on-investment analysis. Here, potential cost savings, time savings and effects of the new model is evaluated and compared to the existing process.

The results will be presented as an evaluation of the model based on numbers provided from Tinn and Sensorita, performed through the key metrics set in the ROI analysis. A cost/benefit analysis will also provide a social economic evaluation of the project. Based on this, a conclusion and recommendations for further work regarding the subject are given.

1.1.4 Limitations

Early in the project planning, the team had a desire to perform a pilot testing of Sensorita´s product in Tinn as this would serve as a data basis for the project. However, due to the timeframe of the project, this was deemed unfeasible and disregarded. The thesis focuses on the as-is process in Tinn municipality today and how this can be improved through digitalization. It is assumed that Tinn will be a representative municipality to answer the problem statements.

Waste management is a comprehensive sector. It involves many steps, from where the waste is recycled to how the waste is handled in a facility. The thesis will only focus on the waste collection process, disregarding the other processes in the waste management chain. The process has been narrowed down to only involve waste collection, as looking at the process from the tender process up until the waste is handled will be too extensive.

The tender process in Norwegian municipalities is quite complex and bureaucratic. Therefore, the process will be narrowed down. The focus is on how non-economic factors are valued when choosing a waste management provider. As a result, environmental sustainability and innovation are the only factors considered when looking at this process.

Implementation of the project is not discussed in detail, nor will a strategy for implementing the product. This is due to the scope and limitations of the thesis. However, the importance of correct implementation will be discussed in chapter 5.

The Covid-19 pandemic has placed further limitations on this thesis. Ideally, the team would have wanted to visit Tinn and review their daily affairs. This has not been possible due to national Covid-19 restrictions. Meetings have been conducted digitally since the early phases of the thesis planning.

1.2 Sensorita

Sensorita is a start-up company with a mission to increase the rate of recycling by providing leading-edge analytics. The company was founded by Ulrikke Lien and Emil Skar in 2020 (Sensorita, n.d.-a). They signed a pre-study contract with Asker municipality in February 2020, and they were also granted 1 MNOK from the Norwegian Research Council May (Dagens Næringsliv, 2020). The goal of the pilot project is to test 22 prototypes and add 200 sensors by August 2021. Their ambition is to become a global supplier of data-driven waste management analytics.

The Sensorita system consists of a hardware component, level measurement sensors, and software. The sensor collects data pertaining to volume and temperature. This information will be processed into useful information about waste patterns and identify areas for improvements in the waste collection systems (Sensorita, n.d.-b). Currently, they are testing their sensors in Asker as part of the pilot.

Tinn Municipality has shown great interest in Sensorita´s product. Since Tinn is a small, rural municipality in Norway, whereas Asker is a big and rich municipality, a project here will be very interesting. Tinn Municipality is a small tourist municipality where the population varies greatly in seasons. As a result, waste management can be problematic at times.

This project will look at municipal waste collection and how the process can be elevated from the process used today by using digital tools and a methodology corresponding with innovation and efficiency. In order to achieve this, key concepts must be introduced to create a framework for the thesis.

1.3 Literary research method

The thesis is based upon several theoretical concepts, and there is a lot of information available regarding the relevant subjects. Specific search strings were used to find theory and information regarding these topics. Sensorita and assigned supervisors from NMBU have contributed so that the theoretical part of the thesis became manageable. Through the database Oria and Google Scholar, the team searched for relevant theory.

Avfall Norge works closely with various municipalities and has a lot of useful information available on their platform. The Norwegian government also publishes rules and regulations regarding tender processes and public procurements. They have reports and plans on how municipalities can work towards becoming more innovative and have an environmental impact.

In order to find the information needed regarding waste management, specifically in Norway and Norwegian municipalities, it was necessary to get in direct contact with the municipalities. Sensorita has worked closely with Asker municipality for the past few years, and it was, therefore, possible to talk with people that handle public procurements directly in the municipality. Through local contacts in Tinn municipality, the renovation company in Tinn and the municipal manager were interviewed. The selection process will be described in chapter 1.4.

1.4 Qualitative Interviews

As the thesis aims to develop a contextualized data model for waste management, it is essential to gain insight into the most important criteria to measure the effects of such a model. The objective is to incorporate Sensorita´s sensor into the current process and thus help make waste management more efficient. Since the project deals with municipal work, it is relevant to examine how the tender processes work and how innovation is emphasized. Qualitative interviews were used to gain better insight into the current process for waste management in Tinn Municipality and show how innovation is emphasized in a tender.

1.4.1 Selection of interview objects

The project is largely based on interviews with experts. Cambridge dictionary defines an expert as *"a person with a high level of knowledge or skill related to a particular subject or activity"* (Cambridge Dictionary, n.d.). In order to understand the waste management process in Tinn Municipality, talking to crucial persons was necessary. The same applies to the tender process. To gain insight into the tender process, it was imperative to talk to someone who has excellent knowledge of how tenders work.

The interviews were conducted digitally through Microsoft Teams and recorded for later transcription. Through the help of the project group's network and Sensorita, key persons from Tinn municipality, Asker municipality, and the local renovation contractor in Tinn municipality were identified and interviewed. It was an advantage that the informants did not wish to be anonymized as their position and role in the municipality is central in referring to their expertise. They handle cases regarding public procurement and waste management in the municipalities. The following subsections will provide a summary of the main findings from the interviews.

The goal is for the designed model that several municipalities can use. Since most municipalities work with inter-municipal companies or have an intermediate solution where they rent out parts of the job, it is vital to understand how innovation is incorporated in a tender. The aim was to determine how innovation is emphasized in a tender and how municipalities can facilitate more innovative alternatives.

1.4.2 Findings

Findings from the interviews are presented below. These are essential insights diligently used throughout the assignment. To develop a contextualized model for process improvement within waste management, it is crucial that the model improves the process by making it more seamless through solving identified problems. Furthermore, it was essential to gain insight into the tender process as this is a central part when looking at municipalities. The local renovation contractor was also contacted to gain insight into costs and time spent related to the current process. The findings from this interview will be presented in chapter 5 as they are linked to the cost analysis.

1.4.2.1 Tinn Municipality

John Sortland is the municipal manager in Tinn, and amongst several varying tasks following this job, he is responsible for waste management. The job includes monitoring the contract made with the renovator and all the other details that may follow due to ongoing projects.

Tinn Municipality has identified a need for more effective and digital inventions considering waste management. They are currently finding a location for their new recycling plant, and their goal is to reduce the number of return points for waste collection. In addition, they are also in the process of preparing a tender regarding waste management. The tender will be characterized by an increased focus on the environment and will depend on how they solve the new recycling plant and a reduction of return points. As of now, the driving routes in Tinn have remained unchanged for the last ten years.

Currently, the municipal residents pay for the waste, not Tinn Municipality. Therefore, it is assumed that it is of customer interest to reduce the costs. This can be possible by analyzing the amount of waste generated per household. In addition to this, waste collected from households in Tinn Municipality is analyzed based on the degree of purity and sorting. This has proven to be an area with potential for improvement. In order to improve, streamlining of the waste collection must be of focus. As a result, it is interesting to look at more digital ways to solve these problems. It would be beneficial if the sensors register waste behaviour for every customer so the municipality can give feedback regarding sorting of different fractions. Thus, if this is achievable, it can make it possible to constantly improve and have an overview of the amount of waste from each household. This can result in a waste fee based on individual waste requirements.

Tinn Municipality is characterized by having many tourists during the holidays, making waste management more challenging. Having clear indications based on predictions of when waste must be collected is extremely important. Good predictions based on patterns of emptying different fractions could create value in general as the combinations of trucks can become much more efficient. This can save time, people, and equipment. As with all technology, there are some concerns. It is important that the data is correct and that everyone involved always has the same information. John Sortland designates that it is advantageous if the investment cost is not too high and if it is possible to install the sensors on existing trucks.

1.4.2.2 Asker Municipality

Gjert Anders Glesne works with public procurements in Asker municipality. He either handles the procurements directly or works as a project manager when Asker municipality considers public procurements. When looking at a new procurement, he goes through all the stages of the tender process. This includes identifying needs, market analysis, data collection, supplier criteria, and requirements specification.

Correct pricing of demands is an essential part of the tender process. The municipality needs to find a realistic cost for the supplier who is making the offer. In addition, it is crucial to identify the needs of the municipality based on the tasks they need to perform. The municipality needs to demand what best suits them based on these needs and the price and not over-specify the demands. A requirements specification sets the threshold for whether the municipality can cooperate with a supplier or not. Supplier criteria set what the municipality will get beyond the minimum of what they can expect. The municipality needs to evaluate what they can expect based on what they requirements, what they want, and how much they wish to pay to get what they want.

However, defining these demands can be challenging. To best choose what fits the need of the municipality, they need to stipulate exactly what they see as essential as these necessities must be specified down to the finest detail. Newer procurements need to intertwine with the other tasks performed in Asker municipality every single day. Contracts need to be made for every task that must be completed. Limited time can also be an issue, as there is a lot to handle in a tender process, making it hectic if they are to fall behind.

How municipalities weight innovation and non-economic factors in a tender process varies from different procurements. The municipalities are usually updated on trends and invested in the different sectors, making it easier for them to plan when considering potential projects.

Asker municipality encourages their suppliers to be innovative. Innovation is not always a demand in the tender but can be implemented in the contracting process. Communication with the suppliers is crucial when developing an innovative process or product. They also look to other municipalities and see what they can learn from their previous implementations of similar alternatives in the past.

2 Key concepts

In this chapter, key concepts that the thesis is based upon are presented. This includes terminology and methodology found relevant for a project of this manner. Through a literature review, all concepts used in the thesis are researched and will be accounted for.

2.1 Industry 4.0

The digital process is known as Industry 4.0 or the fourth industrial revolution. It is a new industrial stage where different manufacturing operations systems are integrated with different technologies connected to information and communication (Dalenogare et al., 2018). This paradigm shift will change the way people interact, live, and work (ISWA, 2019). Incorporating customers and business partners, value-added processes, strong individualization, and adaptable and flexible production will differentiate the future industry from the previous years (Norsk Industri, n.d.). An important outcome is the opportunity to collaborate across sectors and knowing that technology can be used in several applications (Innovasjon Norge, 2020). Industry 4.0 opens up a new range of opportunities with emerging new technologies such as IoT, machine learning, AI, robotics, block-chain, and more (ISWA, 2019). Some of these terms are explained in the following sections.

2.2 Internet of Things (IoT)

IoT, also called the Internet of Things, is a global network of machines and different devices that can interact (Lee & Lee, 2015). Internet of Things will lead to a highly distributed network of devices that can communicate with humans in addition with other devices (Xia et al., 2012). The main advantage of IoT is the potential to enable communication both with and among objects, which allows for communications “anytime, anywhere, anymedia, anything” (Atzori et al., 2010).

2.2.1 Artificial Intelligence (AI)

Artificial intelligence revolves around the concept of creating intelligent machines that can replicate and perform tasks that usually would require human intelligence. Powered through deep learning and machine learning, the AI systems can perform tasks within customer service that would typically require human resources. To use artificial intelligence, algorithms are made to predict, analyze, and categorize data (Shroff, 2019). Through learning from new data and making conclusions based on the data, the algorithm will continue to improve over time. This will happen on its own by the algorithm, without the need for human intervention or explicit programming (Shroff, 2019)

2.2.2 Machine learning (ML)

Machine learning is a form of artificial intelligence that automatically learns and improves based on experience. Computer programs are developed to analyze and use data in the learning process (Expert System, 2020). The data enables the algorithm to deliver dependable, repeatable decisions and results (SAS, n.d.). The system will improve itself as it learns more and the experience level grows, without any improvements explicitly needed to be programmed. When done correctly, the system will continue learning and growing independently, leaving human intervention excluded from the learning process (Expert System, 2020).

2.3 Innovation

To improve and modernize a business model, companies must innovate and build their business model around modern technologies such as AI, machine learning, and big data analytics (Parida et al., 2019). Innovation is about identifying opportunities and finding new ways of exploiting them (Tidd & Bessant, 2018). Businesses must change how and what they offer in order to stay competitive. Hidden innovation is not reflected in traditional indicators like R&D investments. However, it can be generated from, for instance, a combination of existing technologies and processes in order to improve the business model (Tidd & Bessant, 2018).

2.3.1 Sustainable oriented innovation

Sustainability and innovation are some of the greatest buzzwords of the 21st century. In a paper on sustainable oriented innovation, Adams et al. provide a systematic review of what SOI is and provide a framework to how firms can implement this type of innovation. They define it as a process where the firm intentionally changes how the entire firm operates to create economic returns along with social and environmental value (Adams et al., 2016).

However, as with innovation in general, SOI also brings uncertainty. Hansen and Grosse-Dunker present sustainable oriented innovation to have directional risks in regards to how the environmental and social effects of innovation can bring uncertainty in the long run (Hansen & Grosse-Dunker, 2012). They use biofuel as an example, as the initial impact of biofuel was environmentally beneficial before negative side effects were discovered. This weakened the positive effects that biofuel initially had (Hansen & Grosse-Dunker, 2012).

To implement SOI, three main steps are presented: *Innovation activities of Operational Optimization*, *Innovation activities of Organizational Transformation* and *The innovation activities of Systems Building* (Adams et al., 2016). The first step, operational optimization, is when the organization looks for more efficient and sustainable means to perform the same processes within the organization. Organizational transformation meaning that there is a change of mindset in the organization, where there is a transition from a "do less harm" attitude to directly valuing a deliverance of greater benefits to society. The final step, systems building, is where the organization changes its core ways of thinking to look at a broader perspective. The broader perspective includes looking further than just the organization itself and rethinking the position of businesses within society (Adams et al., 2016).

2.4 Digitalization in waste management

The Norwegian Ministry of Foreign Affairs defines digitalization as "*a collective term for implementing digital tools and methods that makes processes more effective and changes society*" (Meld. St. 11 (2019–2020)).

In 2017, ISWA conducted a global survey within waste management where the participants were asked numerous questions related to Industry 4.0 and the possible impacts. The survey shows that 14% knew a lot about Industry 4.0, while 29% said they knew almost nothing about it (ISWA, 2018). Based on the survey, 97% believed that Industry 4.0 would impact on waste management, where there was a 50/50 split whether the respondents expected a significant impact or not. The same survey also showed that over half of the respondents assumed driverless trucks and robotic waste bins could be possible as soon as 2030. It seems that the consensus multiple surveys regarding Industry 4.0 readiness is that the sector is positive towards digitalization and is anticipating change within waste management. However, some confusion is related to the impact and outcome (Mavropoulos & Nilsen, 2020b).

Along with many industrial sectors, the waste management sector in Norway has amplified its focus on digitalization and circular economy. One of the waste management organizations focusing on digitalization in Norway is Avfall Norge. They have created a road map for digitalizing the waste management sector (Avfall Norge, 2020). Creating this map aims to show the industry the potential and expectations they could meet by moving towards a more digital business. Avfall Norge points to some important principles to consider when testing and implementing an invention that aims to digitize a service or a product. The product or service should be a result of an identified need from the customer. It should be easy and fast to implement, test, and evaluate to ensure continuous goal achievement. In addition, it is important to involve the correct strategic people during the process (Avfall Norge, 2020).

2.5 Circular economy

The classic industrial model is a take-make-waste model, which is a linear economic model. The linear path starts by collecting the resources needed for the product, using it, and ultimately throwing it away when it has served its purpose (Ellen Macarthur Foundation, 2021). A circular economy changes the linear model into a circular one, aiming to make the economy more environmentally-sound, while still strengthening society and businesses. It builds upon three core principles: reducing waste and pollution through design, regenerating natural systems, and keeping the products and materials in used (Ellen Macarthur Foundation, 2021).

Circular Economy has become an increasingly popular subject during the last couple of years, with the European Union and China as its trailblazers within the matter. The EU has set multiple goals within waste reduction and reuse of products by 2030. This includes recycling 65% of municipal waste, reducing landfills to a maximum of 10% municipal waste, and recycle 70% of all packaging waste (Mavropoulos & Nilsen, 2020a). China has worked on a strategy for a circular economy since 2002. However, a circular economy is not seen as a means to reduce waste and promote environmental friendliness. It is rather seen as a new model to promote economic growth, environmental sustainability, and economic sustainability (Mavropoulos & Nilsen, 2020a).

With the inevitable technological change within waste management, Industry 4.0 can positively and negatively affect the circular economy. Amongst the positive effects, the various technologies and sensors being used are becoming easier to incorporate. This means that the sensory capacity with waste management is growing, and it is easier to follow the entire life cycle of any product being sold (Mavropoulos & Nilsen, 2020d). In contrast to a linear economic model, where products with a lower durability increase revenue, Industry 4.0 allows for service-based business models, giving businesses a recurring revenue instead (Mavropoulos & Nilsen, 2020d). On the other hand, Industry 4.0 also comes with adverse effects. Not all raw materials used are recyclable. In addition to this, new technologies come with a rebound effect. This effect is defined as "*a ratio of the lost benefit to the expected environmental benefit when hold consumption constant*" (Mavropoulos & Nilsen, 2020c). A rebound effect can occur both directly and indirectly. A direct rebound effect is when a lower cost of a product leads to increased consumption. At the same time, an indirect rebound effect occurs when a cost reduction of a specific product leads to increased consumption of other goods and services (Mavropoulos & Nilsen, 2020c).

2.6 Tender

A tender is a legally binding contract where a service or product is offered based on specific terms set by the buyer of the service or product (Hugsted & Anderssen, 2021). A tender aims to provide the buyer with the lowest price available in the market or to best meet the specific terms set by the buyer. When considering a tender, there are two options. Choose the provider with the lowest price or make a decision where price, timing, and quality are equally considered (Hugsted & Anderssen, 2021).

2.6.1 Tender competition

Tenders are usually gathered through a tender competition. This is done through a procedure procurement which is regulated by national laws. The client must follow these laws and regulations in a tender competition, and there are different laws for public and private procedure procurements (Krüger & Anderssen, 2021). There are several methods within the tender competition. In waste management, either open or limited tender competition are appropriate methods (Avfall Norge, 2017). In an open tender competition, every service provider or product relevant to the client draws up a tender. Limited tender competition is a bit different. Here, every provider of the relevant service or product inquires to be a part of the process, and the client invites providers to make a tender (Krüger & Anderssen, 2021).

2.6.2 Non-economic factors in a tender process

In 2017, Avfall Norge presented a guidance report presenting the use of non-economic factors in a tender process. The goal of the report was to highlight successful tender processes with a focus on the weighting of non-economic factors. Some non-economic factors are innovation, environmental effect, and quality of the service (Avfall Norge, 2017).

Regarding innovation, the procurement procedure law states that the client is allowed to use innovation as a criterion in the tender, as long as the innovation directly links with the service provided (Avfall Norge, 2017). Avfall Norge presents the relevant non-economic factors used in a tender process, but innovation is not mentioned directly. This falls under the criterion *Quality of the service/product provided*, stating that this criterion can be used in a tender process where is "*a demand for new solutions that demand innovation*" (Avfall Norge, 2017).

The reason why innovation is not a criterion on its own is also explained. Innovation has evident importance in the tender process, but it can be hard to value innovation directly when municipalities are evaluating different tenders (Avfall Norge, 2017). Innovation is applicable to almost all the criteria set by Avfall Norge. Therefore, they look to reward the result of innovation, and the added effects innovation brings with it. This can vary from increased efficiency, improving the service quality, or having an environmental improvement.

2.7 Methodologies

In this subsection, the appropriate methodology related to the problem thesis is reviewed. Based on relevant theory, a conclusion that will state which methodology is most appropriate for this master thesis is presented.

2.7.1 LEAN

LEAN is a philosophy committed to delivering impeccable products and services for the customer and making this process as efficient as possible (LEAN Communications, n.d.). LEAN originates from the development of Toyota, where the goal was to modify the way supply chains and production systems are run (Ries, 2011). The methodology can be defined as eliminating "waste" in a production system related to human activity (Palange & Dhatrak, 2021). It showed how to manufacture quality into products by teaching the difference between value-creating activities and waste (Ries, 2011). Waste is defined as an activity that does not add value to the end product (Gbededo, 2018).

Kaizen is often contemplated as the foundation of all LEAN production methods (EPA, 2019). Kaizen is a Japanese word translated to "continuous improvement". Kaizen is a part of the LEAN process as it focuses on process improvements (Ortiz, 2010). The same applies to the 5S method, which focuses on sort, set in order, shine, standardize and sustain (Ortiz, 2010). Sort is about identifying and keeping only the necessary items to complete a task. Standardizing is about making rules for how and when the tasks "sort, set in order and shine" should be performed. Sustain is all about preserving discipline (ASQ, n.d.). LEAN is a business strategy used to be competitive by reducing waste and adding value to the product (Palange & Dhatrak, 2021).

2.7.2 Six Sigma

Six Sigma is an organizational tool that aims to find and remove causes of errors in an organization's processes by focusing on customer-relevant activities (Drohomeretski et al., 2014). It is a systematic and analytical approach and can be applied using various methods.

The DMAIC-method, which is the most common method, is based on defining, measuring, analyzing, improving, and controlling (Drohomeretski et al., 2014).

According to Charkravorty, there are six steps to implementing a successful Six Sigma program. Step one is to create a strategic analysis based on the current market and the target customer. The second step is to assemble a competent team to assess the implementation of improvements. Then, the cause of the issues is analyzed in step three. Step four is to analyze a process map, looking for the best opportunities for improvement. In steps five and six, one develops a plan for improvement before implementing and a review of the process (Chakravorty, 2009).

While Six Sigma is a popular method to improve the quality of a business process, it has also been found to reduce costs significantly. Using Six Sigma, General Electric saved roughly $2 billion in 1999 (Drohomeretski et al., 2014).

2.7.3 Agile Method

Agile Project Management (APM) is a methodology working towards being able to adapt easily and move quickly, focusing on innovation, improve time-to-market, people and process adaptability, and creating results of quality (Loiro et al., 2019). Agile Software development focuses more on collaboration, coordination, and learning (Dybå et al., 2014). There are five key concepts of agile project management: adaptability, efficiency, collaboration, disruption, and simplicity (Elmhurst University, 2020). Adaptability is about adjusting along with the process. Planning and execution happen in enduring waves, which require efficient work. All parties involved must contribute, and it is important to challenge the traditional culture to be competitive (Elmhurst University, 2020).

2.8 Summary

As a result of Industry 4.0, digitalization has become an essential concept for more efficient resource use and time. Since information systems and communication depend on different technologies, IoT is becoming an essential part of this paradigm shift as it enables communication to happen anywhere and anytime. As digitalization is not only about efficient communication, it is clear that also smart machines are becoming a massive part of this evolution. Efficiency and time-saving activities are an important part of business life today, and as a result, the demand for artificial intelligence technology is increasing. Since AI revolves around the concept of replicating and performing tasks that would typically require human intelligence, there is an increasing demand for competence in the field of machine learning. Data is a vital part of machine learning and, therefore, an important factor in developing industry 4.0.

Stricter environmental requirements create increased interest in environmentally friendly inventions in most sectors, and the waste industry is no exception. Staying innovative and looking for improvement is becoming a critical part of business operations. As a result, sustainable oriented innovation has emerged as a vital method in innovation. This is a process where the firm changes how the entire firm operates to create not only economic returns but also social and environmental value. Increased focus on innovation has also been noted in tender processes in municipalities.

Since the goal of the thesis is to look at the existing process within waste collection, examining whether it can be improved based on several criteria through digitalization, the LEAN methodology is considered to suit the project's objectives the best. While Six Sigma is a more analytical and strategic approach to improving a business process, LEAN and Agile project management focus on efficiency and innovation. The LEAN methodology also follows Avfall Norge’s principles. Their roadmap to digitalization points out that improvements and use of digital tools should be based on a direct, identified need of the customer. Sensorita helps to digitalize the current process and collect data from waste bins using sensors on the trucks.

3 Technical review

This chapter will provide a description of Sensorita's product and its mechanisms. Different technologies used within the digitalization of waste collection are discussed, and some of Sensorita's major competitors, both nationally and internationally, are introduced to provide a market overview. Sensorita will be compared to their competitors, what distinguishes them from their competition will be analyzed. There are some limitations regarding the technical review which is presented. The information used in this section is directly provided by Sensorita and from the competitors' official websites.

3.1 Limitations for the technical review

The relevant technologies will only be presented to gain a better understanding of the technologies. They will be reviewed in enough detail to understand how the technologies work, but there will be no further examination into the depth of the technologies. Since the market for level measurements has been growing within waste management in the last years, a list of Sensorita´s closest competitors is presented. However, only a few of them will be given in detail. As Sensorita is a relatively fresh start-up company, they have not been able to test the durability of their sensor over several years. The expected timeline is five years, corresponding with the general duration of a standard tender in Norway.

3.2 Analysis of Tinn municipality

To understand the case, it is crucial to get a better understanding of Tinn municipality. This includes looking at geography, economic budget, population, and population density. Tinn municipality is compared to Asker municipality, as this is where Sensorita is currently testing a prototype. The reason is to see potential benefits Tinn can achieve from using a digital waste collection alternative that Sensorita offers.

In 2021, there were 5 604 residents in Tinn municipality, and most of them live in Rjukan (Statistisk sentralbyrå, 2021b). The municipality has a total area of 2 045.13 km^2, leaving Tinn with a population density of 3 people per km^2 (Statistisk sentralbyrå, 2021a). In 2021, Tinn municipality has budgeted with a NOK 674 187 total operating revenue loss (Tinn

Municipality, 2020). Asker municipality, on the other hand, has a population of 94 915 (Statistisk sentralbyrå, 2021b). With a total area of 376.62 km2, giving Asker a population density of 252 people per km^2 (Statistisk sentralbyrå, 2021a).

Tinn municipality has budgeted 4, 17, and 10 MNOK on renovative investments in 2021-2024 (Tinn Municipality, 2020). The plan is to build a new renovation facility in Gausta and a recycling facility for the rest of the municipality.

The Norwegian Ministry of Local Government and Modernisation presents a report regarding the economic situations of Norwegian municipalities. They aim for a fair distribution of revenue between the municipalities, allowing all municipalities to provide the same services and be economically competitive regardless of the population and geographical size (Prop. 192 S (2020–2021)). This means that Tinn should have the same opportunities as larger municipalities, such as Asker, based on their economic strength.

These statistics show some significant differences between the two municipalities. Asker outweighs Tinn on all the metrics analyzed, apart from geographical size. This shows a potential for making the driving routes in Tinn more efficient. There are not as many bins to empty, but the driving distance is far greater per household than in Asker municipality.

3.3 Technologies used within digitalization of waste collection

The market for level sensors is a growing, global market. Reports show that the level sensor market was estimated to be at USD 4.3 billion in 2020 and is expected to reach USD 6.1 billion by 2025 (Markets and Markets, 2019). The Asia Pacific is the region with the highest expected growth over this period, with China as the leading country (Markets and Markets, 2019). The report is based on numerous technologies within level sensors, such as ultrasound, radar, optical, and laser, to mention a few. Radar, laser, and ultrasound level measurement sensors are described as Sensorita, and their competitors use these three technologies.

3.3.1 Radar

Radio detection and ranging, or radar, is an electromagnetic sensor that sends out electromagnetic waves to track and measure the distance to an object (Skolnik, 1999). Radio waves are produced by the sensor and track the reflections returned when the radio waves hit an object. This allows the sensor to determine the distance to the object and calculate what type of object it is (LiDar and RADAR Information, 2021). During the 1930s and 40s, there was an increased focus on developing radar technology for military use. While still being a popular technology within the military, radar is also used in civilian industries. Common uses for radar are aerial and naval navigation, traffic controls, and observation of weather, to mention a few (Skolnik, 1999).

Sensorita uses radar in a new application in their sensor, measuring waste levels. The sensor sends out microwaves at the speed of light, recording the echoes produced back from the object when the microwave hits. It operates in the high frequency category of radars. A higher frequency microwave comes with both advantages and disadvantages. The narrow beam helps the sensor avoid obstacles and perform well for short-range measurements (Cahill, 2016). Regarding waste management, a higher frequency microwave can penetrate the plastic lids of waste bins when registering waste levels. However, the narrow beam requires a free line of sight to perform, and performance can be affected by exterior conditions such as dust or condensation (Cahill, 2016).

Using the echoes produced back from the objects hit by the microwave, the data can differentiate between the materials. In theory, the radar sensor can measure the various types of municipal waste in the waste bins, allowing for a more extensive data set to be collected. However, the distinction of various materials using microwaves requires that the sensor is calibrated correctly (Barowski & Rolfes, 2017).

3.3.2 Ultrasonic measurement

Ultrasound is defined as a non-audible sound with a high frequency that usually surpasses 20 kHz (Sonotec, n.d.). Ultrasonic waves can be divided into low to medium frequency, 20-1000 kHz, and high frequency at 2-10 MHz (Tyagi et al., 2014). High-frequency waves are primarily used in medical examinations, while low to medium frequency waves are used in industry and nanotechnology (Tyagi et al., 2014).

Ultrasonic level measurement works in the same way as radar level measurement. However, while radar level measurements use radio waves in the measurements, ultrasonic level measurements build upon sound waves (Coulton, n.d.). The sensor emits sound waves that reflect off an object, and the echo is reflected to the sensor. Based on the time traveled by the echo, the sensor can calculate the distance to the object (Coulton, n.d.). The documentation provided by Sensorita shows that a common factor within ultrasonic level measurement in the waste management sector is that the sensors are placed within the lids of the waste bins. This allows the companies to have a continuous real-time measurement of waste levels in the bins.

3.3.3 Laser

Laser level measurement works very similarly to ultrasound level measurement and radar level measurement. Similar to radar, laser level measurement uses pulses of laser moving at the speed of light to measure depth. The sensor is placed at the top of the bins and emits a light that measures the time from the laser pulse is emitted until the reflection is registered back from the object (ABB, 2021). Based on the time it takes for the reflection to be registered, the sensor can calculate the distance to the object.

3.4 Technical description of the Sensorita system

The Sensorita System contains three components, a hardware, software, and a sensor. The sensor is located on the back of the truck and collects data from wastebins using radar technology. Radar waves are emitted from the sensor when the bin is to be emptied. Moving from one material to another, such as air to plastic or plastic to waste, it will produce reflections. Along with information about the size of the container, the reflections enable Sensorita to calculate how much waste one specific bin contains. The data collected is sent to the cloud for big data analysis and is later used to gain better insights into consumer behaviour, waste trends and utilization of capacity.

Sensorita uses machine learning to predict waste levels in the waste bins. This means that Sensorita can predict the most efficient routes for waste collection based on the amount of predicted waste. The challenge is to create a data set the machine learning algorithm can learn from. For the algorithm to be as accurate as possible, the data used needs to be validated. The data validation happens manually, where the actual waste level is controlled against the predicted waste level. It is crucial that Sensorita gets as much training data as possible, as this will improve the overall performance of the model. The sensors are assumed to have an estimated durability of 5 years and it will be constructed from materials, designed to be as recyclable as possible when it is swapped out.

3.5 Competitive Analysis

There is a variety of companies offering level measurement within waste management. Table 1 shows a detailed list of the main competitors of Sensorita. This includes the country of origin, the product offered, the technology used, and revenue. To establish the revenue, the public, Scandinavian service Proff.no, has been used for the Scandinavian companies. For foreign companies, ZoomInfo.com has been used. All the competitors offer waste level registration in waste bins, while Sensorita is the only company offering level measurement from the back of the waste trucks. This section provides a closer look at some of the competitors compared to Sensorita using the competitive forces model. The information used about the competitors is based on information available on the company's websites.

Table 1. List of Sensorita´s main competitors

Company	Country	Product	Technology	Revenue
Nordsense	Denmark	Waste level registration in bins	Laser	NOK 81 000 (Proff DK, 2019b)
Fieldata	Norway	Platform for data analysis	N/A	NOK 125 360 (Proff NO, 2019b)
Flexi	Singapore	Waste level registration in bins	Laster and tilt measurements	NOK 42 479 400 (ZoomInfo, 2021b)
BrainyBins (Maacks)	Denmark	Waste level registration in bins	N/A	NOK 9 525 (Proff DK, 2019a)
Wastehero	Denmark	Waste level registration in bins	Optical/Laser	N/A
Sensoneo	Slovakia	Waste level registration in bins	Ultrasound	NOK 50 975 280 (ZoomInfo, 2021d)
BrighterBins	Belgium	Waste level registration in bins	Ultrasound	N/A
Staal Instruments	Netherlands	Waste level registration in bins	Radar	NOK 33 910 600 (ZoomInfo, 2021e)
Waste Vision	Netherlands	Waste level registration in bins	Radar and Ultrasound	N/A

Poul Tarp	Denmark	Waste level registration in bins	Ultrasound	NOK 84 776 500 (ZoomInfo, 2021c)
Bintel	Sweden	Waste level registration in bins	Laser and radar	NOK 2 791 000 (Proff SE, 2020)
Enevo	Finland	Waste level registration in bins	Ultrasound	NOK 161 075 350 (ZoomInfo, 2021a)
EnviroPac	Norway	"smart" waste bins		NOK 16 225 800 (Proff NO, 2019a)
Farsite	Great Britain	Waste level registration in bins	Ultrasound	N/A

3.5.1 Nordsense

Nordsense was established in 2015 and is a Silicon Valley-funded company based in Copenhagen, Denmark. They have businesses in Europe, Israel, and North America. According to Nordsense, 90% of the world's waste is collected at the wrong time (Norsense, n.d.). They aim to expand further into both the private and public Norwegian market. Avfall Norge has published a feature article about Nordsense to help them expand and get in contact with potential Norwegian partners (Avfall Norge, 2021). Nordsense can measure fill levels, temperature, and other data points through a smart sensor placed in the waste bins. The optical sensor in the bins captures data every 15 minutes and can produce 3D depth maps of the contents of the bins. They offer a variety of sensors to suit different container types and sizes. Based on the data collected, Nordsense also offers intelligent routing. This is a digital platform that provides optimized and dynamic routes for the drivers. The dynamic route is based on containers that are already full and bins that are predicted to be full that day. If a bin should suddenly be full, a notification is sent out to the nearest driver, alerting them of a new pickup. The platform includes a daily work schedule and step-by-step navigation for the dynamic routes the drivers are on.

Figure 1 One of the sensors used by Nordsense (Nordsense, 2021)

3.5.2 Sensoneo

Sensoneo is a global smart waste management company based in Slovakia. They are spread across five continents and 56 countries in total. They claim that their system reduces waste collection costs by at least 30% and lower emissions by up to 60%. Using an ultrasonic smart sensor in waste bins and containers of various sizes, they offer data-driven waste management and route planning. The sensors use IoT networks and GPRS to monitor waste levels in the containers while also having tilt recognition and a fire alarm as additional features. Constructed from recyclable materials, the sensors can measure from 3 cm up to 400 cm in depth. Route planning is also offered to provide an end-to-end solution. Based on the data from the sensors, routes are optimized and automized to reduce the costs and emissions regarding waste collection. Drivers are provided with a navigation app to collect waste based on pre-determined data. A dashboard is also offered, allowing the management to monitor and analyze the waste collection efficiency.

Figure 2 Level measurement sensor used by Sensoneo (Sensoneo, 2021)

3.5.3 FLEXI Systems

FLEXI systems are an international company established in Singapore in 2005 with 400 employees in Singapore, Malaysia, Indonesia, India, and Bangladesh. They developed a continuous monitoring system that monitors various parameters around the clock to access information about wastewater quality easily. Their newest development, BrainyBins, which is based on Litter Bins Management System, consists of sensing hardware and intuitive, user-friendly software that gives insights into waste management and cleaning operations. The smart bins are assembled with BrainyBins sensors which make it possible to detect the waste level of bins, monitor cleaning activities, and track the locations of the different bins. There are two types of sensors, a laser sensor and a tilt sensor. The laser sensor can detect all types of materials and provide full coverage of the bin, while the tilt sensor can detect expected emptying of the bin or even vandalism.

3.6 Competitive Forces Model

Porter's five forces analysis is a framework used to analyze an industry in order to identify the attractiveness based on five competitive forces (Johnson et al., 2017). Industries are not attractive where the forces are high and strong, and the profitability is affected by rivalry between competitors, powerful buyers and suppliers, and threat of substitutes or new entrants (Johnson et al., 2017).

3.6.1 Threat of entry

Stricter environmental requirements made by the government create increased interest in solutions considered to be more environmentally friendly. This could mean an increased interest amongst existing and new companies to enter new markets with new innovative and smart inventions. Waste management in Norway is a municipal responsibility, and to be responsible for this task, companies must go through a tender process. Non-economic factors are becoming an increasing focus which indicates that factors such as innovation, environmental effect and quality of the service is becoming quite important. Several of Sensorita´s competitors are more established companies with more resources. This can indicate an advantage in terms of research and development. They may easily obtain the money necessary to convert an idea into something valuable. Sensorita has an advantage of having a pilot-project with Asker municipality which, if successful, can give them a huge advantage when approaching other municipalities in Norway.

3.6.2 Threat of substitutes

As presented in table 1, there are currently two competitors in Norway. Implementing a new waste management system requires investment in both time and money, and as a result, the switching costs can be high. Being a software and hardware supplier, as Sensorita, it is important that the products generate profit for the customer which makes it difficult to substitute it or doing it themselves.

3.6.3 Threat of buyers

The fewer the customers, the more power they have. Since waste management is a municipal and state responsibility, buyers are limited. As the price will be an important part of the tender process, the product must be superior considering other aspects. Sensorita has an advantage as the sensor is located on the back of the truck, unlike their competitors, who have sensors placed in the waste bins. Having sensors on the truck can possibly be cost-effective in the long run as fewer sensors are needed.

3.6.4 Threat of suppliers

Sensorita currently depends on a couple of specific suppliers for different parts of their sensor system, making them vulnerable to changes in the market. It could be valuable if they had more suppliers as they are particularly exposed to price changes and other challenges that may arise. Problems like this may be easier to deal with when they become more established and have considered what is required to get a perfect end-product.

3.6.5 Extent of rivalry between competitors

The competition is spread internationally, which means that the market has excellent growth potential. Companies such as Nordsense and Flexi systems have already spread to several countries, establishing a reputation. Currently, there are only two competitors in Norway that deliver a similar product as Sensorita. It is pivotal that Sensorita is successful in the ongoing projects to build a solid reputation in the market. They currently stand out being the only identified supplier who has sensors placed on the back of the truck, which can be shown to reduce costs. Unlike ultrasonic measurement and laser, radar technology is advantageous considering that the electromagnetic waves can go through the lid while providing a reflection of the content. The same applies to laser, but there may be problems with plastic waste as the laser will have a hard time reflecting the plastic object. Radar can also detect objects in harsh weather conditions.

3.7 Summary

Many technologies are used in the level measurement market, but three technologies have been highlighted regarding level measurement within waste management. Radar, ultrasonic, and laser are the three technologies chosen, as these are the ones used by Sensorita and their competitors. All three technologies work in a similar manner. Radar uses radio waves moving at the speed of light to measure the distance to an object by recording the time traveled of the radio wave reflections. Ultrasonic uses sound waves moving at the speed of sound to record the distance to the object, also measuring the time traveled of the reflections back from the object. Laser sends out laser lights moving at the speed of light to measure the depth to an object, building upon the same principles as radar level measurement.

Sensorita aims to use machine learning and prediction algorithms to make waste collection more efficient and cost-effective. This is done by having a radar sensor placed on the back of the waste collection trucks, measuring how full each bin is when emptied. The data is then stored in a cloud database, generating data that the prediction algorithm uses to be trained. To correctly predict future waste levels in the bins, Sensorita depends on a large dataset and an algorithm that is well trained.

Level measurement within waste management is a growing market, both in Norway and internationally. Sensorita has 14 direct competitors. The companies vary in size and how established they are, and the company list spans from multinational corporations to startup companies. Nordsense, Sensoneo and FLEXI Systems are the three companies that have been looked further into by the project team, to better understand the positioning of Sensorita in the market.

Sensorita can experience a first-mover advantage as they are the first supplier of sensors placed on the back of the truck. They can achieve a competitive advantage if the pilot project in Asker goes well, and they succeed in establishing a sufficient market share. A problem that has already occurred derives from movement in the car. It has proven to be more difficult than expected to use sensors on waste trucks. The various renovation employees do not empty the bins exactly the same at each waste collection. This has proven to be a challenge due to the waste bin not having a stable and consistent speed or path when emptied. The sensors are dependent on a solid prediction algorithm to make waste collection routes more efficient. Sensorita has to create a good data set so the sensors can be utilized to their full potential. Having sensors in the lids of the bins can provide real-time data, making it easier to create an exploitable algorithm.

4 Method

The key objective of this project is to look at the existing process within waste collection and see if it can be improved based on several criteria through digitalization. In this chapter, the project group intends to develop a contextualized data model for waste management. The aim is to analyze and measure the effect of logistics solutions within waste management. In this thesis, it means an assessment of Sensorita´s sensor system. Firstly, a model basis, which will provide a foundation for further development of the contextualized model, is given. Furthermore, a preliminary and contextualized model is presented, followed by an evaluation of the two processes. Finally, a ROI model for evaluation of socio-economic effect.

4.1 Model basis

The model basis provides a foundation for further work. In order to develop a model where the aim is to optimize the waste management process in Tinn Municipality, it is critical to have completed solid groundwork. Table 2 summarizes the most important points for further model development.

Table 2 Summary of the model basis.

Requirements	What it means
LEAN	Elimination of "waste" activities and continuous improvement
Innovation	Use AI, machine learning and big data analytics for process optimalization
Environment	Help reach goals set within waste reduction set by EU
Circular economy	Reducing waste and pollution through design, regenerating natural systems, and keeping the products and materials in use
Municipal requirements	Meet the requirements and demands of the municipality. Map out the existing resources in the municipality
ROI	The model must be measurable
Data	Transform data into information. Make the data measurable
Cooperation	A close relationship between the municipality and the supplier
Tender	Highlight the important criteria in the requirements specification

LEAN creates the basis for the model as the methodology is based on delivering quality services to the customer and making the process as efficient as possible. The most important part of LEAN is focusing on the difference between value-creating activities and waste. The elimination of activities perceived as waste enables more efficient time-use and making continuous improvement possible.

For municipalities to become more efficient and create the most optimal process for waste management, the project team believes that innovation is key. Implementing AI, machine learning, and big data analysis is crucial for process optimization. The goal is to make the data assessable in order to make accurate decisions and evaluate measures. Continuous follow-up of measures makes it possible to monitor that requirement set for residents are met, while at the same time making sure that goals set by the state and municipality within waste reduction is achievable and realistic.

As previously mentioned, most municipalities work with inter-municipal companies or have an intermediate alternative where they outsource part of the job regarding municipal work. As a result, the project team will focus on how innovation can be emphasized in a tender and how municipalities can facilitate more innovative alternatives.

4.2 Preliminary Model

To identify potential for improvement, it is crucial to understand and learn about the as-is process of waste management in Tinn Municipality today. To get an enhanced insight into the process today, the municipal manager in Tinn has assisted with domain knowledge and experience.

Tinn Municipality pays a waste management company to perform the process of collecting waste from their residents. This is done through a tender which means that the municipality does not provide garbage trucks, equipment needed for waste collection, workers to collect waste, or anything related to the collection process itself. However, they take care of customer inquiries, collaborate with the waste management company to make waste management plans, and look at different requests that must be answered and how to solve them.

Historical data is used to analyze waste patterns and develop the waste management plan sent out to households every year. The driving routes are the same every month, and there are fixed days for different fractions. There may be changes in the high season when more cabin owners and tourists are in the municipality, but this is also determined based on waste patterns from previous years.

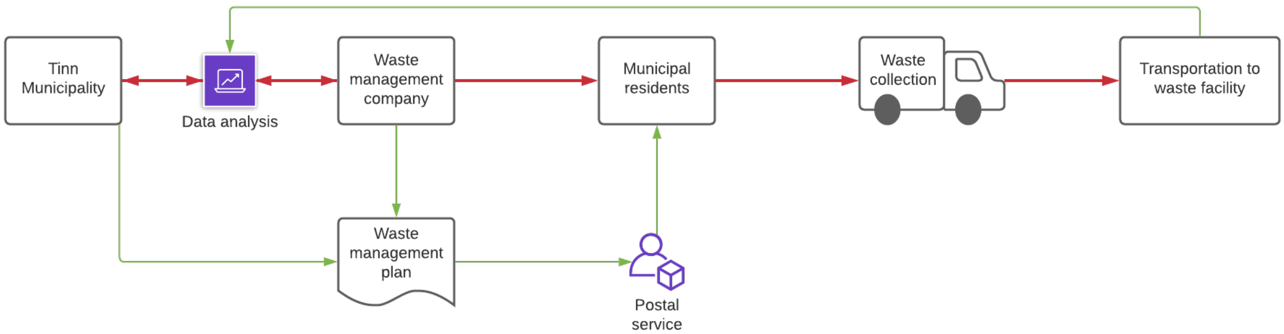

Figure 3 The as-is waste collection process flow in Tinn municipality.

As shown in figure 3, there are two stakeholders specifically involved in the process, Tinn municipality, and the waste management company. They must work closely together to develop a waste collection procedure. This is done every year. The plan is based on historical data and is sent by post to all residents every new year. The type of waste collected varies based on analyzes done at the waste facility. Different waste is collected weekly in a set cycle.

The most important part of the process is analyzing historical data to create a waste management plan. This plan determines the driving pattern for an entire year. The municipality is dependent on previous data to make precise predictions for waste patterns the following year. Making choices based solely on historical data can be unpredictable, and problems can occur if unforeseen situations arise. Unforeseen situations may be that the number of tourists increases or that cabin owners use their cabin more frequently as there are restrictions on travel abroad due to covid-19. Because historical data can be unpredictable, this part of the process has potential for improvement.

4.3 Contextualized Data Model for waste management

The goal is to demonstrate how Sensorita can contribute to a more seamless value chain regarding to waste management. This means a value chain that can help increase customer experience while delivering added value (Prophetic Technology, n.d.). This is done by implementing IoT, machine learning, smart systems, and close cooperation between the parties involved. These parties include Tinn Municipality, the waste management company, and Sensorita.

As shown in figure 4, Sensorita can contribute to making the waste management process more efficient. Tinn Municipality, the waste management company, and Sensorita will collaborate in making the waste management plan. The sensors placed on the garbage trucks will constantly send data to the cloud. Here, data will be converted into information that Tinn and the waste management company will use to create the waste management plan.

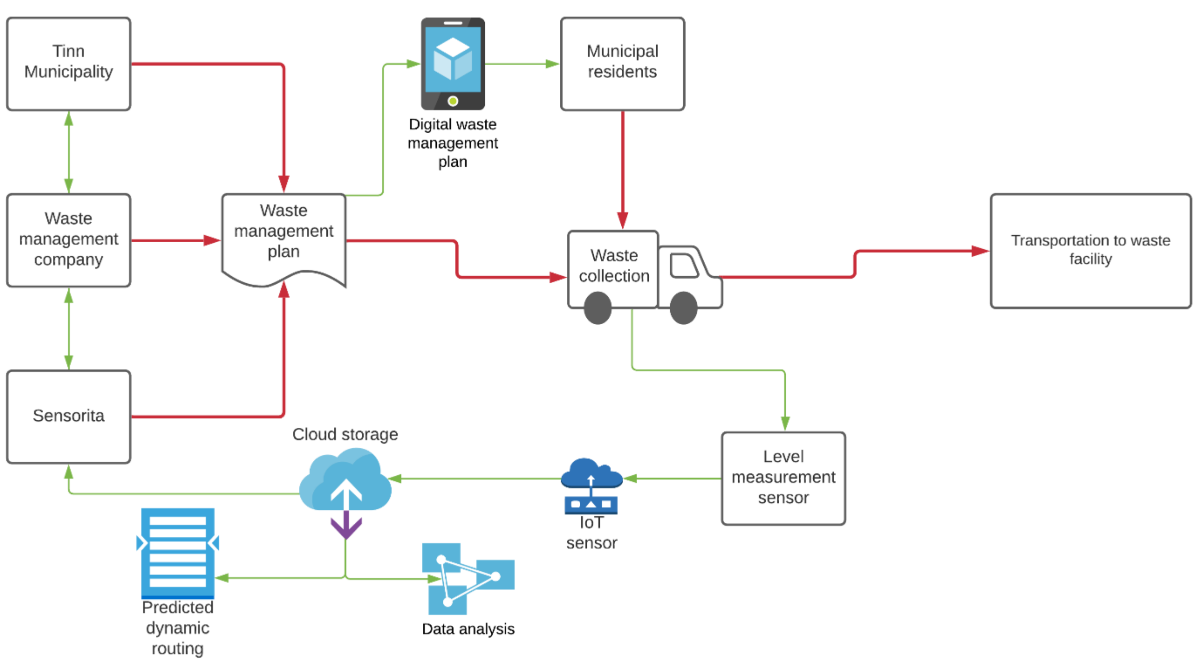

Figure 4 The proposed new process flow with the implementation of Sensorita´s product.

As the bins are analyzed on every pick-up, the data used for predictions are more recent and updated than historical data from past years. Using this data, compared to historical data, allows for precise predictions about waste patterns and makes it possible to make dynamic driving routes. This enables continuous improvements regarding waste management and ensures that the residents are satisfied with the waste disposal. Implementing an app allows for communication between Tinn and the residents, allowing the municipality to update driving routes based on needs.

By using sensors from Sensorita, the garbage is analyzed every time a waste bin is emptied, and the data is sent up to the cloud. Here, the data will be analyzed and converted into information that can further be used for analyzes, optimal routing and predictions. The process is shown in figure 4. The model aims to explain how modern technologies such as IoT and machine learning can optimize and make value for all parties involved in waste management. The model builds upon the principles of LEAN, where the goal is to get rid of activities that do not create value. It also focuses on efficiency and innovation as new technology is incorporated to create added value.

4.4 Evaluation

In order to measure the performance of the new, suggested model against the existing as-is process today, a measurable metric was made. This allowed the project team to evaluate the model performance objectively, providing an evaluation rooted in hard facts and numbers. A return-on-investment analysis helped perform this task, and the key metrics, used to conduct this analysis, is explained in chapter 4.5.

4.4.1 ROI analysis

To evaluate the performance of the model, a return-on-investment (ROI) analysis was conducted. Chapter 4.4 provides the foundations the analysis is based on, and the key factors used in the analysis. ROI analysis make it possible to evaluate the total effect of the project (Autodesk, 2015). The key metrics can be interpreted as a hypothesis. These are the effects that the team wished to verify through the analysis.

4.4.2 Limitations and assumptions

Most of the numbers used in the analysis are provided directly by Tinn Municipality and Sensorita or based on assumptions. Tinn provided data contributing to craft an overview of the as-is process today. Through previous experience in other municipalities, Sensorita helped with numbers to identify savings potential by implementing a level measurement sensor in Tinn.

The analysis aims to illustrate the potential effects of transitioning to a digitalized waste collection system in Tinn.

The analysis is based on the needs of Tinn municipality. The project team assumed that Tinn is a representative municipality regarding small, rural municipalities in Norway. The needs of Tinn municipality may be subject to change in the future.

4.4.3 Key metrics

There were three important points identified in order to look at the ROI investment. This is cost savings, time savings, and the potential for better project results (Autodesk, 2015). Table 3 shows a summary of the key metrics.

Table 3 Summary of the key metrics used for the model basis.

Cost savings	**Time savings**	**Effect**
• Reduction in fuel costs • Reduced waste cost for households and local businesses • Reduced maintenance cost of trucks • Reduced cost per load through more efficient routes	• Reduced time planning routes • More efficient routes • Reduction of total waste collection time	• Reallocate resources to other parts of waste management • More efficient driving routes • Environmental gain from reduced driving • Improved recycling in municipal households • Increased incentive to use digital solutions. • Increased knowledge regarding digitalization • Easier tracking of municipal waste levels • Easier monitoring of the overall process • Better communication between the municipality and households

Cost savings are directly tied to the potential of economic savings by implementing a digital alternative. It is expected that the transition from static to dynamic routes would decrease in total, leading to a potential reduction in fuel costs. This might also reduce the need for waste truck maintenance. More efficient routes can allow the waste trucks to be filled to maximum capacity, potentially reducing the cost per load. The population of the municipality also pays a fixed waste management fee. Measuring the exact amount of waste each time the waste is collected can allow for dynamic pricing of the waste management fee, allowing the residents to pay for the actual waste they generate.

Another part of making waste collection more efficient is the potential for saving time. Route planning can become dynamic using data and machine learning. This might lead to a time reduction for the management. Today, Tinn uses historical data when planning the waste collection routes. More efficient routes might allow for emptying waste bins that are full, reducing the time spent emptying bins that are not full.

The third and final part of the key metrics are the positive effects of the model. These are potential improvements that come as a result of the project. Reducing the total waste collection time can free up time for the waste management employees. This can allow them to focus on other business areas that contribute to value creation for both the waste management company and the municipality. Making waste collection routes more effective might not reduce the number of kilometers driven but could allow for more time-efficient routes through emptying bins that have reached their capacity. This can provide an environmental gain for the municipality. The environmental gain can either be a result of fewer driven kilometers in total or more waste bins emptied per kilometer, reducing the number of kilometers needed to be driven between the emptying of the bins.

As the measuring of waste can lead to a dynamic waste fee, this could allow for a waste cost system that is better for the local population. The tracking of how much waste is generated in the households may lead to an increased incentive to improve their recycling. It is easier for the municipality to track the amount of municipal waste, as the data is recorded upon emptying the bins. This would allow the municipality to understand the overall process better and make changes based on recent data rather than historical data. Initializing a digitalization project such as using Sensorita´s system might provide valuable experience for the municipality when considering other modern and innovative alternatives. A digital product can allow for easier changes considering the waste plan and increase the communication between the municipality and the residents. This could increase the transparency between the two parts.

4.4.4 ROI factors

Some ROI factors needed to be determined to evaluate the difference between the as-is process and the potential effect of a digitalized process. These are costs related to the implementation of the project. The costs are startup costs, project-specific costs, and strategic costs.

All numbers presented used the net present value (NPV) calculation method. This means that the costs are discounted using a standard discount rate of 4%, as recommended by The Norwegian Agency for Public and Financial Management (DFØ, 2018). The numbers are calculated using the following formula:

Equation 1. NPV formula used to calculate the costs

$$Cost\ at\ time\ \boldsymbol{n} = \frac{(Yearly\ cost * (1 + price\ adjustment) * (1 - effeciency\ factor))}{(1 + discount\ rate)^n}$$

The efficiency factor is a percentage that varies from year to year. This efficiency factor is added to reflect the potential gains the process improvement can contribute with. By using a process flow rooted in the LEAN methodology, it is assumed that the process can become more efficient over the duration of the project period. The values for the efficiency factors are summarized in table 4. n varies between 1-5, depending on the year. It is assumed that several of the project-specific and strategic costs can decrease when the project progresses. All prices and wage costs are adjusted through a price/wage adjustment based on economic trends provided by Statistics Norway (SSB, 2021). The Consumer Price Index (CPI) is used to adjust the prices, and wages per standard man-year is used to adjust the wages. Since SSB only provides economic trends up until 2024, it is assumed that the economy stabilizes in 2024. All costs in 2023–2027 are based on the costs in 2022, adjusted for prices and wages.

4.4.4.1 Start-up costs

There are several startup costs related to implementing radar level measurement on waste trucks. The first cost is related to the purchasing of sensors and installation. All trucks are assumed to be equipped with a smart device (an iPad, for example) and Sensorita will charge the municipality for their services and the sensors. Depending on existing IT services in the municipality, both software and hardware upgrades may be needed regarding implementation and optimal use of the sensors. The final cost is related to the development of the new waste plan app used to communicate with the residents in the municipality. Whether Tinn municipality wants to use existing resources to develop this themselves or use an external party is unknown.

4.4.4.2 Project-specific costs

Concerning project-specific costs, there are several costs to be aware of. Costs may arise due to increased time spent transitioning and learning the new system. This applies to both the management and truck drivers. The management need to learn the system and adjust to the dynamic routes. This might lead to administrative costs. The drivers transition from driving the same routes Monday through Friday, to a more dynamic route, possibly changing from week to week based on the waste levels. This is a new adjustment for the drivers, and they will need to get used to the new process.

4.4.4.3 Strategic costs

The project also brings several strategic costs. The first cost arises as a result of planning. This involves both the day-to-day planning, but also the implementation of the system. There will most likely arise an increased time use due to monitoring the new waste collection process for the management. They will most likely spend more time observing the process more closely. Depending on existing IT resources in Tinn municipality, it might be necessary to create new roles regarding IT support regarding the new digital system. The knowledge to secure an efficient operation may already exist in the municipality, but there might also be a need to move existing IT personnel into new roles or hire additional IT personnel.

4.5 Summary

As a result of the following problem statement, which aims to digitalize waste collection in the municipality, a contextualized data model for process improvement has been created. The model is based on LEAN principles, innovation through new technology, and the goal of creating a seamless value chain when it comes to waste management. The model aims to transform data collected from the sensors into useful information. To evaluate model performance, a ROI analysis is presented. The intent is to show potential effects occurring by implementing a forward-looking alternative used in waste management. To evaluate the difference between the as-is process and the potential effect of a digitalized model, startup costs, project-specific costs, and strategic costs are evaluated through a cost-benefit analysis.

5 Results and discussion

The purpose of this chapter is to answer the research questions using findings found in cost analyzes and close dialogue with Tinn municipality, the renovation company inn Tinn and Sensorita. All results presented in this chapter are estimates and serve the purpose of illustrating a potential economic effect of implementing the project presented in the thesis.

5.1 Contextualized model for waste management

The goal of the model is to use recent, historical data to make precise predictions of waste patterns in households. For this to be possible, the model uses sensors. These sensors analyze each bin and send information about volume and temperature to the cloud, where further analyzes are conducted. This allows for dynamic driving routes and more efficient use of time and resources in the municipality.

The use of recent data is what distinguishes the proposed model from the preliminary model. As shown in figure 4, they are using historical data to predict waste patterns. Historical data forms the basis for the waste management plan that applies for one year and is sent out to each household by postal services. As the bins are analyzed when emptied, the data used for predictions are more recent and more accurate than historical data. The contextual model does not only allow for more efficiency in waste collection, but by using an app, the municipality can easily communicate with the customer and thus collect waste based on needs.

5.2 ROI analysis

The ROI analysis will provide the costs of implementing the Sensorita project in Tinn municipality. The costs are based on information provided from Sensorita, Tinn Municipality, and assumptions made by the project team. The calculations are available in appendix 4. Following a brief explanation of the assumptions, the result of the analysis is presented. A more detailed description of the assumptions is available in appendix 1.

5.2.1 Basis for ROI Analysis

Table 4 summarizes the assumptions made for the calculations in the ROI analysis. The costs consist of start-up costs, project-specific costs, and strategic costs. Since the product is not yet finished, Sensorita has provided estimates in relation to costs associated with the sensors to make this analysis possible. App development is based on information from Getonnet, a Norwegian digitalization agency, who estimates that the price of developing an app is on average NOK 200 000–300 000 (Getonnet, 2019).

Primarily, both project-specific- and strategic costs consist of wage-based costs. App maintenance and the Sensorita subscription are the only costs that are not based on wages. The remaining costs are assumed to have a percentage reduction throughout the project period. This is assumed due to the expectation of improvement in project flow after implementing the project. The process of waste management is expected to become more streamlined.

Table 4 Summary of the ROI analysis basis.

Start-up costs	
Sensors	NOK 75 000 per sensor. 4 trucks require 4 sensors. Up-front fee the first year of the project.
App development	NOK 300 000 cost to develop a new waste plan app the first project year.
Project-specific costs	
Sensorita subscription	Annual NOK 5 000 subscription fee to access the data and Sensorita´s platform.
IT support	Assume a full years' worth of work the first year. 10%-30%-50%-70%-80% cost reduction the following years. Based on the average wage of an IT employee (NOK 650 000).
App maintenance	Fixed yearly cost based on the initial cost of NOK 300 000. Set to 20% of said cost.
Strategic costs	
Structural changes	Based on the average wage of an IT employee (NOK 650 000). Assumed to be 50% of this wage the first year, with a 10%-30%-50%-70%-80% cost reduction the rest of the project period.
Monitoring new system	Based on average wage of a municipal manager (NOK 650 000). Assumed to be half of this the first project year, due to

	most of the responsibility lying with the renovation company. 30%-50%-70%-80%-80% reduction the following years.
Planning of digital waste plan	Half the wage of the municipal manager the first six months of year 1, reduced to 25% the remaining six months. 50%-60%-70%-80%-80% cost reduction the remaining years.
Driver adjustments	Assumed to be half the wage of an average renovation employee (NOK 450 000) the first six months of year 1, reduced to 25% the last six months. 50%-50%-70%-70%-90% reduction in costs the following years.

5.2.2 Results

In order to calculate the total cost of the project, the ROI factors presented in chapter 4.4.4 are used as a foundation. These are start-up costs, project-specific costs, and strategic costs. The highest costs are project-specific and strategic. These costs are linked to IT support and App development due to new technology, guidance, and monitoring related to the new system.

As shown in table 5, the highest cost occurs in 2022, as this is where most of the start-up costs and implementation costs occur. This is a one-time investment, and it will only be a subscription fee of NOK 5 000 every year. Based on the assumptions in table 4, the costs will be reduced every year, and by 2025 the project costs will be significantly reduced when compared to 2023. A detailed breakdown of all the costs can be found in appendix 4.

Table 5 Total project cost per year.

	2022	**2023**	**2024**	**2025**	**2026**	**2027**	**Total project cost**
Project cost per year	**NOK 2 795 068**	**NOK 1 613 259**	**NOK 1 052 803**	**NOK 530 283**	**NOK 233 592**	**NOK 200 578**	**NOK 6 425 583**

The strategic costs are the highest. These are costs related to implementation of new systems and routines. Costs related to structural changes are specifically related to the project and will therefore decrease and become insignificant at the end of the project. It will be time-consuming to incorporate new routines for waste planning, but it is a reasonable assumption that this will only be at the beginning of the project and gradually decrease. It is also presumed that there will be increased IT costs due to the implementation of the sensors, but like the other costs, these will also be reduced over time. As shown in table 5, there is an apparent reduction in costs over the project period.

The total project cost is estimated to be NOK 6 425 583. This is far less than what the municipality has budgeted for. They plan to set aside 4, 17, and 10 MNOK for investments in renovation in 2021–2024. This indicate that there is approximately 24,4 MNOK that can be invested in building a new recycling station as budgeted.

5.3 Potential savings using Sensorita

To illustrate the potential effect of implementing radar level measurement technology in Tinn municipality, the team got valuable help and data from Tinn municipality themselves, the local contact at the renovation company in Tinn and Sensorita. The findings have been reviewed in detail along with Sensorita, allowing them to ensure the quality of the findings through their experience with Asker municipality. Three different scenarios are presented to show the potential savings from implementing the Sensorita system. All numbers have been adjusted by the same wage factors as the ROI analysis and discounted into the value today.

5.3.1 Assumptions

The data used is provided directly from the renovation company in Tinn and Tinn municipality themselves. There are four trucks driving the various routes, with two trucks driving the routes at once. One is a larger truck for more populated areas of the municipality, and the other is a smaller truck for the trickier routes in the municipality. A total of three employees drive the municipal routes each week. These trucks drive a total of 32 524 kilometers annually. Total yearly costs are calculated based on total time spent emptying bins and driving. These costs will remain the basis for further years, where wage growth adjustments are made. Table 6 summarizes all assumptions used to calculate the total savings potential using Sensorita. Three different scenarios are presented to show a broader span of the savings potential.

Table 6 Summary of the model basis for calculations of the savings potential.

Wage used	The average wage of a renovation employee has been used (NOK 450 000). Assume 5 weeks' vacation, the wage has been divided by 47 weeks and then 37.5 hours to find the hourly wage of NOK 255.32.
Number of trucks and weekly distance driven	4 trucks in rotation, two trucks driving the various routes each week. 1 larger truck and 1 smaller truck. The trucks drive a total of 692 kilometers per week. 2 employees on the larger truck and 1 employee on the smaller truck.
Time to load waste bins onto trucks	It takes about 20 seconds to get the waste bin on and off the truck, with 10 seconds to empty the bin itself. Amounts to 30 seconds per waste bin emptied.
Municipal customers and number of bins	The municipality has a total of 3133 municipal customers. Each customer is assumed to have three bins emptied on average per week.
Yearly costs of driving and emptying bins	Based on the 37.5-hour work week, the 3 employees have a total work week of 112.5 work hours. 78.33 hours are spent emptying bins, while 34.18 hours are spent driving. Multiplied by the hourly wage to find the cost per week, then multiplied by 47 to find the total yearly cost.

5.3.2 Potential cost-saving results

The analysis is based on three different scenarios to give a realistic picture of possible cost savings from implementing sensors from Sensorita. The three scenarios presented are optimistic, realistic, and pessimistic. The scenarios have a cost-saving and driving distance reduction of respectively 30%, 20%, and 10% and are shown in table 7.

The total cost of the as-is process is estimated to be NOK 7 022 080. If a cost-saving of 10% is assumed, the municipality can save over half a million NOK over the period 2022–2027. Compared to the competition, 10% is a relatively small cost saving and therefore categorized as pessimistic. Sensoneo claims that their system reduces waste collection costs by at least 30%. A list of what several of Sensorita´s competitors claim to provide regarding cost reductions is provided in appendix 3. This argues that it is a realistic assumption that implementing sensors from Sensorita can contribute to saving at least 20% of the costs related to waste management. If this is shown to be correct, the municipality can save as much as NOK 1,560,462 using Sensorita as an alternative to optimizing waste management.

Table 7 Potential savings for each of the presented scenarios.

Potential savings		
Scenarios	**Cost savings**	**Driving distance saved**
Optimistic	NOK 2 340 693.51	9757 km
Realistic	NOK 1 560 462.34	6505 km
Pessimistic	NOK 780 231.17	3252 km

In figure 5, an overview of total cost savings compared to current costs is shown. The highest cost throughout the period is related to emptying the waste bins. This indicate that by making the process more effective, the costs could be reduced. A cost reduction may be a result of emptying more bins that are actually full and optimizing the waste collection routes based on the data provided by Sensorita. Driving has a significantly lower cost than emptying the bins. It is uncertain how much the reduction can be due to low population density per kilometer and many challenging roads in the municipality. However, optimizing the routes may lead to a reduction in total driving distance per week, as not all bins need to be emptied regularly.

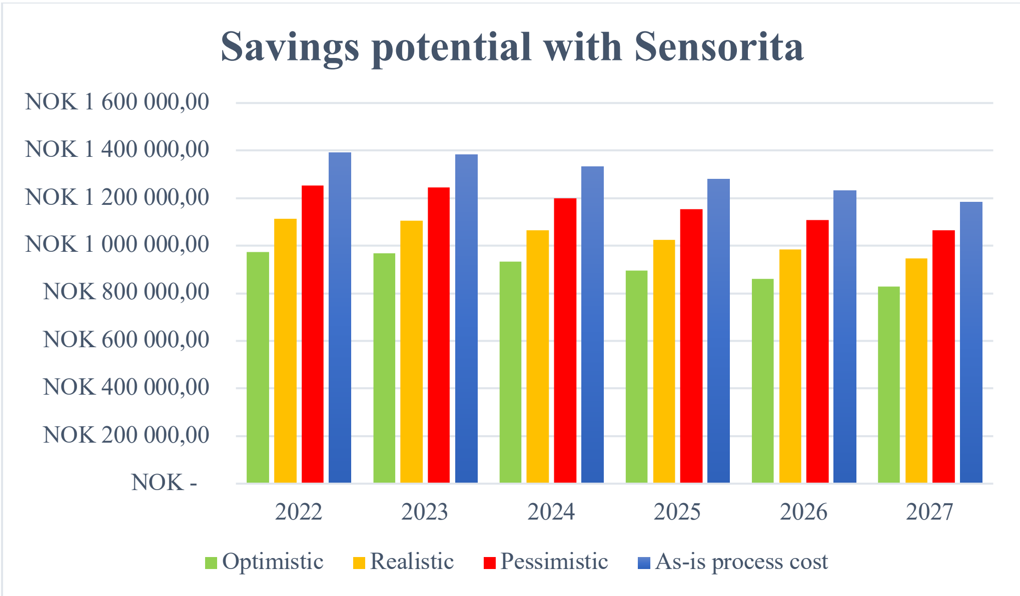

Figure 5 Calculated savings potential for each year with each scenario and as-is process included.

Through implementing radar level measurement technology in the waste collection process, there is a considerable potential for reducing costs related to waste collection in Tinn. The three scenarios are constructed to demonstrate a broader perspective of the savings potential and highlight the possibilities of the project. There are several factors and added effects that could potentially reduce the cost of the waste collection process in Tinn municipality. This is further explained in chapter 5.4.

5.4 Total costs and savings potential

The estimated project costs presented in chapter 5.2 and the potential savings presented in chapter 5.3 have been added together in order to find the total costs and savings potential. Table 8 shows the total costs and savings potential for each scenario discussed in chapter 5.3.

Tinn municipality has budgeted a total renovation cost of NOK 2 900 000 in 2021 (Tinn Municipality, 2020). Assuming this cost will remain stable from 2022–2027, the total renovation cost for Tinn municipality in this period will be NOK 16 233 500 when adjusted for prices and wage increases. This is assumed based on the fact that the waste collection routes, and the process around it has been the same for the last ten years. A total of 32 524 kilometers are driven annually to collect municipal waste in Tinn, and there are a total of 3 133 municipal clients. This amounts to an estimated cost of NOK 1 036 and 10.38 kilometers driven per municipal customer. Total project costs and investments are estimated to be NOK 6 425 583 from 2022–2027.

Three scenarios are presented when considering the total savings potential. The realistic scenario includes an 20% reduction in costs and driving distance. This reduces the cost to NOK 808 and annual driving to 8.30 kilometers per municipal customer. The total costs and savings potential are given by adding the estimated project- and waste collection costs. This is summarized in table 8. The realistic scenario presents an estimated savings potential of 22.0% when compared to what Tinn municipality has budgeted. This is close to what Sensorita´s competitors claim to save when implementing a digital waste collection system.

Table 8 Total costs and savings potential

Scenario	Total cost	Total savings potential
Optimistic	NOK 11,887,201.05	26.8%
Realistic	NOK 12,667,432.22	22.0%
Pessimistic	NOK 13,447,663.39	17.2%

5.5 Effects of the model

To look at the effects of the model, the key metrics from chapter 4.4.3 is discussed. The first two factors are cost- and time savings. Cost savings are directly tied to the potential of economic savings by implementing sensors from Sensorita. Potential time savings come due to more dynamic driving routes, which can lead to a time reduction.

Based on data collected from the sensors, Tinn Municipality can optimize their routes and make them as automated as possible. This can reduce costs and emissions due to more efficient waste collection. By making waste collection more efficient, because of the routes being planned based on need instead of assumptions, it is fair to assume that a reduction in waste costs for some households is feasible. If the waste trucks drive routes that enable them to fill up the car with enough garbage, this can help reduce the number of trips made to the recycling station. This would imply a reduction in emissions as the driving routes are planned more precisely based on waste level data.

As shown in the calculations in appendix 3, some time is set aside for scheduling the waste management plan. These costs are assumed to decline as machine learning is used to design more strategic driving routes which would reduce the time an employee has to spend on this. As drivers are provided with driving routes based on pre-determined data, the routes will allow for the emptying of waste bins that are actually full, possibly reducing the time spent emptying bins that are not.

A stable reduction in costs, as illustrated in figure 6, supports the theory presented within LEAN. Costs are expected to decrease every year as a large part of the waste management process is characterized by smart technology. Machine learning and IoT help eliminate "waste" in the production system that are be related to human activity, like planning the driving routes and collecting waste bins that are not filled to their maximum capacity yet.

Figure 6 Total project cost of the as-is process each year.

Measures that can lead to time savings make continuous improvement possible. By digitizing parts of a process, one can focus on other important parts of the process. This could result in overall process improvement as activities referred to as waste is eliminated. This would contribute to a more seamless value chain when it comes to waste management.

The last factor in the key metrics is effect. It addresses the positive effects of the model that cannot be explained by numbers. The events previously explained can trigger a chain reaction. Time-saving effects might influence the use of resources. Time spent planning driving routes can be minimized as machine learning is incorporated. This can result in a reallocation of resources to other parts of the value chain. Positive effects arising from digitalization could increase the incentive to invest and spend more time learning about the possibilities.

Technology is constantly evolving as a result of increased demand and knowledge in the field. The sensors are currently collecting data about volume and temperature. Further development of the sensors according to demands from the municipality is realistic. A request from the municipality is the ability to analyze the degree of purity and sorting in the households. If this was possible, the municipality would be able to communicate directly with their residents through the waste app, and together they could work towards common goals.

5.6 Value creation for Sensorita

As previously mentioned, this project will only look at municipal waste collection and how the process can be elevated from the process used today by exploiting digital tools and a methodology corresponding with innovation and efficiency. This could result in useful knowledge for further development.

The project team has been in close contact with the municipality to identify needs and requests, and pinpoint problems within the current process. Identified needs is presented in chapter 1.4.2. Identified problem areas in the current process give Sensorita important indications of what they should focus on further, such as the possibility to analyze the degree of purity and sorting.

A collaboration with Tinn municipality can create significant value for Sensorita. As data is collected simultaneously, the machine learning algorithm improves itself as it learns more. This could also lead to increased performance of the sensors. This make it possible to constantly have continuous improvement, making sure Sensorita is able to stay competitive.

5.7 Potential project risks

As with every project, the project comes with certain risks. It is crucial that the machine learning algorithm is properly trained, tested, and ready for deployment when the project is set to start. In order to make the driving routes more effective, the algorithm need to predict waste levels correctly. If this does not happen, one can end up in situations where some bins are emptied too often and others not often enough. This might lead to a massive backfire and criticism from the local community. Further, it can lead to added cost for the municipality, Sensorita, and the renovation company as more time is spent getting the project back on track. Extra resources may need to be used to manually override the dynamic routes and additional personnel must work to empty the overfilled waste bins. As for Senorita, increased use of time and resources to repair potential damage can occur. This might affect other projects as they are a small company.

Correct implementation of the project is key to secure success in the project. Therefore, the costs regarding project implementation are extra high the first years compared to later years in the project period. The estimates ensure that there is enough time and costs to monitor the early phases of the project correctly and allow for a seamless process flow in the future.

For the project to succeed, a certain amount of willingness to change is required from both the municipality and the renovation company. The driving routes in Tinn have been unchanged the last ten years. Changing from static waste collection routes to dynamic routes will be a fundamental change in the daily operation. If all parties involved in the project is open-minded, accept incoming changes, and show willingness for adaptation, it might increase the chances of success.

The project will affect the local population. Moving from a set, analog waste collection plan to a dynamic, digital waste collection plan might be viewed as a radical change as the waste collection process has remained unchanged for nearly a decade. The municipality must have a consistent flow of information to the public regarding changes. This would possibly make it easier for the population to embrace the changes.

5.8 How innovation is emphasized in tender processes

A part of the problem statement is to study how innovation is weighted in a tender process in smaller, rural municipalities. How municipalities value innovation is an abstract concept that varies from different municipalities. The topic was addressed during interviews with Tinn municipality and Asker municipality. Tinn emphasize and consider innovative systems with positive environmental impact. They would prefer a more costly project with greater environmental gains compared to a project that would cost less but could damage the environment more. Asker, a larger and more economically robust municipality, states that innovation is always considered. They make an effort to include innovation in their demands when considering different contractors. They do not explicitly state innovation as a demand but try to incorporate it indirectly through other requirements in the tender. The two municipalities wish to embrace digitalization and are consistently looking for projects with positive environmental impact. This demonstrates a growing consensus within the sector to further improve.

Avfall Norge addresses using non-economic criteria in a tender process. Innovation is not listed as a specific criterion in the tender process. They state that innovation is implicitly included in their criterion where the total quality of the service provided is evaluated. Increased focus on climate might indicate that alternatives, with proven positive environmental impact, should be given greater focus in a potential tender process. Sensorita´s sensors can contribute to more environmentally friendly driving by planning routes based on needs, causing elimination of unnecessary stops at households that do not need it.

6 Conclusion

In this chapter, the problem statement of the thesis will be addressed. In chapter 1.1.2 the following problem statements were presented:

- How to create a contextualized data model for process improvement in waste management?
- What are the most important criteria to measure the effects of such a model?
- How is innovation weighted in a contracting process in small, rural municipalities?

The team also created a zero hypothesis, assuming that Sensorita´s product will reduce costs and climate gas emissions compared to the current process.

6.1 Contextualized data model

In order to create a contextualized data model for process improvement within waste management, the project team found that it is important to improve areas of the process that can be classified as “waste”. These were identified through close dialogue with the municipality and made it possible to map out potential for improvement.

Parts of the process that are time-consuming have been evaluated. This is identified to be how the municipality communicates with the inhabitants and how driving routes are planned. Currently, the municipality is communicating using a waste plan sent out every year, and the driving routes are based on historical data. The proposed model incorporates sensors from Sensorita, making it possible to send recent data collected directly from the trucks when they are emptying bins. This make it possible to create more dynamic driving routes as the predictions are more precise. It is also recommended to use an app to communicate with the households making it possible to change the waste management plan based on needs and not pre-determined routes.

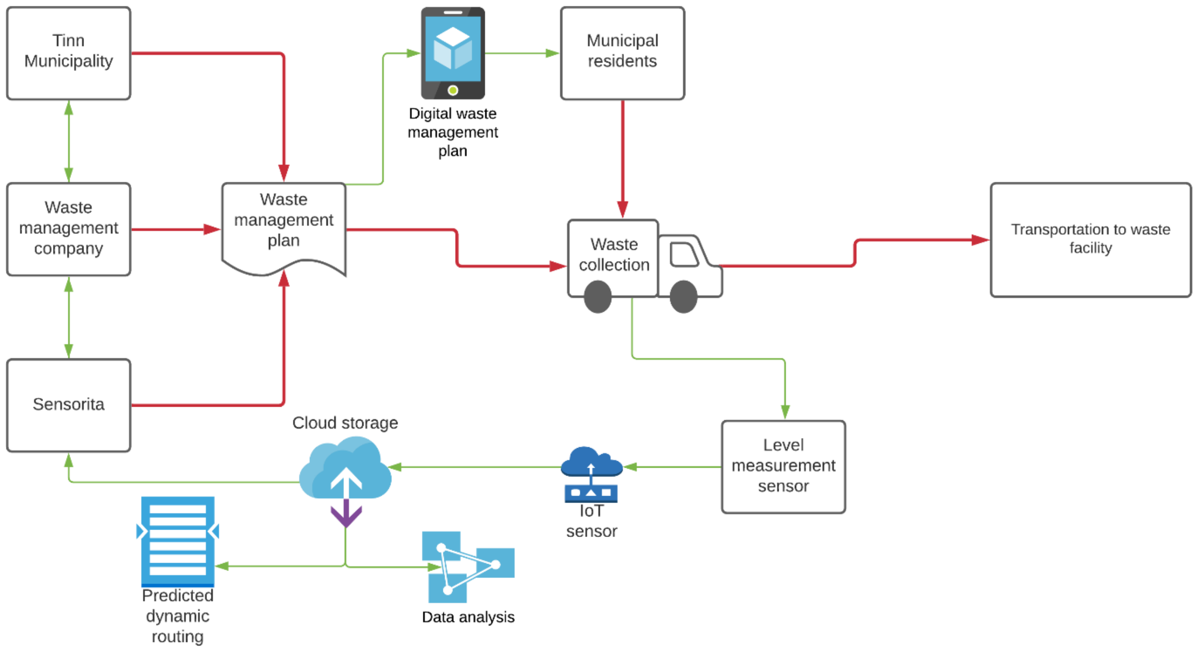

Figure 7. The proposed new process flow with the implementation of Sensorita's product.

In addition to this, it is essential to make the model measurable. The data collected is converted into quantifiable information. This makes it possible to do analysis based on recent data and ensure continuous improvement in the waste management process. The analysis makes it possible to easily map the current process to see if there has been improvement, but also discover new potential for development within the waste management process.

6.2 Key criteria to measure the effects of the model

When conducting a ROI analysis in order to measure the effects of the contextualized model, there are three important criteria to look. These are presented in the key metrics in chapter 4.4.3. The three factors are cost savings, time savings and effect. All these factors will give indications of how the contextualized model is working.

Cost savings are directly tied to the potential of economic savings by implementing sensors from Sensorita. In this case, Tinn municipality can save NOK 1 560 462 by using Sensorita as an alternative to optimize the waste management when assumed that the sensors can contribute to a cost saving of 20%.

Time savings concerns how much time Tinn municipality can save by using sensors from Sensorita. More dynamic driving routes can lead to time reduction from a managerial point of view as the sensors use machine learning to learn and grow independently, leaving human intervention excluded from the learning process. Using sensors could also lead to more efficient time use by emptying bins that are actually full instead of spending time emptying bins that are not.

The last factor in the key metrics is effect, and it addresses the positive effects of the model that cannot be explained by numbers. As a result of implementing sensors, cost savings can lead to a new cost strategy, meaning that the municipality can spend the money on other areas that may need it more. Time savings can improve resource allocation by digitizing parts of a process, and it is possible to shift focus to other important parts of the process.

6.3 Innovation in a tender process

Tinn municipality has a desire to transition towards becoming a modern and digitalized municipality. This means that innovation is something they value quite highly when considering potential new projects. Digitalizing the waste collection process can be a steppingstone for Tinn to digitalize other organizational processes. An ambition to become more digitalized is confirmed through close cooperation and conversation with Tinn.

This goal of modernization and digitalization is shared by Asker municipality. They continuously search for more innovative alternatives for their municipality, and they incorporate innovation indirectly through their requirements in the tender process. It is difficult for municipalities to demand a more innovative solution directly, as innovation can come in many forms. This means that it is crucial that the municipalities are thorough in the tender process and set their requirements correctly based on their current needs and aspirations.

In order to define the right needs, it is essential that the municipality evaluate the as-is process and look for areas that can be improved and how this can be achieved. Tinn need to specify, in their requirements, that they are looking for a system that can digitize the waste collection, thus encouraging innovation indirectly from the supplier and themselves. It is vital to have communication with various suppliers when the aim is to develop an innovative process together. In this case, it would require a close relationship between Tinn municipality, the renovation company, and Sensorita.

For Sensorita to compete in tender processes, they need a municipality that want to make the waste collection more efficient and wish to use level measurement to achieve this. Having sensors on the trucks rather than in the lid of the bins is one of their advantages in the market. This is a way for them to differentiate themselves from their competition. As they are a relatively new start-up company and have an ongoing pilot project in Asker, it would be wise to look to smaller municipalities when pursuing to secure a new contract. This can enable them to use what they have learned in Asker in a smaller municipality. They also need to participate in innovative tender competitions to grow as a company. Municipalities must demand that data regarding municipal waste is collected in order for companies, such as Sensorita, to be competitive in a tender process. Sensorita also need documented results to be competitive in a tender process. This means that they need to further build upon their existing pilot project and initiate new pilot projects in other municipalities.

6.4 Reduction of costs and climate gas emissions

Looking at the cost analysis and information acquired through Sensorita and their competitors, it is reasonable to expect a reduction in both costs and climate gas emissions. However, this depends on several factors. Based on the calculations done in chapter 5.3.2, all scenarios provide significant cost savings for the municipality. These calculations are meant to illustrate the example of potential savings by transitioning to a digital waste collection system, and the actual cost savings may vary. However, based on the information provided by Sensorita and information available from their competitors, it seems highly likely that the new system will make the waste collection process more time and cost-efficient. The realistic scenario shows a savings potential of 22% when compared to the as-is process and the budget in Tinn municipality.

To ensure that the cost reductions are realistic, it is critical that the waste collection system is implemented correctly. This could require additional resources like IT support, more follow-up from the management, increased monitoring of the new process, and adjustments to the new workflow for the employees. In the cost analysis, this is the main reasoning for the high costs the first few years of the project. In addition to implementation, both the municipality and the renovation company must embrace the changes being made to their existing process.

In the economic plan for 2021–2024, Tinn has budgeted roughly 31 MNOK for future investments within renovation and waste management. The economic five-year scope of the Sensorita project fits well within the economic boundaries that Tinn has set.

The reduction of climate gas emissions is difficult to determine based on the data provided. It is assumed that the digital waste collection system will reduce emissions. This is based on information from Sensorita and their competitors. A reduction be a result of emptying more bins and collecting more waste using dynamic routes. This means fewer stops and unnecessary trips to bins that have not reached their capacity. Reorganizing the routes to become more efficient may also reduce the total amount of kilometers driven per year. The waste management employees currently drive approximately 32 000 kilometers per year, spread across the four waste trucks in rotation. To get a more accurate measurement of the potential environmental benefits, a pilot testing of the project is necessary.

Similar to the expected cost savings, a reduction in climate gas emissions also depends on the correct implementation of the process. Additionally, it is crucial that the machine learning algorithm provided by Sensorita is adequately trained and can predict waste levels correctly. Wrongful predictions may lead to false predictions about whether a bin is full or not. This can lead to increased driving instead. This could also lead to frustration within the workforce and the municipal residents, potentially leading them to lose belief and distrust the project.

7 Recommendations for further work

In this thesis, the project group has developed a contextualized model for process improvement and evaluated the effects based on specific criteria of implementing sensors in waste management. How innovation is weighted in a tender is also discussed in some detail. Based on this study, these are our recommendations for further work:

- How should the municipalities implement sensors in waste management?
- Test sensors in a smaller municipality, and actually measure and evaluate the effects
- Test the sensor in areas with dense population
- Analyze whether cost per capita will pay off if the sensors are used to track waste levels for each household
- Investigate whether gamification of recycling is relevant to get the population to contribute more. This could increase the incentive to recycle

As for Sensorita, the project group recommends starting more pilot projects in order to gather more data and experience. In this way, they can build a solid foundation for further development of the machine learning algorithm. This could, in addition, strengthen their position in a potential tender. Sensorita should also look at how AI can automate both driving routes and the waste plan. They should also look at analyzing weight as this is something many of their competitors already offer. This could help strengthen their position in the market. In relation to the current situation, Sensorita should focus on collecting more data, verifying the technology they are using, document savings and learn from the process.

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Appendix

1. Basis for the ROI analysis further explained

The projects startup costs consist of two main costs: waste level measurement sensors and development of an application for the waste plan. Sensorita have provided prices directly for the analysis. The price of one sensor is NOK 75 000. Tinn municipality wishes to develop an app that can provide the residents with a digital waste plan. App development is based on information from *Getonnet*, a Norwegian digitalization agency, who estimate that the price of developing an app is on average NOK 200 000–300 000 (Getonnet, 2019). NOK 300 000 has been used for this project, and this will be a flat fee the first year of the project. Hardware and software upgrade costs have been considered, but later disregarded. This is due to the hardware cost being something that can be included in the tender process, and the software cost lies on Tinn Municipality as a whole, not solely on this project.

Project specific costs are tied to a subscription fee from Sensorita, increased IT support and maintenance of the new waste plan application. Sensorita have set a price of NOK 25 000 over the five-year period, meaning an annual fee of NOK 5 000. IT support is based on the average wage of an average IT employee. This is set to NOK 650 000 per year (ProDataConsult, 2020). We assume that IT support will be a full-time job the first year, with the amount of work diminishing over the project period. Maintenance of the app is set to a fixed percentage of the initial app development cost (Empatix, 2016). App maintenance is estimated to be 20% of the initial app cost.

The strategic costs are costs that arise when the project causes strategic changes. Structural changes are costs that occur when the work force needs to be shifted internally to successfully implement the project. This is assumed to be mainly IT support and is based on half of the IT support wage of NOK 650 000. The cost will decrease throughout the project period as the need for increased IT support is assumed to be reduced. There will also be an increased workload in the form of monitoring the new system in place. This cost is based on wage statistics from *The Norwegian Association of Local and Regional Authorities* for male and female managers in the public sector, and is set to NOK 650 000 per year (KS, 2021). The cost is set to half of this wage the first year with a percentage-based reduction through the project period. This is done as most of the maintenance of the new system will be performed by the contracted renovator. The same wage is used to find the cost of planning and monitoring the new waste plan. Based on this managerial wage, it is assumed that the cost will be half of the managerial wage the first six months, be halved once again the last six months to 25% of the wage. This is due to the data provided by the sensors should create a stable waste plan the first six months of the project. Again, the cost will be assumed reduced over the 5-year course of the project. Adjustments to the driver's daily routine is the last post of the strategic costs. The average wage of a Norwegian waste management employee has been used. This is NOK 450 000 per year and is backed up by the *Norwegian Union of Municipal and General Employees* (Utdanning.no, 2019). Just as the cost for the planning of the waste plan, the cost is assumed to be half of this wage the first six months and halved again for the remained of the year. A reduction throughout the project period is also expected as the drivers get more adjusted to their new daily routines.

2. Basis for the savings used the Sensorita system further explained

The data regarding Tinn municipality and the daily as-is routine of the waste management provider in the municipality is provided directly from the two parties. Tinn has a total of 3133 municipal customers that require waste collection. The team assumes there are 3 bins being emptied at each stop on average throughout the year. The cost of the as-is process is primarily based on two things: The cost of driving when collecting the waste and the cost of emptying the bins themselves. This is all based on the average wage of NOK 450 000 per year. Assuming the employees have 5 weeks of vacation, the wage is divided by 47, giving a weekly wage of NOK 9 574.74 and an hourly wage of NOK 255.32. A work week of 37.5 hours is also assumed. One is a larger truck for the more populated areas of the municipality, and the other is a smaller truck for the trickier routes in the municipality. A total of three employees drive the municipal routes each week. The two trucks combined drive a total of approximately 692 kilometers per week. Two employees are on the larger truck, and one employee operating the smaller one. This leaves a total work time of 112.5 hours each week. It takes 30 seconds to empty one bin, meaning that it 78.33 hours is spent each week emptying the waste bins. This leaves 34.18 hours for driving each week. Combining these numbers with the hourly wage, the yearly cost of driving is NOK 314 119.15 and the yearly cost of emptying bins being NOK 719 923.40, leaving a total yearly cost of the as-is process today to be NOK 1 006 097.87, after adjusting for wage factors in 2022.

3. Cost savings based on Sensorita's competitors

Company	Country	Savings potential
Nordsense	Denmark	80% Reduction of overflowing waste (Nordsense, n.d.)
BrainyBins (Maacks)	Denmark	60% Reduced CO2 usage (Maacks, n.d.)
Wastehero	Denmark	Up to 50% reduction of costs in waste collection (WasteHero, 2020)
Sensoneo	Slovakia	Cost reduction up to 30% and carbon emission reduction up to 60% (in cities) (Sensoneo, 2021)
BrighterBins	Belgium	Save up to 50% on waste collection (BirghterBins, n.d.)
Enevo	Finland	61% fewer miles to collect each ton, reducing lifts and time on site per ton by 79%. 51% increase in average tons per dump. 28% reduction in waste costs for a large doughnut franchise (Enevo, 2021)

4. Calculations

As-is process	
Amount of trucks	4
Employees on the trucks	3
Driving distance per week	350km and 342km
Wage	NOK 450,000.00
Weekly wage	NOK 9,574.47
Work time	06.00-14.00
Hourly wage	NOK 255.32
Total number of municipal clients	3133
Time to empty 1 bin	30 seconds
Total number of bins	9399
Hours used to empty bins each week	78.33
Time spent driving each week	34.18
Yearly driving cost	NOK 410,100.00
Yearly bin cost	NOK 939,900.00
Yearly driving distance (in km)	32524

Data used in calculating the as-is process cost

	2022	2023	2024	2025	2026	2027	Total cost
As-is process cost	NOK 1,391,850.00	NOK 1,382,481.78	NOK 1,331,883.09	NOK 1,280,656.82	NOK 1,231,400.79	NOK 1,184,039.22	**NOK 7,802,311.69**
Optimistic	NOK 974,295.00	NOK 967,737.25	NOK 932,318.16	NOK 896,459.77	NOK 861,980.55	NOK 828,827.45	**NOK 5,461,618.18**
Realistic	NOK 1,113,480.00	NOK 1,105,985.42	NOK 1,065,506.47	NOK 1,024,525.45	NOK 985,120.63	NOK 947,231.37	**NOK 6,241,849.35**
Pessimistic	NOK 1,252,665.00	NOK 1,244,233.60	NOK 1,198,694.78	NOK 1,152,591.14	NOK 1,108,260.71	NOK 1,065,635.30	**NOK 7,022,080.52**

Savings potential using Sensorita compared to the as-is process.

ROI Analysis

	2022	2023	2024	2025	2026	2027		
Startup costs								
Sensors	NOK 305,400.00	NOK -	NOK -	NOK -	NOK -	NOK -	**NOK 305,400**	
Software upgrades	NOK -	NOK -	NOK -	NOK -	NOK -	NOK -	**NOK -**	
Hardware upgrades	NOK -	NOK -	NOK -	NOK -	NOK -	NOK -	**NOK -**	
App development	NOK 305,400.00	NOK -	NOK -	NOK -	NOK -	NOK -	**NOK 305,400**	
Project Specific costs								
Sensorita subscription	NOK 5,155.00	NOK 4,552.48	NOK 3,987.15	NOK 3,450.42	NOK 2,949.07	NOK 2,481.19	**NOK 22,575**	
IT Support	NOK 670,150.00	NOK 599,075.44	NOK 401,285.28	NOK 184,613.54	NOK 48,999.52	NOK 41,682.97	**NOK 1,945,807**	
App maintenance	NOK -	NOK 59,787.92	NOK 57,544.86	NOK 55,440.20	NOK 53,307.88	NOK 51,257.58	**NOK 277,338**	
Strategic Costs								
Structural changes	NOK 325,000.00	NOK 281,250.00	NOK 182,022.00	NOK 80,908.45	NOK 20,748.26	NOK 17,052.90	**NOK 906,982**	
Monitoring new system	NOK 335,075.00	NOK 232,973.78	NOK 111,468.13	NOK 30,768.92	NOK 5,444.39	NOK 926.30	**NOK 716,657**	
Planning of waste plan	NOK 502,612.50	NOK 249,614.77	NOK 192,383.11	NOK 138,737.82	NOK 88,934.50	NOK 85,513.94	**NOK 1,257,797**	
Driver adjustments	NOK 346,275.00	NOK 186,005.08	NOK 104,112.25	NOK 36,363.31	NOK 13,208.65	NOK 1,663.28	**NOK 687,628**	
Project cost per year	**NOK 2,795,068**	**NOK 1,613,259**	**NOK 1,052,803**	**NOK 530,283**	**NOK 233,592**	**NOK 200,578**	NOK 6,425,583	**Total project cost**

All calculations from the ROI Analysis

5. Interview guide Tinn Municipality

Generelt

1. Hvilken tilknytning har du til avfallshåndteringen i Tinn Kommune?
2. Hvor lang tid bruker dere på å lage kjøreplan for innhenting av søppel?
3. Hva anser du som mest utfordrende ved innhentinga avfall?
4. Hva er det viktigste å tenke på ved innhenting av avfall?
5. Hvilke forbedringspotensialet har dere ved innhenting av avfall?

Hoveddel

6. Er prosessen for utarbeidelse av kjøreplan tidkrevende?
7. Hvilke steg inngår i utarbeidelse av kjørerutiner?
8. Tror du at en mer digitalisert løsning (Eks. Sensorita) vil gjøre din og arbeiderne sin hverdag enklere?
    a. Hvorfor?
9. Dersom dere skulle vurdert en mer fremtidsrettet løsning, hvilke krav er viktig at det oppfyller?
10. Har dere vurdert noen slike løsninger tidligere?
    a. Hvis nei, hvorfor ikke? Hvis ja, hvorfor akkurat den/de?

Avsluttende

11. Hvordan tror du fremtiden til avfallshåndteringen i Tinn Kommune vil se ut dersom dere benytter en mer digitalisert løsning?
12. Hva tror du skal til for å lykkes ved implementering av en slik løsning som Sensorita har å tilby?
13. Hva er målet deres med tanke på avfallshåndtering de kommende årene?
    a. Mer digitalisert?
14. Hvordan skal dere forbedre dere?
15. Tror du at du Tinn Kommune har behov for å fokusere mer på digitale løsninger?
16. Tror du det kommer til å skje store endringer i fokuset til Tinn Kommune med tanke på innovasjon og digitalisering?

6. Interview guide Asker Municipality

Generelt

1. Hvilken tilknytning har du til anbudsprosessen i Asker Kommune?
2. Hvor lang tid bruker dere på å utarbeide et anbud?
3. Hva anser du som de viktigste punktene i et anbud?
4. Hva er fordelene ved anbud?
5. Hvilke utfordringer møter dere i en anbudsprosess?

Hoveddel

6. Hvor mye vektlegger dere innovasjon i et anbud?
7. Med tanke på innovasjon, hva er det viktigst at aktørene fokuserer på?
8. Tror du innovasjon vil bli et større fokus fremover?
9. Tror du at mer fokus på innovasjon vil øke konkurransen blant aktørene?
10. Hvilke andre krav enn innovasjon tror du vil bli viktige fremover?

Avsluttende

11. Hva er avgjørende for at dere velger om dere skal håndtere renovasjon selv eller velge en ekstern part?
12. Hvilke fordeler/ulemper ser du ved å håndtere renovasjon selv?
13. Hvilke fordeler/ulemper ser du ved å bruke en tredjepart?
14. Ser dere til andre kommuner når dere velger hvilken løsning dere går for?
15. Hvordan kan anbudsprosessen forbedres for å bedre ivareta de ikke-økonomiske faktorene i en beslutningsprosess?

7. Consent form

Vil du delta i forskningsprosjektet

«Digitalisering av avfallsinnhenting i Tinn Kommune – En casestudie»

Dette er et spørsmål til deg om å delta i et forskningsprosjekt hvor formålet er å gjennomføre en case studie rundt Tinn kommune hvor hensikten er å komme frem til en lavterskel «lean» metodikk for å digitalisere renovasjon sektoren i distrikts-Norge. I dette skrivet gir vi deg informasjon om målene for prosjektet og hva deltakelse vil innebære for deg.

Formål

Hensikten med masteroppgaven er å kartlegge dagens rutine og videre kartlegge effekten av digitalisering av kommunal avfallshåndtering. Gjennom et vellykket prosjekt kan gruppen bidra til å kickstarte digitaliseringsprosjektet i Tinn Kommune. I tillegg håper vi at casestudien vil bidra med verdifull informasjon og viktige erfaringer til Sensorita slik at de kan fortsette å utvikle seg som selskap.

Hvem er ansvarlig for forskningsprosjektet?

NMBU, Norges miljø- og biovitenskapelige universitet, er ansvarlig for prosjektet.

Hvorfor får du spørsmål om å delta?

Vi ønsker å komme i kontakt med personer som sitter med kunnskap om avfallshåndtering, samt personer som har kunnskap om relevante temaer innenfor vår oppgave som industri 4.0, sirkulær økonomi, anbudsprosess, innovasjon mm.

Hva innebærer det for deg å delta?

Vi ønsker å gjennomføre et personlig intervju med deg der vi stiller spørsmål knyttet til ditt yrke og kompetanse. Intervjuet vil vare i ca 30-60 minutter. Det er ønskelig å ta lydopptak av intervjuet der hensikten er at transkriberingen skal være så korrekt som mulig. Du vil få tilsendt dette i forkant slik at du kan godkjenne eller komme med eventuelle kommentarer før det eventuelt brukes i oppgaven.

Det er frivillig å delta

Det er frivillig å delta i prosjektet. Hvis du velger å delta, kan du når som helst trekke samtykket tilbake uten å oppgi noen grunn. Alle dine personopplysninger vil da bli slettet. Det vil ikke ha noen negative konsekvenser for deg hvis du ikke vil delta eller senere velger å trekke deg.

Ditt personvern – hvordan vi oppbevarer og bruker dine opplysninger

Vi vil bare bruke opplysningene om deg til formålene vi har fortalt om i dette skrivet. Vi behandler opplysningene konfidensielt og i samsvar med personvernregelverket.

- Det vil kun være prosjekteiere som har tilgang på lydopptak fra intervju
- Veileder vil ikke ha tilgang på lydopptakene, kun informasjonen som blir brukt i oppgaven.
- Intervjufilene vil lagres kryptert på en lokal server.

Du vil kunne gjenkjennes i oppgaven ut ifra informasjonen vi samler inn. I oppgaven kommer vi til å bruke navn, yrke og faglig kompetanse.

Hva skjer med opplysningene dine når vi avslutter forskningsprosjektet?

Opplysningene anonymiseres når prosjektet avsluttes/oppgaven er godkjent, noe som etter planen er 01.06.2021. Lydopptaket vil slettes ved prosjektslutt.

Dine rettigheter

Så lenge du kan identifiseres i datamaterialet, har du rett til:

- innsyn i hvilke personopplysninger som er registrert om deg, og å få utlevert en kopi av opplysningene,
- å få rettet personopplysninger om deg,
- å få slettet personopplysninger om deg, og
- å sende klage til Datatilsynet om behandlingen av dine personopplysninger.

Hva gir oss rett til å behandle personopplysninger om deg?

Vi behandler opplysninger om deg basert på ditt samtykke.

På oppdrag fra Norges miljø- og biovitenskapelige universitet har NSD – Norsk senter for forskningsdata AS vurdert at behandlingen av personopplysninger i dette prosjektet er i samsvar med personvernregelverket.

Hvor kan jeg finne ut mer?

Hvis du har spørsmål til studien, eller ønsker å benytte deg av dine rettigheter, ta kontakt med:

- Norges miljø- og biovitenskapelige universitet ved Kristian Omberg (kristian.omberg@nmbu.no), Jørgen Rekdal Mangelrød (jorgen.rekdal.mangelrod@nmbu.no) eller Pia Zcimarzceck (pia.zcimarzceck@nmbu.no)
- Vårt personvernombud: Hanne Pernille Gulbrandsen, personvernombud@nmbu.no
- Hvis du har spørsmål knyttet til NSD sin vurdering av prosjektet, kan du ta kontakt med:
- NSD – Norsk senter for forskningsdata AS på epost (personverntjenester@nsd.no) eller på telefon: 55 58 21 17.

Med vennlig hilsen

Kristian Sørby Omberg (Forsker/veileder) Jørgen Rekdal Mangelrød/Pia Zcimarzceck

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Samtykkeerklæring

Jeg har mottatt og forstått informasjon om prosjektet *[sett inn tittel]*, og har fått anledning til å stille spørsmål. Jeg samtykker til:

☐ å delta i personlig intervju

☐ at intervjuet tas opp (lydopptak)

Jeg samtykker til at mine opplysninger behandles frem til prosjektet er avsluttet

Norges miljø- og biovitenskapelige universitet
Noregs miljø- og biovitskapelege universitet
Norwegian University of Life Sciences

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