Supuni Fernando

Turning Waste into Value: A Conceptual AI-Supported Model to Promote Circular Economy Participation in Vaasa and Its Potential for International Application.

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Author: Supuni Fernando
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ABSTRACT:

This research examines the role of AI-based, incentive-enabled digital solutions in supporting participation in municipal waste management and circular economy (CE) activities, particularly for immigrants and the long-term unemployed in Vaasa, Finland. Although the municipality has advanced waste management systems, participation is unequal and reveals structural barriers to engagement. A qualitative case study methodology was utilized, based on semi-structured interviews with institutional stakeholders in the fields of waste management, regional development, and the circular economy (CE). The results show that the barriers to participation are primary structural rather than motivational and include issues with the flow of communication, the accessibility of information, the limited availability of engaging and adaptive digital solutions, and the fragmentation across CE ecosystem. Using the Technology Acceptance Model (TAM) and the Theory of Planned Behavior (TPB), the study outlines a conceptual AI-supported engagement model focusing on multilingual digital facilitation, behavioral incentives, and ecosystem coordination. Although the model has not been empirically tested, it provides a framework to show how digital tools can increase the perceived benefits, ease of use, and behavioral control of the user, and in this way, can promote greater participation. The research contributes to CE scholarship by emphasizing inclusive participation and the integration of behavioral and technological perspectives. Although context-specific, the results imply potential relevance for other urban areas experiencing similar participation issues.

KEYWORDS: Circular Economy, Waste Management, Digital Engagement, Social Inclusion

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Abbreviations

AI	**Artificial Intelligence**
CE	**Circular Economy**
DRS	**Deposit Refund Schemes**
EU	**European Union**
PAYT	**Pay As You Throw**
RVMs	**Recycle Vending Machines**
SE	**Sharing Economy**
TAM	**Technology Acceptance Model**
TPB	**Theory of planned behavior**

1. Introduction

The rapid growth of the global population has driven a parallel increase in production and consumption, which has in turn accelerated waste generation. On a global scale, municipal solid waste (MSW) is expected to grow from 2.01 billion tons in 2016 to 3.40 billion tons in 2050, with urbanization expected to make up nearly 70% of this increase (Kubanza, 2024; Liu et al., 2025). Under the traditional linear economic structure, resources use follows a take-make-dispose framework. This means limited consideration is given to manage waste after products have been used (Claudio‐Quiroga & Poza, 2024). The result is a vast amount of waste that is directed to landfills and subsequently destroyed, which causes severe environmental degradation, greenhouse gas emissions, and public health risks (Liu et al., 2025; Hossain et al., 2024). This is highly critical for low- and middle-income countries, where the limited existing infrastructure combined with financial constraints, leads to waste collection efficiency being less than half of high-income countries (Kubanza, 2024). Although waste sorting has been introduced, many systems are still based on linear disposal which greatly reduces the effectiveness of this intervention (Kihila et al., 2021).

Addressing these issues, a rising number of countries are turning to the Circular Economy (CE) model instead of the linear model. The CE focuses on the reuse, repair, recycling, and recovery of materials ensuring they are recirculated to the economy instead of disposed of in landfills (Dey et al., 2022). Apart from minimizing the challenge to the environment caused by the accumulation of waste, this model also provides economic opportunities through the creation of new jobs, increased competition, and financial advantages (Dey et al., 2022). Although the concept dates back several decades, the importance of CE has grown in recent years due to increasing challenges in sustainability such as resource scarcity, ecosystem degradation, as well as climate change (Negrete-Cardoso et al., 2021). Currently, CE has gained growing recognition as a sustainable development approach that enhances macroeconomic and environmental sustainability while decoupling economic growth from resource utilization (Bodislav et al., 2025). The adoption of CE differs from nation to nation: Developed countries are advancing much

quicker due to stronger infrastructure and financial capabilities but, both developing and underdeveloped countries face challenges such as limited finance and resource availability, inadequate infrastructure, as well as policy restrictions (Claudio‐Quiroga & Poza, 2024; Negrete-Cardoso et al., 2021). Most European Union (EU) member states, as well as Iceland, have made significant regulatory progress, such as stricter regulations and limitations on landfilling and incineration in several member states (Ögmundarson et al., 2022). In contrast, a lot of developing countries still struggle to adopt basic waste segregation systems. This illustrates the disparity, along with the potential and challenges of CE in achieving a sustainable future.

The EU has emerged as one of the leading regions adopting the CE among the global regions. The EU has implemented the CE Action Plan and the European Green Deal which aim to reduce waste, promote the sustainable use of resources, and achieve carbon neutrality by the year 2050 (Belle et al., 2024; Bodislav et al., 2025; Hossain et al., 2024). These policies are a systematic response to manage decoupled economic growth from resource consumption, which positions the EU to align with the United Nations Sustainable Development Goals (Liu et al., 2025). One of the Western European countries, Germany is at the forefront of practicing a CE, particularly in the recycling of fiber-based materials, due to both domestic and international support (Belle et al., 2024). The EU's strategy also focuses on the involvement of small and medium-sized enterprises (SMEs) in Decarbonization of the Value Chain, highlighting the need for broad cross-sectional and multilevel participation (Dey et al., 2022). Despite these advances, there is still an uneven distribution of progress among member states. Previous studies indicate that while a portion of Europe is adhering with CE model, other parts of Europe are struggling due to technological capacity, infrastructure, and policy alignments (Claudio‐Quiroga & Poza, 2024). To address the issue, the European Commission has implemented monitoring frameworks with indicators of production, secondary raw materials, waste management, and innovation performance (Negrete-Cardoso et al., 2021). Fundamentally, the EU's approach stands as an example that coordinated policy frameworks and monitoring systems could resolve the issue of transitioning from a linear to CE. In addition, there is a need for one integrated policy across other member states which are still

striving to achieve these goals, invest in digitalization, and greater inter-state collaboration (Bodislav et al., 2025).

Among the members of the EU, Finland is regarded as one of the fastest adopters to adopt the CE concept. The government of Finland, has published the Carbon Neutral Finland 2035 target and SITRA's CE Roadmap, showcasing the country's obligation to achieve long-term systemic change (The Finnish Innovation Fund Sitra, 2024; State Treasury Republic of Finland, n.d.). Finland actively integrates the "5Rs"—reduce, reuse, recycle, recovery, and repair within its waste management framework as fundamental principles of sustainable waste management (Abila & Kantola, 2019). Financial incentives such as "Pay-As-You-Throw" (PAYT) systems and deposit return schemes for beverage containers also encourage the participation of household recycling (Abila & Kantola, 2019). Despite these efforts, the country is still struggling with challenges. Finland has been able to recycle only around 41% of its municipal waste, which is far behind the expected EU average of 65% by 2030 (Abila & Kantola, 2019). This emphasizes that, there is still a significant degree of progress needed for Finland to be more representative of the "global frontrunner" title. In addition to this, Finland shares the unique attribute of being a CE enthusiast with Austria and the UK but to achieve these aspirations, there is a high requirement of more coherent policy framework (Claudio‐Quiroga & Poza, 2024).

The following study is based on Vaasa, one of the multicultural cities in Finland, where represents both possibilities and obstacles in the integration of CE approaches. Vaasa is a midsized city in the Ostrobothnia region of western Finland. Currently, the city has a population of about 70,000 residents. This growth has contributed to increasing cultural diversity within the city. In the Vaasa region, the employment outlook is one of the best in Finland. However, there are still socially excluded groups such as immigrants, and the long-term unemployed individuals remain disproportionately affected by unemployment (City of Vaasa, 2025). Vaasa operates within Finland's highly developed recycling system, which demonstrates strong national performance in material recovery. In Finland, over 2.3 billion bottle and can returns were recorded as a record in a single year, reflecting high levels of material recovery (YLE, 2015; Finland.fi, n.d.). Even with this sophisticated system, differences in participation remain, especially among marginalized

groups who either lack the incentive or encounter systemic obstacles to sorting waste. Vaasa's unique blend of technological readiness, economic engagement, and social mix makes it particularly a relevant case for studying the potential of Artificial Intelligence (AI)-based, incentive-driven digital tools to boost engagement in CE practices.

Immigrants form an increasingly significant proportion of Vaasa's population, which in turn developing the challenge for education and employment opportunities (City of Vaasa, 2024). On the other hand, the city records one of the highest unemployment rates in Finland (City of Vaasa, 2025), which makes it important from the perspective of studying waste participation in combining with social inclusion. Moreover, Vaasa is home to the public waste management company Stormossen, which is playing crucial role in the processes of waste collection, sorting, and recycling. Although Stormossen supports the collection and sorting of waste and tries to raise awareness and incentivizes participation, most of their actions are processed manually, by limiting the scale of engagement effectively. Based on this gap, there is an opportunity that digital tools can offer new avenues of reaching communities in a more meaningful manner. In addition, the unemployed immigrant population is often culturally and linguistically marginalized, which limits their active participation in waste sorting. As noted in earlier works, a lack of proper waste management in communities can lead to environmental damage and pose health risks to the public (Kubanza, 2024). In Finland, households are actively involved in the management of municipal solid waste by delivering recyclable materials, including plastic bottles, glass, and cans, to specially designed collection systems, which are supported by property owners and municipalities (Abila & Kantola, 2019). However, despite the city's reputation as the "Energy city in Finland" and available infrastructure, involvement in waste collection and sorting can differ among various demographic groups, and viewpoints from stakeholders indicate that specific populations, like immigrants, might encounter obstacles to complete participation.

1.1 Problem statement

Due to the rapidly integration of technology into daily life, distributing leaflets or arranging awareness campaigns like traditional approaches will not be sufficient to make a behavioral change in waste management specially to the immigrants who are coming from

different social and cultural backgrounds. This challenge is more evident in Vaasa, where immigrants and unemployed internationals usually remain underrepresented in waste sorting and collecting, despite the city having sufficient infrastructure. As has been previously identified, waste can be considered a resource and recycling drivers like monetary motivation, convenience, and proximity to facilities can play an essential role in influencing their respective behavior (Iqbal et al., 2022; Abila & Kantola, 2019). In Finland, households already play a pivotal role in municipal solid waste through reverse vending machines and kerbside sorting of municipal solid waste, and there is evidence that small monetary incentives can influence recycling behavior in favor (Abila & Kantola, 2019). According to previous studies, although recycling mechanisms exist for materials such as glass and tetra packs, participation rates remain only moderately above average, indicating opportunities to further increase public engagement (Abila & Kantola, 2019). However, this study does not provide empirical data that would show differences in participation across certain demographic groups. Instead, based on stakeholder perspectives, it is suggested that some groups, such as immigrants and unemployed, are believed to have obstacles to fully participating in waste sorting.

One possible way to address these gaps is through the conceptual use of AI-driven applications, which may offer digital access and encourage participation through incentive-based mechanisms. This could be a more transparent way of sorting waste and may even be an economic boost to the marginalized communities. Due to its technological readiness and the diversity of the population, Vaasa will provide a relevant environment to explore the applicability of this concept. The suggested model, although locally oriented, may have potential for adaptation in other contexts with similar challenges, especially in environments encountering comparable issues. Nonetheless, it is important to note that this research does not empirically evaluate the implementation or outcomes of the proposed AI-driven model, and the anticipated advantages are grounded in theoretical reasoning and stakeholder viewpoints rather than empirical evidence.

1.2 Research gap

The study of waste management has discussed the collection systems, sorting efficiency, and optimization of recycling logistics in significant amounts, focusing less on

behavioural participation but on the operational component of waste management (Abila & Kantola, 2019). Researchers have also recognized that waste can be regarded as a resource which can be used to meet national sustainability and greenhouse gas reduction goals (Iqbal et al., 2022). Though, the studies emphasize the need to enhance the efficiency of systems and to recover the resources but rarely cover the role of engagement and motivation of citizens in the effectiveness of waste management systems.

Besides, the waste hierarchy system categorizes management alternatives according to the environmental, social, and economic advantages (Abila & Kantola, 2019). However, practically, behavioral drivers (including distance to the recycling centers, knowledge, and financial benefits) are critical to influence consumer recycling (Abila & Kantola, 2019). Empirical data of Finland proves that one of the major factors to stimulate recycling is financial incentives, and the current rates of recycling are relatively average despite the systems and infrastructure (Abila & Kantola, 2019). This implies that there is a current gap in behavioral participation in even the advanced circular economies.

Although some previous research has been explored into conducting digitalization and AI in waste operations to increase its efficiency, minimal research has been conducted on the possibilities that it has on promoting behavior change in a sustainable practice, especially towards marginalized or low participation groups. Also, there has been under discussion on the economic inclusion potential of AI-based incentive system of generating value and alleviating unemployment by participating in social activities. Lastly, the literature on the topic is rarely concerned with the international relevance of these models of digital engagement, whereas the disengagement and under-engagement in waste management is a universal issue (Abdallah et al., 2023 & Peura et al., 2022).

Therefore, this research seeks to address these gaps by presenting an AI-inspired incentive framework to increase the waste sorting involvement in Vaasa, Finland, as connect to immigrant and unemployed populations. The proposed study will provide an opportunity to present a localized and yet globally applicable model of involvement in the CE by combining the perspectives of technology, behavioral involvement, and inclusion.

1.3 Research aim, objectives and questions.

Research Aim

To explore how AI-driven, incentive-based digital solutions may support participation in waste collecting and CE activities, with a focus on immigrants and unemployed population, from a stakeholder perspective, using Vaasa, Finland, as a case study with insights applicable to global contexts.

Research Objectives

1. To explore perceived challenges faced by immigrant and unemployed groups in Vaasa, based on stakeholder perspectives regarding the collection and participation of waste.
2. To explore perceived potential of proposed AI-driven, incentive-based digital solutions to improve waste collection and CE adoption.
3. To examine how AI-powered engagement is perceived to have the potential to support inclusion of communities in the economy by providing financial opportunities and addressing employment challenges among marginalized populations.
4. To explore the proposed AI incentive model's scalability and transferability to other countries with comparable low participation problems.

Research Questions

1. How can participation in waste collection and other circular economic activities be supported by AI-driven, incentive-based digital solutions?
2. How are AI-driven engagement solutions perceived to support the creation of economic value and social inclusion for marginalized groups?
3. To what extent is the proposed AI-based incentive model perceived to be transferable to other regions with similar participation and waste management challenges?

1.4 Significance of the study

This study applies the Technology Acceptance Model (TAM) is developed by Davis (1989), and the Theory of Planned Behavior (TPB) is developed by Ajzen (1991), in relation to the use of AI-driven digital solutions in the fields of waste management and CE. It is

innovative in looking at the behavioral engagement of the unemployed and immigrants, which has not received much attention in the previous studies.

This study offers practical insights for Stormossen and the City of Vaasa on enhancing waste sorting participation while generating economic activity for marginalized populations. Furthermore, the research suggests potential relevance and applicability in broader contexts of AI-driven incentive systems, illustrating their applicability toward achieving CE objectives and sustainable business operations globally.

To address these gaps and possibilities, the following section evaluates literature concerning waste management, the adoption of the CE, and the role of digital and AI technologies, focusing on engagement and inclusivity, aiming for the development of the study's conceptual framework.

2. Literature Review

This chapter explores the theoretical foundations of participation in the CE, within the context of advanced urban waste management systems. The review consists of seven sections, each contributing to the overall development of the conceptual framework of the study.

The first section investigates the evolution of the CE from the global level to the EU, Finland, and municipal levels, and notes differences in structural preparedness and participation. The next section explores migrants and marginalized groups in sustainability transitions, and it highlights the governance silos and gaps in inclusion that limit their formal participation in the CE. The following section covers the behavioral and incentive mechanisms, deposit-refund systems, and PAYT arrangements. It further illustrates the theoretical foundations of TPB and TAM as engagement drivers. The subsequent section focuses on digital waste management tools and examines the degree to which they are informational and oriented towards efficiency. The next section focuses on community-based reuse systems and discusses forms of engagement and structural constraints. The next section examines the integration of AI in waste management, emphasizing its key technological features and the insufficient integration of participatory and interaction-oriented dimensions. The final section summarizes the identified research gaps and contextualizes the conceptual contribution of the study to the municipality of Vaasa.

2.1 CE and Waste Management

2.1.1 Conceptual and Governance Foundations of CE

The linear economic model of “take-make-waste” is progressively being replaced by a CE model because of its potential to respond to issues such as climate change, resource scarcity, and environmental degradation (Anne P.M. Velenturf & Phil Purnell, 2021; Khanna et al., 2022). The authors further argue that, unlike the linear model, CE is not extractive; instead, it fosters regenerative and restorative systems where it is possible to minimize the exploitation of resources and the generation of waste (Anne P.M. Velenturf & Phil Purnell, 2021). Consequently, the linear economic model’s structural

incompatibility with sustainable development has positioned CE as a structural shift rather than a marginal modification (Khanna et al., 2022). Despite the continuing evolution of its institutional profile, CE lacks conceptual coherence. According to Kirchherr et al. (2023), definitions of CE range from narrow recycling-focused interpretations to broader systemic transformations encompassing supply chains, production and consumption systems, and collaborations among multiple actors. Although this diversity has complicated theoretical clarity, recent literature emphasizes the necessity of fundamental restructuring in the production and consumption systems and coordinated action among producers, consumers, policymakers, and civil society.

Although progress has been made in CE discourse, the limited integration of social dimensions remains a concern. While CE is often linked to sustainable development, empirical research pays limited attention to equity, justice, and welfare (Kirchherr et al., 2023). Furthermore, Anne P.M. Velenturf & Phil Purnell (2021) highlight that CE, without a clear connection to social sustainability, risks prioritizing material efficiency while overlooking participatory and distributive outcomes.

At the global level, CE has evolved into a governance model. Global actors have incorporated circularity into their governance frameworks as a means of positioning CE as a strategy for resource productivity, resilience, and climate-oriented sustainable growth (Kirchherr et al., 2023). Khanna et al. (2022) further argue that material-intensive circular strategies can reduce greenhouse gas emissions while generating innovation and employment opportunities, positioning CE at the intersection of environmental and economic strategies.

The EU has integrated CE into its environmental governance as a central component of its environmental strategy. Since the CE Action Plans of 2015 and 2020, CE has shifted from a policy document to a regulatory framework, guiding reforms in product design, waste legislation, and industrial strategy (Calisto Friant et al., 2021; Watkins & Meysner, 2022). EU policy focuses on the entire value chain and emphasizes lifecycle thinking, the closing of material loops, and enhanced traceability across value chains (Dragomir & Dumitru, 2024).

However, Nogueira (2022) highlights that the transformative power of the EU circular policy is heavily influenced by the instruments employed. Measures range from command-and-control regulation to economic incentives and information-based tools. The author further argues that while economic instruments influence behavior through financial incentives, informational tools rely on voluntary behavioral change. A significant reliance on informational measures has raised questions regarding their effectiveness in achieving systemic transformation. Moreover, Calisto Friant et al. (2021) observe that although the policy is often represented in a rather ambitious rhetoric, the actual implementation often remains technocentric with an emphasis on end-of-pipe recycling solutions rather than the restructuring of the socio-ecological order in general.

2.1.2 Finland's CE Strategy and Municipal Systems

Lazarevic et al. (2022) argue that Finland has developed into one of the top CE actors in Europe. National strategies have a conceptualization of CE as a wider sustainability change that aims to redesign socio-technical systems through innovation and niche development. The authors also observe that the strategy of Finland is indicative of well-coordinated governance frameworks and prospective policy aspiration. The study however notes that the focus in policy has been more towards speeding up the process of innovation as opposed to destabilizing incumbent linear regimes.

Investigations into multiple CE projects in Finland indicate that the application of the latter has been largely technology- and recycling-centered and seemingly lacked the social and participatory aspects (Hosseinian et al., 2021). Although Finland has made initiatives to improve material recovery and reduce emissions by developing special initiatives, including national plastic strategies, there are still structural problems, including the growing volumes of waste and the ongoing use of energy recovery (Judl et al., 2023). This highlights the difficulty of the process of switching to effective waste management to a more profound restructuring in a circular way. The change of social norms, collective imaginaries, and everyday practices is a long-term circular success in CE. Technological and regulatory measures are not enough but systemic change demands the participation of citizens and the behavioral change (Marjamaa & Mäkelä, 2022).

The CE is mobilized at the local level by the local waste management systems. An example that can be given is the Vaasa region, which has shifted its model of landfill to an integrated waste management model (Peura et al., 2022; Outreach, 2023). The authors continue by clarifying that, since the late 1980s, the level of waste discarded in landfills has declined dramatically because of the development of infrastructure and implementation of regulations. The functions of municipal waste management companies have also evolved beyond being an infrastructure provider to an institutional intermediary that facilitates the adoption of circular practices and aligns the stakeholders (Tuuli Leskinen, 2025).

2.1.3 Participation Gaps in Advanced CE Systems

Participation, despite good technical performance and institutional capacity remains skewed. Some demographic groups demonstrate lower levels of engagement in waste separation. Information, language, or access barriers are some of the factors that reduce participation (Tuuli Leskinen, 2025). In a more general sense, CE research remains engineering-oriented, and micro-level practices and cultural dimensions are not yet well-researched (Zavos et al., 2024). Although the CE is often linked with the creation of employment and inclusive growth, to achieve the potential benefits, a targeted approach is needed with the help of institutional support and motivation (Van Opstal et al., 2024; Lazarevic et al., 2022).

The regulatory framework of the EU, the national policies of Finland, and the municipal systems are strongly prepared to be structured to undergo a circular transformation. But in all the governance tiers, a similar para-dox is evident: although the technical and regulatory mechanisms are developed at a relatively high level, the concept of inclusive participation and equal engagement is not evenly distributed.

Despite Finland having good institutional and structural preparedness to develop CE, there is still unequal participation among the population groups. This asymmetry focuses the analysis on the involvement of marginalized communities in municipal systems of sustainability, which is the subject of the next section.

2.2 Immigrants, Unemployed, and Social Inclusion in CE

2.2.1 Informal Circular Practices and Structural Barriers

In contrast to the dominant narratives that misrepresent migrants as passive actors in sustainability transitions, global scholars have begun to conceptualize migrants as socio-ecological agents through their daily practices that resonate with the principles of the CE (Fry et al., 2023; Ten Caat et al., 2024). Shaped by experiences of mobility and resource scarcity, migrants tend to engage in low-consumption lifestyles, material reuse and repair practices, and community-based sharing (Ten Caat et al., 2024). Fry et al. (2023) further highlight that while such practices are largely overlooked in the dominant sustainability discourse and policy frameworks, they nonetheless contribute to greater resource efficiency and waste reduction.

Despite the promising contribution of migrants, several structural barriers inhibit their engagement in formal sustainability initiatives. Their engagement in environmental governance is limited due to language barriers, unfamiliarity with culturally embedded environmental practices, discrimination, precarious legal status, and limited access to participatory decision-making (Fry et al., 2023; Ten Caat et al., 2024). Furthermore, Ten Caat et al. (2024) observe that migrants actively participate in informal sustainability practices, such as low-waste living and community redistribution networks, but these contributions are often disconnected from formal transition programs. Zickgraf et al. (2024) argue that governance fragmentation reinforces exclusion, as sustainability and migration policy domains often operate in institutional silos. Moreover, the authors highlight that the lack of systematic coordination between migration and environmental governance limits opportunities to integrate migrants' knowledge, networks, and adaptive practices into formal CE strategies.

Immigrant labor is becoming increasingly important for the global green transition. Migrants constitute a significant share of employment in renewable energy and electric mobility sectors in high-income countries (Hooper & Huang, 2024). However, Hooper & Huang (2024) further contend that immigration policy and green transition strategies remain weakly aligned, limiting structured integration into green labor markets. They

also emphasize that while migrants possess adaptability and workforce capacity, structural and policy barriers continue to constrain their full participation. This suggests that green and circular transitions represent not only environmental imperatives but also underdeveloped opportunities for inclusive economic engagement, particularly for migrant populations.

In the Nordic countries, sustainability and green transition objectives are increasingly incorporated into integration policies. In some municipal introduction programmes, CE principles have been integrated into wider societal orientation frameworks (Nordic Council of Ministers, 2025). Ten Caat et al. (2024) further note that migrants express strong interest in sustainability and actively engage in informal sustainability practices within their communities. These activities tend to be out of line with official municipal CE systems.

The shift to a sustainable circular bioeconomy accentuates the importance of inclusive workforce development. According to Antikainen et al. (2017), policy frameworks are to facilitate reskilling and upskilling that deliberately include immigrants, long-term unemployed persons to facilitate social sustainability in circular transitions. Nevertheless, the authors also observe that integration of migration governance and policy of sustainability is not well-developed, and inclusive participation is usually a policy aim, but not always implemented.

2.2.2 Integration Systems and Untapped Circular Workforce Potential

According to the Nordic Council of Ministers (2025), the institutional frameworks in Finland make it possible to organize the integration of immigrants, which is based on employment, language learning, and civic education. Key factors such as the TE Office and the ELY Centre work together with municipalities to coordinate labor market integration and regional development. However, Fry et al. (2023) argue that while many of these systems are structurally coherent and effective in supporting immigrants' entry into the labor market, participation of immigrants in the CE remains insufficiently embedded. The scholars further highlight that environmental themes may appear in civic education or green skills training, but the integration systems for immigrants do not systematically

incorporate everyday circular practices such as waste sorting, reuse, and local material recovery.

The lack of integration of CE principles into immigrant integration systems is especially concerning given the emphasis on job creation, local value generation, and inclusive growth. Immigrants as well as the long-term unemployed are a particularly important but currently underutilized workforce for the emerging CE sectors, especially in waste management, reuse, repair, and local material recovery services (Hooper & Huang, 2024; Antikainen et al., 2017). In addition to the structural barriers faced by migrants, unemployed individuals often lack clearly defined participation frameworks, incentive systems, and targeted institutional support in CE initiatives. Without explicit linkages between labor market integration mechanisms and local CE initiatives, these populations remain marginal to formal circular systems, despite their economically valuable service-oriented roles within the CE.

Across the literature, immigrants and unemployed people demonstrate informal sustainability-aligned practices but remain marginal to formal CE systems and decision-making structures (Fry et al., 2023; Ten Caat et al., 2024). The literature identifies structural barriers including language limitations, lack of targeted information, insufficient incentive structures, and the absence of inclusive mechanisms that restrict participation in institutionalized waste management and circular programs. Social inclusion potential of the CE is not yet fully achieved even in the developed circular economies such as Finland.

A paradox in the structure arises: despite the focus on inclusivity and employment offered by CE frameworks, there are few instances of institutional arrangements that incorporate immigrant and unemployed groups as full-fledged members of the daily circular system. This gap between circular ambition and inclusive participation highlights the need to develop more systematic models that connect integration policies, active participation, and municipal CE practice. This gap directs analytical attention toward the behavioral and incentive mechanisms that shape participation, including financial instruments and technology acceptance frameworks such as TPB and TAM.

2.3 Incentives and Behavioral Theories in Waste Sorting

2.3.1 Economic Incentives in Waste Management (DRS and PAYT)

Behavioral economics has significantly shaped sustainability policy by demonstrating that incentive structures, feedback systems, and perceived rewards shape environmental behavior. Gamification, defined as the application of game design elements in a context outside of a traditional game, has been used to promote waste sorting (Lab & Douglas, 2020). The authors further emphasize that mechanisms such as feedback loops, progress systems, social comparison, and rewards make sustainability goals more interactive and tangible. They also demonstrate that, compared to purely informational interventions, gamification has been shown to generate stronger psychological engagement, especially habit formation and social influence.

Lab & Douglas (2020) caution that extrinsic rewards alone are insufficient to sustain long-term behavioral change. The authors further note that while perceived usefulness increases adoption of sustainability applications, financial incentives must be complemented by intrinsic motivation, and social norms and feedback loops are essential to produce durable recycling behavior.

In addition to gamification, the adoption of economic incentives has demonstrated measurable impacts on recycling performance. Incentive-based systems, such as tax incentives, subsidies, progressive pricing schemes, and Deposit Refund Schemes (DRS), as well PAYT tariffs, have been shown to improve household recycling rates (Zhou et al., 2021; Romano & Masserini, 2023). Zhou et al. (2021) further demonstrate that smart incentive systems integrating digital monitoring and adaptive pricing increase recyclable waste collection. These findings indicate that the most effective incentives are those that are implemented as part of systemic, data-driven systems, not as a standalone financial measure.

Among the many instruments of recycling, DRS represents one of the most empirically validated mechanisms. In DRS systems, consumers pay a deposit that is refunded upon return of the product. This is an example of both a negative and a positive incentive and reflects the polluter pays principle (Calabrese et al., 2025). Calabrese et al. (2025) and

Picuno et al. (2025) demonstrate that, compared with countries that have no DRS systems at all, countries implementing DRS consistently demonstrate much higher product return rates. The authors also indicate that the value of the deposit, the availability of the return infrastructure and common knowledge of people have a strong impact on the effectiveness of DRS. Calabrese et al. (2025) warn that the application of one incentive system can lead to short-term behavior change or create fairness issues, which further supports the importance of a combination and context-sensitive model.

PAYT systems are made to work with usage-based pricing, which involves a direct connection between waste generation and financial cost (Romano & Masserini, 2023). The authors also demonstrate that the PAYT systems contribute to a reduction in total unsorted waste and quality of source separation in European municipalities. Digital reward-based systems depict how technology can enhance financial incentives even more. Reward systems with web-based and mobile applications that provide virtual tokens, lottery systems, and real-time tracking have been shown to improve participation and sorting accuracy (Gibovic & Bikfalvi, 2021).

One of the most institutionalized and successful national models is the deposit-refund system of beverage containers (pantti system) (Numata, 2016). The system has a return rate of more than 90, with infra-structure of reverse vending machines and material-specific deposits (Laubinger, 2022). The author further emphasizes that effective pantti returns are the result of adequate deposit levels, improved refund systems, and effective communication. From an economic standpoint, DRS systems are similar to Pigovian instruments that incorporate external costs into market pricing (Walls, 2011).

The overall recycling outcomes of plastic packaging in Finland highlight a structural limitation of DRS. The system primarily targets beverage containers and does not address broader household waste sorting practices (Reijonen et al., 2021). Reijonen et al. (2021) further demonstrate that the attitudes toward the behavior and perceived behavioral control strongly influence recycling behavior, while facilitating conditions such as proximity to collection points play a decisive role. Even highly effective incentive systems depend on psychological and contextual determinants.

2.3.2 Behavioral Foundations: TPB and TAM

The TPB has been widely applied to explain these behavioral mechanisms. TPB states that behavioral intention is determined by one's attitude toward the behavior, the subjective norms, and perceived behavioral control. There is meta-analytic evidence confirms that these constructs predict recycling intention and behavior (Novanda et al., 2026). Nevertheless, TPB is able to explain only a fraction of the variance in intention (Wan et al., 2022), and its predictive strength varies across socio-economic and cultural contexts (Novanda et al., 2026). Recycling intentions are affected by moderating factors such as place attachment, trust in government, perceptions of policy design, and perceived time costs. The behavior of recycling is driven not only by financial incentives but also by psychological determinants such as trust, identity, habits, and facilitating conditions (Wan et al., 2022; Bruno et al., 2022).

With the growing digitalization of waste management systems, understanding technology adoption is essential. TAM conceptualizes technology adoption via perceived usefulness and perceived ease of use (Zhang et al., 2024). Zhang et al. (2024) further show that perceived usefulness and ease of use positively influence attitudes and behavioral intention, while social influence and perceived risk are moderating factors influencing adoption. Effective use of digital recycling technologies is only possible when they are used to complement the current incentive structures with usability, trust, and transparency.

2.3.3 Structural and Inclusion Limitations

Although there is solid evidence to back the economical incentives and behavior theories, the emerging research on this area throws considerable attention on social inclusion constraints. CE models are known to be more material-efficient and technology-optimized but less concerned with accessibility, equity, and distributional issues (Rezaie et al., 2022). There are also informal and necessity-based circular activities of marginalized communities that tend to be left out of the formal discourse of the CE (Korsunova et al., 2022). Also, informal waste recovery can put vulnerable populations at risk of environmental and health problems due to lack of regulation (Wright et al., 2019). Even the high performing systems such as DRS might not equally reach all demographic groups when

infrastructure, communication, or incentive frameworks are distributed unevenly (Laubinger, 2022).

Accordingly, three structural limitations emerge:

1. Technocratic orientation – Incentive systems are aimed at the material recovery at the cost of social accessibility (Rezaie et al., 2022; Korsunova et al., 2022).
2. Fragmented policy integration – The systems of incentives are quite autonomous of integration systems and workforce policy (Laubinger, 2022).
3. Restricted focus on marginalized communities – Incentive frameworks seldom directly consider underrepresented groups (Rezaie et al., 2022; Laubinger, 2022).

Collectively, incentive mechanisms, the TPB, and the TAM provide robust explanations for recycling behavior and the adoption of technology. Nonetheless, current models seldom combine financial incentives, digital support, and targeted inclusion strategies in municipal CE frameworks. This fragmentation limits understanding of how behavioral motivation can be operationalized through digital infrastructures to support inclusive participation. The following section therefore examines digital waste management solutions and their role in shaping engagement within municipal circular systems.

2.4 Digital Solutions for Waste Management

2.4.1 Operational and Informational Digital Systems

Digital technologies in waste management have evolved significantly. Recycling Vending Machines (RVMs) exemplify automation and behavioral nudging made possible by digital infrastructure. While RVMs nudge environmentally positive behavior by offering financial rewards via a digital interface, they reward individuals for packaging return (Zhang et al., 2024). Zhang et al. (2024) further demonstrate that perceived risk seems to negatively impact participation. These results provide evidence that digital engagement systems are designed to address the behavioral and emotional aspects of waste management in addition to logistical considerations.

Beyond technology that engages consumers, digital CE innovations also include business and system-level developments. Industry 4.0 technologies (e.g., data integration, tracking, analytics) enhance materials and resource management and the development of

circular business models (Ranta et al., 2021). Ranta et al. (2021) further note that in the Nordic region, digital tools are used for both incremental and radical transformations in value creation and supply chain transparency. In Finnish cities, IoT-based Smart Waste Management systems have been implemented at the municipal level to improve monitoring, decision-making, and sustainability assessment (Sosunova et al., 2024). These systems exemplify operational efficiency and data-based governance improvements that digitization can support.

At the household level, mobile applications are used to provide instructions, enable scanning, locate recycling points, and provide educational resources about recycling (Saptaputra et al., 2023). Finnish respondents show positive attitudes toward these technologies and consider them useful for improving sorting and accessibility (Mykkänen & Repo, 2021). Nonetheless, providing information alone does not guarantee enhanced recycling practices. Behavioral research on plastic waste sorting in Finland shows that costs associated with cleaning, sorting, storing, and transporting materials to recycling facilities greatly affect participation (Reijonen et al., 2021). The authors further observe that easier access to information about recycling paradoxically led to a decrease in recycling behavior, highlighting the need to address practical barriers rather than a sole emphasis on information and educational digital tools.

2.4.2 Engagement and Inclusion Gaps in Digital Tools

The gap in engagement is particularly pronounced in recycling and waste management applications, especially among younger users. Gamified reward systems increase participation and improve sorting behavior (Santti et al., 2020). However, Santti et al. (2020) further observe that many applications primarily apply educational approaches and lack structured systems of long-term motivation and engagement. As a result, the available digital tools function primarily as informational resources.

The development of waste management within the Vaasa region showcases the relationship between waste management systems and society's evolving needs. Over the past decades, the region has moved away from landfill-based disposal to integrated circular systems, owing to collaboration and the development of new infrastructure (Peura et al., 2022). Peura et al. (2022) further note that regulatory, normative, and value chain

changes facilitate technological progress. The authors additionally highlight that the evolving strategy in the region is oriented towards material management and service-based waste ecosystems, indicating an increasing need for digital service innovations at the municipal level.

Finland and the Nordic region are advanced in digital infrastructure, but the current digital waste solutions focus mostly on efficiency, monitoring, and information provision. Adoption of technology depends on perceived usefulness, ease of use, and trust. Perceived risks and behavioral costs may deter adoption (Zhang et al., 2024; Reijonen et al., 2021). Digital systems are often not designed with explicit inclusion strategies for diverse and marginalized groups.

Thus, although digitalization has improved operational efficiency and accessibility in waste management, it has not systematically incorporated behavioral incentives, adaptive personalization, and inclusion mechanisms within municipal circular systems. There is an existing gap between technological optimization and socially integrated, motivational digital engagement systems. Closing this gap requires moving beyond just informational systems to integrated solutions that combine digital systems, behavioral reinforcement, and participation.

These gaps underscore the necessity to investigate community-based systems and alternative involvement approaches.

2.5 Community-Based Platforms and Reuse Practices

2.5.1 Platform-Based Reuse and Grassroots Practices

Globally, community-based reuse and sharing platforms are important grassroots mechanisms for CE transitions. Integrated digital platform technologies support circular business models and enhance resource flows among networks of participants (Blackburn et al., 2022). Value is created by facilitating redistribution of materials through peer-to-peer exchanges. Circular start-ups that are platform-based and service-oriented encourage access rather than ownership and extend product life spans (Henry et al., 2020). These models are widely recognized as key facilitators in the shift from linear to circular economic systems.

The Sharing Economy (SE) is frequently seen as a subset of CE, yet it more precisely embodies a consumer-oriented, digitally facilitated reuse framework (Henry et al., 2020). Digital platforms have the potential to operate as circularity brokers by filling gaps in the CE, or "circularity holes" (Ciulli et al., 2019), created by limited connections between waste producers and potential users. Through brokerage functions such as connecting, informing, mobilizing, and integrating actors, platforms promote localized waste recovery and value retention within communities and supply chains.

In Finland, grassroots reuse practices are visible in social media-based giveaway groups, referred to as Roskalava-type Facebook groups, where users redistribute items free of charge, extending product lifetimes and delaying disposal (Mykkänen & Repo, 2021; Laukkanen & Tura, 2020). The convenience and ease of use, environmental advantages, and community feeling are valued by the users of these groups. The participation rate is high among young adults, students, lower socio-economic groups, and new immigrants (Mykkänen and Repo, 2021). The main drivers of participation are their affordability, accessibility, and opportunities for social interaction. The platforms are particularly advantageous to those with limited financial means as well as those who are barred by obstacles in the formal reuse or secondhand markets.

These platforms have great opportunities for social inclusion. They appeal to the members of different demographic categories, including those that are underrepresented, such as immigrants and those with lower socio-economic status (Mykkänen and Repo, 2021). Through these informal sharing networks, it is shown that groups that are not well considered in society are very active in their day-to-day reuse and redistribution within the CE.

2.5.2 Governance Disconnect and Structural Constraints

However, there are still major structural limitations. Informal sharing platforms are based on a format of grassroot and decentralized format, with no formal structure, incentives, and schemes of integration with local waste management systems (Mykkänen and Repo, 2021). As a result, these activities do not always contribute to national or local CE goals, such as recycling, waste diversion, and resource recovery. Absence of policy integration, financial incentives and oversight mechanisms limits scalability and long-

term sustainability. These platforms are enabling local reuse efforts but are not tied to formal CE governance systems. There is still a significant gap between community-based reuse and institutional CE frameworks. Although community-based platforms have proven to be highly engagement and inclusive, they remain unintegrated with municipal systems, policy tools, and economic incentive systems (Mykkänen and Repo, 2021). Their effect is localized, not systemic, without alignment to formal goals, monitoring mechanisms, or systematic incentives.

In Finland, the reuse platforms of communities demonstrate the social worth of grassroots circularity. Nevertheless, they are yet to be used as policy-oriented, incentive-driven parts of municipal CE governance. They are voluntary and decentralized and limit their integration with formal waste systems, digital monitoring systems, and structured participation channels, highlighting the relevance of frameworks that bring together community involvement and coordinated technological infrastructures and incentive-based systems.

2.6 AI in Waste Management and User Engagement

2.6.1 Operational AI and Efficiency-Oriented Systems

AI is now being recognized as a revolutionary approach to waste management systems. The primary goal of AI applications in the world is to improve efficiency. These applications are oriented on automation, predictive analytics, and system optimization. Convolutional Neural Networks (CNNs) and other deep learning models have been shown to have high accuracy in automated classification of waste with a rate of over 98 percent across various types (Ahmad et al., 2025). The systems overcome persist-tent inefficiencies in the traditional waste sorting system, which is mostly labor intensive, prone to errors and expensive in real time processes.

AI systems facilitate predictive analytics, and IoT-based infrastructures facilitate real-time observation of waste quantities, route optimization, and information-driven planning of waste collection systems (Olawade et al., 2024; C et al., 2025; Chitti et al., 2025). Decision-support systems implemented in European municipalities, such as Finnish cities, demonstrate that digital technologies can enhance sustainability performance and

improve strategic waste management planning (Sosunova et al., 2024; Seker, 2022). Overall, existing research suggests the potential of AI to improve technical precision, operational performance, and resource efficiency throughout the waste management lifecycle.

While AI has considerable potential to enhance participatory CE strategies, many applications remain technocentric, emphasizing efficiency, optimization, and automation rather than citizen engagement and behavioral transformation. Although AI improves sorting precision and logistical coordination, its role in participatory CE strategies remains limited, particularly in real-world citizen engagement contexts.

2.6.2 AI for User Engagement and the Participatory Gap

Recent research introduces a user-centered perspective, showing that AI-driven chatbots and conversational systems enhance engagement and awareness (Zota et al., 2024). These tools include NLP-powered systems with multilingual capabilities that provide guidance in users' native languages. Zota et al. (2024) and Belyamani (2025) demonstrate that these systems have demonstrated their ability to reduce language barriers and knowledge gaps in diverse urban populations. Zota et al. (2024) further indicate that culturally adapted chatbots enhance waste sorting precision and user comprehension, particularly among non-native speakers and less integrated communities. These results indicate that AI can extend beyond operational optimization to reduce structural barriers related to language proficiency, information asymmetry, and perceived behavioral complexity.

AI may be used in the process of overcoming communication and language barriers, particularly in multicultural settings, e.g., Finland, where integration of immigrants overlaps with the sustainability policy. In this case, AI technologies can be used as the enabling infrastructure, which supports the inclusive involvement in the practice of waste sorting. Behavioral literature points to the presence of enabling conditions and the perceived ease of action as key determinants of recycling behavior, meaning that AI-based guidance tools will be able to increase perceived behavioral control.

However, there is still an apparent gap in research. Existing AI applications in waste management primarily focus on efficiency optimization in the sorting process, collection, and

monitoring operations (Belyamani, 2025; Olawade et al., 2024). Chatbot innovations are not normally created to be part of a structured incentive system; rather, they are created as informational resources. The current literature seldom considers AI-based user guidance in combination with behavioral economics, gamification, or relevant inclusion initiatives of underserved groups, including immigrants and the unemployed. Olawade et al. (2024) also pays much attention to technical performance, data quality, and scalability issues, but devote little to the use of AI within the framework of participatory, incentive-driven CE engagement.

Current literature shows that AI enhances operational efficiency and user directions in waste management systems. However, its incorporation with formalized reward systems to promote socially inclusive CE practices is little. The linkage between AI-based directions, behavioral reward systems, and inclusion aimed strategies are still under-established. This disconnection shows a major gap in the research on municipal CE, in which technological progress has not been systematically associated with inclusive participation models. The focus of the practical part of this research is primarily on the digital engagement tools such as mobile applications, community platforms, and incentive-based systems, which are more commonly used in a municipal waste management setting, such as Vaasa, rather than advanced AI systems that are currently being used to achieve citizen-targeted engagement.

2.7 Research Gap and Conceptual Positioning

The above analysis shows that Finland possesses a superior CE framework characterized by effective incentive systems like deposit-refund systems, highly developed municipal waste management and increasing digital information technologies. The use of AI is increasingly being reported in literature as waste sorting, optimization of logistics, and intelligent monitoring systems. Reuse platforms at grassroots contribute additionally to the circulation of materials and engage a wide range of demographic categories, including students and immigrants.

In spite of this structural complexity, these components are not a coordinated system but mainly run in parallel. Current incentive mechanisms are materialistic and are not socially targeted. Digital applications mainly serve as sources of information rather than

sustained behavioral motivators. Grassroots reuse platforms operate outside formal municipal circular governance frameworks. Meanwhile, AI applications remain predominantly technocentric, prioritizing operational efficiency over participatory engagement and structured social inclusion. Nevertheless, in the Vaasa context, existing practices mainly rely on digital applications and information systems, and do not incorporate the direct use of AI-driven tools for citizen engagement.

Across the literature, no integrated framework systematically combines AI-driven multilingual guidance, behavioral incentive mechanisms grounded in the TPB and the TAM, and targeted inclusion strategies for marginalized groups, especially immigrants and long-term unemployed individuals, within municipal CE systems. Moreover, existing incentive systems are rarely linked to employability development or labor market inclusion pathways for marginalized populations.

This gap limits understanding of (1) how AI-driven incentive-based digital solutions may support participation in circular waste activities, (2) how such engagement mechanisms are perceived to contribute to socio-economic value creation and social inclusion, and (3) to what extent integrated AI-based incentive models are perceived to be transferable beyond their original municipal context.

Accordingly, this study develops a conceptual AI-supported engagement model for the Vaasa region. The AI element is suggested as a theoretical extension grounded in stakeholder perspectives and current digital methods, instead of being practically applied in the case setting. Instead of viewing AI as an optimization tool, the model views AI as an enabling infrastructure that lowers the cost of participation, reinforces behavior-al motivation, and inclusive circular engagement. This study contributes to the scholarship of CE by incorporating behavioral theory, digital facilitation, and incentive mechanisms into a socially oriented framework and has the potential to be applied to broader and more systemically oriented models that may be relevant to a broader context than the context of the case under study.

2.8 Theoretical Framework: TPB and TAM

This study is based on two complementary theoretical models, the TPB and the TAM. These frameworks are selected to answer the main question of the research: the

involvement in waste sorting and circularity is still not equally distributed in the developed municipal garbage system like Vaasa. Although there is well-developed infrastructure and incentive mechanisms in place, participation among immigrants and long-term unemployed individuals remains inconsistent. To address this issue, the analytical framework must be able to capture behavioral intention and technology adoption through a human-centered lens in a socially diverse environment.

According to TPB, pro-environmental behavior is determined by the development of behavioral intentions which are influenced by attitudes and subjective norms as well as perceived behavioral control (Ajzen, 1991). Applied to Vaasa, TPB can be used to analyze the perceptions of waste sorting and engagement in circular activities (attitudes), the role of community expectations and social pressure in influencing the behavior (subjective norms), and the presence of practical barriers such as language and lack of knowledge of local systems and perceived complexity (perceived behavioral control) and individuals' perceived capability to participate. Therefore, TPB contributes to the explanation of the presence of gaps in participation not merely as informational gaps, but as the result of social and contextual limitations that manipulate intention and action.

TAM complements TPB because it addresses the specific issue of adoption of digital solutions through perceived usefulness and perceived ease of use (Davis, 1989). Since the research explores the possibility of an AI-driven, incentive-based digital system to aid circular participation, TAM can offer a systematic method of examining whether the suggested solution is considered helpful and worth utilizing (usefulness) and whether it is accessible and operational for diverse users (ease of use). The degree of perceived usefulness in this research context is directly associated with both the reduction in the cost of participating in the solution (reducing uncertainty, time, confusion) and meaningful value added (including possible financial or service-based benefits), whereas the degree of perceived ease of use is also, in turn, directly linked to usability, multilingual instructions, and trust in the functionality of the system.

The integration of TPB and TAM is particularly appropriate for this research since the challenge of participation in Vaasa is both behavioral motivation and digital acceptance. TAM describes the environment in which an AI-supported solution will be adopted,

whereas TPB describes the overall social, cultural, and psychological factors of the participation. Collectively, these frameworks offer a foundation for analyzing the perceived capacity of an AI-driven incentive model to enhance CE involvement by increasing technology acceptance and lowering behavioral obstacles for marginalized communities. This theoretical underpinning is what gives rise to the conceptualization that is outlined in the next section.

2.9 Conceptual Framework of the Study

Based on the gaps that are discussed in Section 2.1 to 2.7, the proposed study presents a conceptual AI-based engagement model that connects municipal CE systems to an inclusive participation process in Vaasa. According to the literature, Finland and the Vaasa region have technical and institutional preparedness of waste management and recycling with well-developed infrastructures and incentive systems. Nevertheless, the existing components, such as economic incentives, informational digital tools, community reuse programs, and operational AI systems, are usually independent of each other and not connected in an ecosystem of participation. As a result, engagement seems to be inconsistent, and viewpoints from stakeholders indicate that populations like immigrants and those who are long-term unemployed might be inadequately represented in official circular initiatives.

The conceptual framework that will guide this study is presented in Figure 1. The model places the AI-supported digital facilitation such as multilingual guidance, interactive assistance, and accessible instructions as a facilitating layer that decreases barriers to participation in daily waste sorting and circular activities. Incentive mechanisms are integrated to make participation more tangible and rewarding. The framework also views AI as an infrastructure within which engagement happens, rather than as an operational optimization tool, thereby improving accessibility, reducing complexity, and strengthening user confidence to engage in circular action.

The participation outcomes are influenced in the framework in two complementary ways. First, the technology adoption status is assessed by TAM. The probability that the target users will adopt the digital solution will be based on whether the associated information is perceived as useful and easy to use, especially within language and cultural

barriers. Second, the conditions of behavioral participation are reflected in the TPB: attitudes towards participation, community social norms, and the perception of behavioral control determine the engagement in waste sorting and circular activities. The model suggests that AI-assisted guidance can improve perceived behavioral control by minimizing uncertainty and practical barriers, while incentive strategies might bolster attitudes and intentions by making participation more meaningful and rewarding.

Finally, the framework incorporates a social inclusion dimension, and it identifies immigrants and the unemployed as key target groups for inclusive participation in the circular economy. The model addresses the research gap in the literature that has been identified: an absence of a direct framework linking AI-based guidance, behavioral motivation, and inclusion in practice involving a municipal CE. This conceptual framework directs the empirical investigation of the perceived capability of an AI-driven incentive system to encourage circular participation in Vaasa and offers insight into its potential applicability in other situations encountering comparable participation issues.

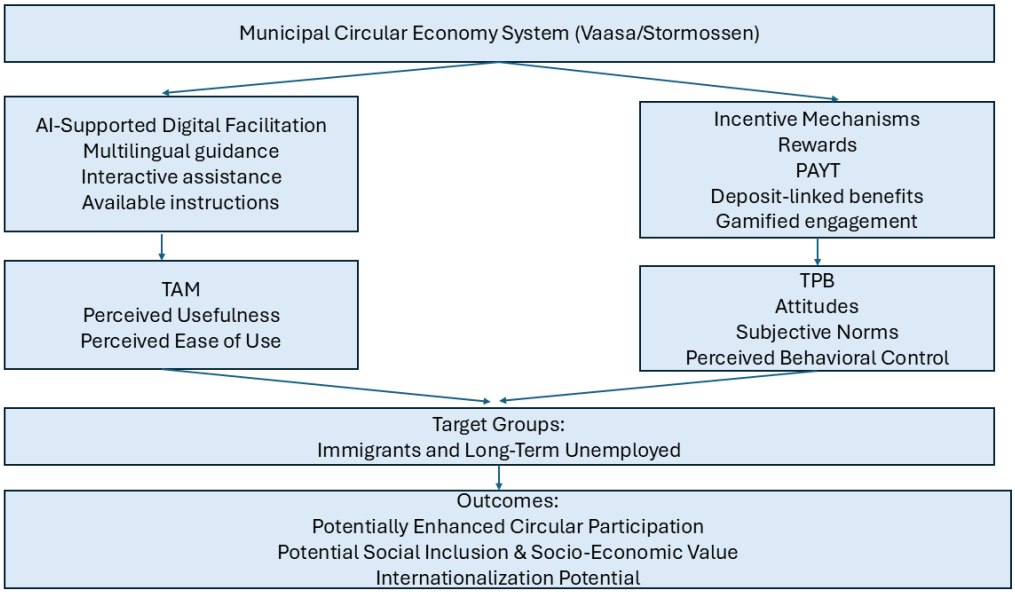

Figure 1. Conceptual Framework

3. Methodology

This chapter describes the methodological foundations guiding the study. It describes the research philosophy along with the theory, design, and strategy employed to analyze how AI-driven, incentive-based digital solutions may support participation of immigrants and unemployed people in waste collection and CE activities in the city of Vaasa, Finland. It also outlines in detail the rationale, the qualitative case study, and the constructive research strategy along with the practical sampling, data collection, and analysis procedures that were employed. This chapter outlines the theoretical and practical inputs of the methodology concerning the social and environmental issues tackled in the research.

3.1 Research Philosophy

The philosophy applied in this research is pragmatism. The core concept of pragmatism is that the framework of the research and its methodology should always be based on the nature of the research problem and the questions being examined. According to Saunders et al., (2019, p. 151), pragmatism starts with a problem and is aimed at providing practical solutions to future practice. This is why pragmatism is specifically relevant in this thesis where the focus is on how AI-driven, incentive-based digital solutions may help to support the engagement of immigrants and the unemployed on waste collection and CE activities in Vaasa, Finland. Therefore, the research does not purely attempt to strengthen the theoretical discussion but also aims to advance knowledge that may result in real-world problem-solving.

Pragmatism focuses on answering the gap between theory and practice. Theoretically, environmental and social issues related to waste management and CE participation of focused groups requires both practical and conceptual knowledge. Pragmatism adopts diversity in methods and values subjective and objective realities. In this case, it enables the integration of perspectives from institutional stakeholders involved in waste management, regional development, and CE initiatives in Vaasa. Therefore, this approach covers the behavioral, cultural, technological, and institutional aspects of CE participation.

Additionally, the suitability of the approach fits well with the aspect of time and practicality of the research. The research will be a cross-sectional study to be carried out during the study period, where data will be collected within a defined time frame. In this phase, primary data were gathered and analyzed to produce a model that is conceptual in nature, and theoretically valuable, but useful in practice.

3.2 Research Design and Approach

The research adopted qualitative case study design in which the city of Vaasa, Finland, will be the main case study area. Case study research is especially applicable to the problems of how or why that do not fit well in real-life scenarios where the demarcation between the phenomenon and context is not well-articulated (Yin, 2018, as cited in (Yustinus Calvin Gai Mali, 2023)). The reason behind selecting Vaasa is that it symbolizes both the opportunities and challenges of implementing the practices of the CE in the immigrants and unemployed populations, which is why it is a valuable and informative location in which the research may be conducted.

The study followed a qualitative research approach, as the aim is to develop an in-depth understanding of institutional perspectives on waste participation, digital engagement mechanisms, and CE practices. Qualitative inquiry is the most appropriate approach to examine how people and organizations interact with technology, incentives, and CE practices due to its focus on meaning-making and context (Saunders et al., 2019, p. 638-639). Specifically, this method offers flexibility of capturing various social, cultural and behavioral aspects that cannot be well comprehended using numerical data alone.

The reasoning in this case was abductive. As stated in Dubois & Gadde, (2002, p. 559), abduction combines elements of induction and deduction by iterating between empirical evidence and theoretical frameworks. Furthermore, instead of having a predetermined theory, abductive reasoning enables the researcher to begin with observations and stakeholder views on the uneven involvement in waste sorting among various population groups in Vaasa, and then finding the most possible explanations, relying on the available theories, of TAM and the TPB. This cycle of repeating processes did not only sharpen the theoretical concepts but also grounds them in the perspectives of the stakeholders involved.

Overall, the approach taken ensures stability between theoretical and practical aspects. While the case study approach allows in-depth exploration of waste participation practices in Vaasa, the qualitative nature of the study, and the abductive approach, ensures flexibility in examining the complex relations of technology use, social inclusion, and practices of the CE.

3.3 Research Strategy

The main research strategy of this study was an early-stage constructive design approach integrated with a qualitative case study design. As outlined by Lukka Kari (2003, p. 83), constructive research is a problem-solving approach that focuses on the development of solutions that are practically relevant while also contributing to the academic body of knowledge. It is based on pragmatism, interpretivism, and empiricism, thus making the results of the research both theoretically and practically oriented.

The constructive research approach fitted this study perfectly since the primary goal is to design a conceptual AI-driven incentive-based model, intended to support participation of immigrants and the unemployed in waste sorting in Vaasa. This approach fosters theory and practice integration by proposing the development of constructions, such as models and frameworks, that can be designed and conceptually evaluated in a context that pertains to academic literature and practical relevance (Oyegoke, 2011, p. 590, Saunders et al., 2019, p. 25). Lukka Kari, (2003, p. 84) argues that constructive research is made up of six elements, that are interdependent:

1. Gathering knowledge from diverse sources to develop a robust foundation.
2. Establishing theoretical linkages to provide context for the research.
3. Articulating practically relevant issues and devising workable solutions.
4. Assessing feasibility at a conceptual level based on stakeholder perspectives rather than through implementation.
5. Describing the construction in a manner that explains the problem-solving pathway.
6. Connecting findings back to the theory establishes both scholarly and practical value.

Employing this strategy gave the research the opportunity to examine institutional perspectives on participation challenges among immigrants and unemployed populations in waste collection activities, while making a theoretical contribution to the literature on digital servitization, CE, and behavioral engagement. In this study, the proposed model is not empirically implemented or tested; instead, its feasibility is explored conceptually through stakeholder perspectives.

Hence, the flexibility and rigor required to create a context-specific model applicable based on Vaasa and the potential for analytical transferability to other contexts with similar participation challenges are supported by a combination of constructive research and a case study design (Lukka Kari, 2003, p. 83).

3.4 Sampling and Participants

This study aimed to examine how AI-based and digital solutions may support the participation of immigrants and the unemployed in waste collection and CE activities in Vaasa, Finland. Because the research objectives specifically address human participation, waste management practices, and engagement, the sampling design focused on institutional stakeholders with direct professional involvement in the topic.

Non-probability sampling was chosen because it allows for the selection of participants in the best position to provide in-depth answers to the research questions. Saunders et al., (2019, p. 321) note that purposive sampling is particularly useful for obtaining rich information samples that provide critical insight rather than explanatory power.

The study included four key participants as illustrated in Table 1:

Table 1. Overview of interview participants

Participant No.	Organization	Role
1	Stormossen	Representative responsible for waste management operations
2	ELY-Keskus	Regional development and employment policy representative
3	City of Vaasa	Municipal sustainability and CE representative

4	Kamupak Oy	Former CEO with expertise in digital circular reuse systems

These individuals were chosen due to their professional knowledge and their participation in CE governance, waste management strategies, and digital innovation related to the research subject.

3.5 Data Collection

The qualitative data in this study were collected through semi-structured interviews undertaken during the study period. The goal of the interviews was to capture the institutional viewpoints on the practices of waste management, engagement in the CE, and the possible role of AI-based digital solutions in facilitating waste collection activities in the city of Vaasa. It is essential to understand that the data represent institutional viewpoints rather than the firsthand experiences of immigrants or those who are unemployed.

As noted by Saunders et al. (2019), semi-structured interviews provide the ability to keep to a specific question scheme but also allow the interviewer the ability to flexibly pursue emerging topics through additional questions. This form of interviewing is particularly advantageous for capturing the perspectives among participants with the most direct involvement in a given area, such as waste management, regional development, and CE activities.

Interviews were held with four institutional stakeholders who possess occupational knowledge about waste management and CE development in the Vaasa region. These were: a representative from Stormossen, the regional waste management company in charge of the collection and recycling of waste; a representative from the ELY-Keskus who oversees regional development and employment policy; a representative from the City of Vaasa who handles the municipal sustainability and CE projects; and the former CEO of Kamupak Oy, which provides digital services for circular re-use systems. These participants were chosen through purposive sampling, owing to their expertise and experience pertinent to the study. This method may introduce institutional bias, as the

results reflect a top-down perspective on participation issues instead of the actual experiences of the target groups.

Based on the key research themes, such as waste participation, engagement barriers, digital readiness, the possible role of AI solutions, and incentive mechanisms supporting CE participation, the semi-structured interview guide (refer to Appendix 1) was created. The interviews allowed respondents to share their institutional experience, the policy viewpoints, and the participation challenges as perceived by them within the waste management systems.

Four interviews were completed. Considering the participants' specialist knowledge and the quality of the interviews, this number was acceptable in this exploratory qualitative case study. The interviews were conducted in English and, with participants' agreement, were recorded. For the purposes of analysis, all interviews were transcribed. While interviews were being conducted, field notes were taken to document contextual observations or supplementary reflections that aided interpretation of the data.

In essence, the data collection process prioritized institutional insights concerning the barriers to participation, waste management practices, and the possible use of AI-based incentive systems within the CE framework of Vaasa. This way, the data obtained remained aligned with the research objective of assessing the potential of digital and incentive-based systems in enhancing participatory practices in the CE among marginalized communities as perceived by institutional stakeholders. Future research could include direct data collection from immigrants and unemployed groups through participatory or survey-based methods to complement institutional perspectives.

3.6 Data Analysis

A combination of qualitative content analysis and thematic analysis was used to analyze the interview data. The combination of the two qualitative methods allowed for a structured level of analysis and a more in-depth analysis of the data.

Qualitative content analysis was first applied to the transcribed interviews. Following the process outlined by Erlingsson & Brysiewicz, (2017, p. 2), the transcripts were read repeatedly to gain familiarity and extract key phrases, known as meaning units. These

meaning units were contracted into short phrases, maintaining their core meaning, and then coded. The codes were categorized based on similarities, creating a preliminary structure for the data. This step reduced the data to a systematic and organized form and highlighted recurring patterns throughout the interviews.

Following content analysis, thematic analysis was used to interpret the data at a higher level of concept. Codes and categories were developed into broader themes that captured the hidden meanings of participants' responses (Braun & Clarke, 2006, p. 15). This phase allowed the researcher to move beyond outer level descriptions and gain deeper insights into participants' perspectives on behaviors, motivations, and organizational practices related to waste participation and digital solutions.

The analysis was done in an abductive way, continuously moving back and forth between the theory and the data. The TAM and the TPB served as lenses through which the interviews were interpreted to understand the role that digital solutions and incentives play in engaging underrepresented groups in waste collection and recycling. The need for abductive reasoning ensures that any unexpected outcomes that may arise from the data can relate to existing theories or to help refine theoretical understanding.

The transcription, coding, defining categories, and creating themes was done manually. These themes are illustrating through anonymized participant quotes in The Results section that show significant themes and preserve participant voice. The recursive analysis approach enabled polishing the analysis unabated as the researcher worked on the data and theory side by side. The systematic and comprehensive findings were obtained by using content analysis to structure the research and a thematic analysis to interpret the results.

The process of coding, categorization, and theme development was conducted manually. Participant quotes are presented in the results section to illustrate key themes and ensure participant voice. The analysis process is iterative and can be continually refined as the researcher simultaneously revisits theory and data. This combination of qualitative content analysis of the structure and thematic analysis of the interpretation enabled the study to produce both systematic and detailed findings about the research problem.

3.7 Reliability, Validity, and Trustworthiness

Qualitative research must also be of high quality and reliable. Unlike quantitative research, qualitative research does not rely on the reproducibility of identical results as a measure of reliability; instead, it relies on trustworthiness, credibility, and transparency (Zohrabi, 2013, p. 259). This research was able to address these points through several parameters.

1. Reliability (Dependability):

Factors contributing to the research's reliability were the clear and structured research methodology employed. Transcripts of the interviews were recorded and transcribed and systematically coded to have uniformity. In the Results section of the study, direct quotes and other low-implication descriptors that provide a clearer understanding of the results to be obtained were used to help the reader assess the balance between the researcher's interpretations and the participants' responses.

2. Validity (Credibility):

The validity of the findings relies on the use of triangulation techniques. Theoretical triangulation was accomplished by analyzing the results using the TAM and the TPB and methodological triangulation through qualitative content analysis and thematic analysis. Together, these methods supported stronger interpretation of the findings. Also, informal clarification with participants was undertaken where possible. The participants had the opportunity to clarify or elaborate their answers, and summaries of the results were compared with their opinions to improve validity.

3. Reflexivity:

The researcher is also an immigrant in Vaasa, and this could have an impact on their relationships with the participants and on their data analysis. Rather than dismissing this form of positionality as a deficit, it was embraced as a reflexive lens adopted to, and expansive of, the experiences of immigrants within a wider frame. At the same time, effort was made to remain within the boundaries of the participants' narratives and avoid the use of personal experiences.

4. Trustworthiness:

The essence of reliability was guaranteed by working within the bounds of credibility, transferability, the principle of dependability, and confirmability. Providing detailed descriptions of the institutional participants and the methods employed of the sample make transferability more reasonable. In support of confirmability and dependability triangulation, reflexivity, and direct quotes from participants were utilized.

The overall balance of these measures brings forward the argument that the outcomes of the study have not only been undertaken in a methodological manner, but also reflect credibility, dependability, and trustworthiness. This expanded the entire value of the study in relation to the underlying existing academic area, as well as the relevant practical applications.

3.8 Conclusion

In this section, the methodological and ethical foundations of the study are grounded in trust, respect, and responsibility. Rights were protected and respected, and data were processed with the utmost honesty and care. The study is based on a comprehensive research methodology that includes research philosophy, theoretical framework, design, sampling, primary and secondary data collection, and data analysis techniques. This methodology supports the reliability and originality of the study findings, and worthy of consideration in the conceptual development of an AI-based incentive model intended to support waste participation among underrepresented groups, including immigrants and unemployed populations, in Vaasa.

4. Findings

This chapter details the empirical results of the qualitative interviews conducted for this study. The analysis focuses on the role of AI-based incentive systems in potentially supporting residents' digital participation in waste collection and CE initiatives, particularly among immigrant and unemployed individuals in the Vaasa region. The results are based on semi-structured interviews conducted with stakeholders involved in municipal waste management, regional development, local government, and digital CE initiatives.

Thematic analysis was used to examine the interview data. Each transcript was analyzed for relevant segments that pertained to CE participation. Each relevant segment was coded to capture the ideas expressed by the participants. An iterative coding process was used to examine the variation within the coded interview data, which helped identify patterns and socio-structural factors that influence participation in the CE as perceived by stakeholders.

A total of 26 preliminary codes were derived from the interviews and organized into broader thematic categories which are illustrated in Table 2.

Table 2. Overview of Interview Codes and Thematic Categories

Theme	Codes	Descriptions
Structural barriers to participation	C1–C6	Communication barriers, instruction visibility, digital access, and cultural adaptation challenges
Digital tools without engagement	C7–C10	Informational digital tools lacking engagement mechanisms and feedback
Informal circular practices	C11–C14	Community reuse activities occurring outside formal waste management systems
Incentive mechanisms	C15–C18	Financial incentives and economic participation opportunities
Environmental and economic impacts	C19–C22	Hidden environmental emissions and financial costs related to improper waste sorting

Ecosystem coordination	C23–C26	Fragmentation among CE actors and lack of coordinating intermediary

While creating these themes, attempts were made to group codes based on similarities and relationships, as well as identify key structural elements influencing participation in the CE. This resulted in a thematic structure that depicts broader patterns that permeate the perspectives of multiple stakeholders rather than the individual perspective of a single participant.

Consistent with the Finnish research ethics guidelines and the institutional requirements, the identities of the interviewees are not disclosed in this thesis. Interviewees are referred to according to their institutional positions. The four interviewees included in the analysis are therefore identified as the ELY-Keskus representative, Former Kamupak CEO, Stormossen representative, and City of Vaasa representative. This approach preserves participant anonymity, while allowing the analysis to differentiate between the perspectives of the different institutional actors.

The thematic analysis revealed six key themes that influence participation in the CE in the Vaasa context:

1. Structural Barriers to Inclusive Circular Participation
2. Informational Digital Tools Without Engagement Mechanisms
3. Informal Circular Practices Without System-Level Integration
4. Invisible Economic Value and Missed Incentive Potential
5. Hidden Economic and Environmental Costs of Improper Waste Behavior
6. Ecosystem Fragmentation and Intermediary Potential

The findings are presented using a structured narrative approach that clarifies the results by weaving them thematically across three layers of analysis. First, the system problem refers to the operational or behavioral issues that were highlighted in the interviews. Second, the structural gap describes the fundamental constraints or limitations in the current waste management system and participation structures within the CE. Finally, the potential digital solution outlines how the identified gaps can be addressed using AI-driven, incentive-based mechanisms. This analytical framework assists in relating the results to the perceived challenges to the suggested digital engagement model.

The interviews also show that there are several practices in the CE system at Vaasa that demonstrates how the CE principles are practically applied, as well as some structural limitations inhibiting citizen participation. The challenges are essential to answer the research question of this study, which is to evaluate how AI-based participatory incentive systems can be applied to facilitate participation in waste collection and CE activities and contribute to the economic inclusion of marginalized groups. Each theme is further explained in the following sections and the findings are given, backed by the interview data.

4.1 Diagnosing the Current System

This section is an analysis of the present situation of CE involvement in Vaasa. It is about the structure of the waste sorting and circular processes within the current waste management system and participation issues that emerge in daily encounters with the system. Although Vaasa has an elaborate system of waste management and recycling channels, interview evidence indicates that structural and behavioral factors are the determinants of citizen participation in the system.

The analysis of the interview on the current situation revealed two major themes. The former theme will cover the structural obstacles which limit the active involvement of various groups of citizens in the CE activities. The second theme deals with the environmental and economic implications of poor waste disposal. Combined, these results suggest that, although the waste management system may be quite efficient at the level of the institutions, the main issues of participation lie at the stage where citizens engage in this system in their everyday activities.

4.1.1 Structural Barriers to Inclusive Circular Participation

Structural factors that can determine participation in CE activities are communication accessibility, behavioral convenience, digital onboarding processes, and cultural adaptation. These aspects influence the way people engage with the waste management system and may cause obstacles that reduce engagement in CE programs.

The interviews highlighted language accessibility issues regarding sorting instructions as one of the key challenges. The issue is captured in **C1: Multilingual communication gap**, which illustrates the problems the residents may face when sorting instructions are

provided in languages they cannot read. A representative from Stormossen described a situation in a residential building where sorting performance was extremely low despite correct sorting infrastructure being in place. The investigation showed that the poor performance was not caused by the infrastructure, but rather communication problems. The representative mentioned that *"all the sorting information was written only in Finnish."* Many residents in this building were immigrants, so they could not understand the provided instructions and, as a result, performed incorrect waste sorting.

This challenge is especially important given the diverse backgrounds of individuals in Vaasa. A representative from the City of Vaasa stated that *"Vaasa has more than 100 spoken languages."* In such a multilingual context, providing instructions only in Finnish or Swedish may be restrictive for people still learning the local language. The ELY-Keskus representative also noted this issue. Such language limitations may make the waste management system difficult to understand for many newcomers. From the viewpoint of digital circular platforms, the former Kamupak CEO noted that language accessibility in digital platforms also affects technology adoption, saying that *"language can become a barrier if the application is not available in multiple languages."* These insights indicate that successful participation in the CE depends on communication systems that accommodate linguistic diversity.

Another issue concerns the visibility and accessibility of sorting instructions. This concern is captured in **C2: Instruction visibility and accessibility failure**. This refers to situations where instructions exist but are not located where waste sorting decisions are made. A representative from Stormossen stated that instructions are posted in places that residents do not pay attention to: *"sometimes instructions exist but are placed in a drawer and people do not see them."* The City of Vaasa representative also commented that for communication to be effective, the information must be placed in an accessible location, saying "*I am not sure whether instructions are always clearly provided or visible in apartment buildings."* In the same manner, the representative was uncertain whether sorting instructions are consistently displayed in apartment buildings, which means that residents may not encounter sorting instructions when using the waste sorting facilities.

These comments show that providing information alone is insufficient when the design and placement of communication materials disregard usability.

The interviews indicate that behavioral convenience plays a role in participation in CE activities. This issue is captured in **C3: Behavioral friction and inconvenience**, which refers to situations where additional effort discourages individuals from engaging in circular practices. The former CEO of Kamupak noted that *"the biggest barrier to adoption was inconvenience,"* highlighting the importance of convenience in circular system adoption. Even small additional actions may discourage individuals from engaging in circular practices. The interviewee illustrated this point well by stating *"even a small additional effort can discourage people."* From the vantage point of the operations of waste management, the representative from Stormossen noted that people gradually adopt the desired sorting behavior, and then it improves as they interact with the system repeatedly and learn how it functions. *"Sorting requires repetition, monitoring, and continuous reinforcement."* These comments indicate the considerable participation barrier posed by the degree of effort required to incorporate circular processes into individuals' daily routines.

There are also barriers within digital systems that may arise from onboarding processes that are complex or that require the submission of sensitive personal information. This issue is captured in **C4: Digital onboarding and trust barriers**, which reflects concerns related to registration requirements and digital accessibility. The former Kamupak CEO described digital reuse systems as requiring users to set up an account and provide credit card details to receive reusable containers back. Such requirements may exclude some people from participating. As the interviewee stated, *"users needed to provide credit card details,"* which may discourage people who do not feel comfortable sharing their financial information in a digital setting. There is also the issue that some people are unable to participate due to limited digital access or skills. The same interviewee stated, *"not everyone has a smartphone or knows how to use an app."* These findings indicate that although digital systems can support CE activities, they can also exclude people if the requirements for system use are not designed to incorporate different levels of accessibility.

Cultural adaptation to waste sorting practices is another factor that influences participation. This issue is reflected in **C5: Cultural adaptation and learning curve**. C5 identifies that CE behaviors are learned through experience and socialization. A representative from the City of Vaasa indicated that most new residents come from countries where waste management systems operate differently from Finland by stating *"People come from countries with very different waste systems."* As such, the Finnish waste management system may be unfamiliar and require time and guidance to learn. The Stormossen representative also noted that they had to adjust their communication strategy because they recognized that *"communication works differently across cultures."* These observations suggest that participation in CE practices requires learning, education, and gradual adaptation.

The interviews show that unwillingness to participate is not a barrier to waste sorting participation for most residents, but rather a structural information gap. This is evidenced in **C6: Structural information gap**, which highlights that incorrect waste sorting often occurs due to limited access to clear information. The Storemossen representative pointed out that *"Sorting issues arise due to lack of information rather than lack of willingness."* In fact, the interviews suggest the opposite, by stating *"Many immigrants are motivated to follow societal norms."* These observations suggest that the barriers to CE participation are not the attitudes of residents, but limitations in communication design and system accessibility.

The findings indicate that structural barriers related to communication, behavioral convenience, digital accessibility, and cultural adaptation and learning processes all impact participation in the CE. These findings also suggest that addressing these structural barriers will enable more inclusive participation in CE systems.

4.1.2 Hidden Economic and Environmental Costs of Improper Waste Behavior

In addition to participation barriers, the interviews also revealed that improper waste sorting leads to environmental and economic impacts that citizens are often unaware of. These impacts, which are not always visible, are detrimental to the efficiency of existing waste management systems and highlight the need to improve participation in the CE. While waste management systems function well at the local authority level, residents

are not always provided with clear explanations of the wider environmental and economic impacts of individual waste behavior.

One key insight concerns the environmental impact of waste management practices. This is captured in **C19: Waste management as a major emission source**, which addresses waste management's place in broader climate and sustainability strategies. In the case of Vaasa, the City of Vaasa representative stated that waste management is a climate action priority. As the representative explained, "*waste management is the third-largest emission source in the city.*" This suggests that waste sorting requires a broader system-level approach that goes beyond the individual behavioral changes at the household level. When recyclable waste is captured in mixed waste, opportunities for recycling and material recovery are lost, increasing emissions associated with waste processing and disposal. Therefore, improved sorting and recycling participation could lead to a corresponding reduction in greenhouse gas emissions and the achievement of municipal climate goals.

The interviews also highlighted the costs that arise from improper waste sorting. This issue is captured in **C20: Financial costs of improper sorting**, which shows the added operational costs incurred when waste is incorrectly sorted. A Stormossen representative said that it is significantly costlier to process mixed waste than to properly separate fractions, particularly bio, metal, or cardboard. When recyclable materials are disposed of as mixed waste, they cannot be collected and thus they cannot recover thereby raising the costs of processing and transporting the waste, since they will have to be processed as residual waste. The representative referred to a residential building where better waste sorting was implemented, and there were significant financial savings. "Improved sorting reduced mixed waste and saved nearly 2,000 euros annually." This is a clear example that better waste sorting can reduce operational costs for waste management organizations and generate financial savings for housing communities and residents.

Many residents have limited understanding of the economic impacts associated with their waste practices. This problem is highlighted in **C21: Citizens lack awareness of system-level costs**, which indicates the limited visibility of financial consequences within the waste management system. The Stormossen representative stated that residents are

more likely to change their behavior when they understand how their actions affect waste management costs. The representative further explained that *"residents must see the benefit in reduced monthly costs."* When the costs of properly sorting waste are integrated into the municipality's operational system and hidden from residents, they may lack a clear incentive to change their behavior. If these economic impacts remain hidden, residents might lack the incentive to adjust their waste practices or invest additional effort in participating in CE activities.

In addition to environmental and economic factors, the interviews shed light on the importance of governance frameworks in influencing waste management behavior. This issue is reflected in **C22: Waste governance** influences behavior, which refers to how governance structures and policy tools shape citizen participation in waste sorting. The Stormossen representative described how countries differ in how they encourage correct waste sorting behavior. The representative noted, for instance, that *"countries like Germany impose graded penalties"* for failure to sort waste. These policies have direct impacts of bad waste disposal and they can result in increased adherence to sorting policies. Conversely, Finland is less dependent on the enforcement of rules and regulations to encourage waste sorting through information campaigns, incentive-based strategies, and voluntary participation compared to other countries. Such differences in the systems of governance underline the contribution of policy and organizational design to the relationship between the citizen and the waste management systems.

The findings show that improper sorting has effects on the environment, monetary expenses, and governance problems that are often not realized at the domestic level. Although waste management systems are efficient at the institutional level, the overall impacts of individual waste behavior are mostly concealed in the operational and policy provisions. Therefore, it is essential to create awareness regarding the impacts of improper sorting as a motivating factor of joining the CE initiatives.

The analysis shows that the systems of waste management of Vaasa in terms of its infrastructure and operational systems are both in place and operational. The results indicate that waste sorting and recycling systems and the policy framework underpinning the CE are already in place. However, the interviews indicate that the stakeholders think there

is still limited citizen level engagement. The participants reported structural barriers in terms of accessibility of information and visibility of information, the convenience of behavior and the digital accessibility. Furthermore, the ecological and economic impacts of improper waste sorting are often unknown to people, which may decrease the incentives towards behavior change. Such findings suggest that lack of infrastructure is not the major factor that has contributed to participation issues, but the system has structural weaknesses in its system of communication, motivation, and citizen outreach. These structural gaps are discussed more in the next section.

4.2 Identifying Structural Gaps

The discussion above demonstrated that the waste management system in Vaasa is functionally sound, yet the structural constraints limiting the involvement of more people in CE activities are also evident in the interviews. Although there are infrastructure, policies and recycling systems, stakeholders reveals that there may be a lot of differences among various demographic groups in terms of participation. The discussion thus transcends the description of the capacity of the system to operate but rather on the structural constraints which restrict the wider involvement of citizens to CE activities.

There are three main themes that can be drawn out of the interviews, and these are the reasons why the current system is not fully inclusive in participation. These themes relate to the lack of engagement ability of the digital systems available, informal circular practices that are not part of the formal waste management system, and the financial incentive mechanisms that are not exploited. In general, these themes imply that although fragmented CE practices are already present in the community, they are inadequately incorporated into a logical framework of participation.

4.2.1 Informational Digital Tools Without Engagement Mechanisms

A structural gap found during the interviews is associated with the absence of digital means through which citizens can actively engage in the CE processes. Although certain digital tools provide the information on how to sort and recycle waste, the data shows that they are rather passively used to give information instead of actively involving the users. This issue is captured in **C7: Informational digital tools without behavioral**

engagement, which highlights the concern that current digital solutions provide guidance but do not meaningfully influence user behavior or participation.

The Stormossen representative explained that the organization offers digital guidance via a mobile app that provides instructions for sorting waste in several languages. However, the representative acknowledged that this tool is underutilized. As the representative explained, *"we already have a phone application that provides sorting instructions in three languages, but people do not use it."* This is a critical observation that highlights a key structural limitation: while digital instructions exist, the way they are designed does not encourage user engagement or sustained participation. Rather than functioning as interactive tools that encourage participation, the applications merely serve as a passive repository of sorting instructions that need to be actively sought out by users. Therefore, the mere offering of digital tools does not lead to the intended behavioral change or heightened involvement in CE activities.

Interview participants pointed out the lack of participation tracking systems as one of the limitations. **C8: Lack of participation tracking systems**, describing the lack of current digital tools that can track, or generate, valuable insights on the participation of citizens. One of the Stormossen representative's main concerns was how to identify active and passive participants among those receiving waste sorting guidance. As the representative stated*, "the challenge is that the people who need the information most do not engage".* Municipal actors need to rely on digital tools to track participation to identify room for improvement in a communication strategy. Lack of participation tracking systems is detrimental to the waste management sector, as it prevent actors creating strategies.

The interviews also underscored the importance of feedback regarding the environmental impacts of personal behaviors. This issue is reflected in **C9: Absence of feedback and impact visibility.** This code emphasizes a structural gap resulting from the lack of feedback systems that show the impact of their participation in circular practices. The former Kamupak CEO stated that individuals are more motivated to participate when environmental benefits of their actions are visible. As the interviewee explained, *"people want to understand what impact their actions create."* In the absence of feedback mechanisms,

individuals might think that their contributions to recycling or waste diversion are insignificant. The absence of feedback systems that would show how individual action affects the situation may decrease motivation and weaken further participation in CE activities. Other limitations were also found during the interviews such as the low use of digital tools to facilitate participation by incentive-based mechanisms. This issue is reflected in **C10: Untapped potential of digital incentive systems**. This code refers to engagement strategies that have been discussed but have not yet been implemented. A representative from the City of Vaasa explained that policy discussions have considered the introduction of digital participatory tools to incentivize citizens. One such method is to promote engagement through the conceptual idea of digital competitions between communities based on waste sorting performance. As noted by the representative, *"there has been discussion about creating competitions between districts based on sorting performance, but it remains conceptual."* This indicates that digital incentive mechanisms are acknowledged for their potential effectiveness but have not been incorporated into the operational waste management system.

Overall, these data suggest that digital tools are nowadays characterized by a small part in active involvement of individuals in CE initiatives. Digital platforms provide a portion of the data on CE practices, yet they lack a range of other desired features such as interactive engagement system, participation tracking, visible feedback system that indicates the effect of participation, and digital engagement rewards. Consequently, most digital platforms are mostly informational and do not include active tools to change behavior or get more people involved in the CE efforts.

4.2.2 Informal Circular Practices Without System Integration

Another structural gap that was also pointed out in the interviews is associated with the informal practices of CE that are outside the official municipal waste management system. Even though the city has developed waste collection and recycling facilities, as seen during the interviews, there are many circular activities both at the community level and on online platforms. This kind of activity shows that the communities already practice reuse and resource recycling. Nevertheless, lack of integration of these practices with the official waste management system implies that their potential is not fully exploited

but not planned in relation to the broader CE objectives. This gap is illustrated in **C11: Informal reuse platforms already exist**, which emphasizes community-led reuse practices functioning beyond the official waste management framework.

The City of Vaasa representative stated that there are several platforms that residents use to exchange second-hand items and reduce waste. In the words of the interviewee, *"residents already use Facebook groups - Roskalava, Tori, Minimosan, Kirrpis and other second-hand platforms."* Such platforms facilitate the exchange, resale, or redistribution of unwanted items. These practices help extend product lifecycles and reduce the volume of waste generated. These programs imply that practices of reuse and waste minimization are already integrated in the community, without necessarily the involvement of municipal waste management institutions. In most cases, members of the community reuse, an extension of their daily consumption, which proves that CE practices are already present on the community level.

Although these activities exist, the interviews indicate that users engage in reuse and CE activities across several digital platforms that function separately from one another. This issue is reflected in **C12: Fragmented circular participation channels**, which highlights the lack of integration between reuse platforms and the formal waste management system. A representative from the City of Vaasa stressed that multiple, stand-alone platforms create fragmentation in the CE ecosystem. *"These systems are fragmented."* With reuse activities being carried out on multiple separate digital platforms, at present, there is no unified system linking these activities to broader CE initiatives or municipal sustainability goals.

This observation corresponds to **C13: Lack of CE measurement**. This code describes community reuse activities, which are typically invisible to the official waste management system. This is confirmed by the Stormossen representative's stament that *"Informal reuse channels such as Roskalava already exist."* The Stormossen representative noted that informal reuse channels are already contributing to local waste reduction efforts. Roskalava and similar platforms enable community members to exchange items, which enables items to be reused instead of being discarded as waste. As they are informal and

not part of formal institutional arrangements, they are not included in the municipal CE and sustainability reporting systems.

The invisibility of these activities creates additional structural challenges related to the availability of reliable data for monitoring the performance of the CE. This challenge is reflected in **C14: Missing data for strategic decision making**, which points to the lack of integrated data systems that capture informal reuse activities. The Stormossen representative pointed out that monitoring CE activities across the city remains limited, stating that *"we need better dashboards and visibility tools."* If there are no integrated data management systems that integrate informal reuse systems and municipal monitoring systems, policymakers and waste management entities encounter challenges in accurately evaluating the true scale of CE participation.

The lack of visibility also limits the ability of municipal actors to integrate community-based circular activities into their strategic planning. When reuse activities carried out on community platforms remain outside official monitoring systems, policymakers face difficulties in assessing how these activities contribute to waste reduction targets and climate objectives. As a result, a significant portion of CE activities that take place in the community remains outside formal governance arrangements.

Community-level CE behavior is evident in the findings. However, these activities are dispersed across several online platforms and disconnected from formal waste management systems. Informal reuse platforms showcase individuals' active participation in resource exchange. Unfortunately, the lack of system integration prevents the activities occurring on these informal platforms from being integrated into local CE strategies. This shows that the potential of community-driven circular participation remains underdeveloped in the current system.

4.2.3 Invisible Economic Value and Missed Incentive Opportunities

The interviews revealed a third structural gap concerning the limited use of financial incentives in driving participation in CE initiatives. The existing waste management system provides both infrastructure and information for the correct sorting of waste. Yet research findings suggest that behavioral economic factors play a crucial role in promoting proper waste separation practices. Nevertheless, economic incentive mechanisms for

circular participation have been largely ignored. This observation is captured in **C15: Pantti system demonstrates incentive success**, which shows that deposit-based recycling schemes successfully encourage recycling behavior.

Interview participants frequently referred to the Pantti deposit-refund system, which provides a small monetary reward when beverage containers are returned to designated collection machines. A representative from the City of Vaasa stated that the system is well known among residents across different demographic groups, and *"many immigrants and students are familiar with the Pantti system."* This high level of recognition demonstrates that financial incentives can effectively encourage participation in circular practices. Pantti system is not similar to other recycling programs because it is the only program to directly reward the efforts of the participants. The system does not allow the participants to dispose containers in the trash, but it rewards them to re-drop it in the machine. The Pantti system pro-vides an excellent example of a deposit-refund system, which can be employed to encourage the users to engage in a CE.

Although the Pantti system has been found to be a useful tool, interviews have revealed that people continue to lack understanding of the potential economic value of the other waste fractions. This issue is captured in **C16: Waste value awareness gap**, which reflects the limited public awareness of the potential, monetary value that can be found in various waste fractions. A representative from the City of Vaasa stated that most residents do not understand that numerous waste fractions contain materials that can generate economic value through recycling or resource recovery. The representative further noted, *"most people are unaware that other waste fractions may also have value."* Since the economic potential of waste materials is not obvious, residents may not fully recognize the importance of waste sorting and reuse. This restricts the efficiency of the existing waste management system.

The interviews further clarify that financial incentives are important for both the adoption and long-term continuation of circular behavior. This observation is reflected in **C17: Financial incentives drive behavioral change**. The former Kamupak CEO explained that it was a matter of financial motivators that drove user engagement with the CE initiatives, explaining that *"financial incentives are the most important factor."* Individuals are more

likely to adopt and maintain circular behaviors when there are clear personal financial benefits to be made from the activities. If participation does not provide visible personal benefits, then the engagement will likely be low, as the activities may require additional participation. Financial incentives can therefore be an effective mechanism for encouraging participation in CE initiatives.

Engagement in the CE can also create economic opportunities within society, alongside influencing environmental conduct. This observation is captured in **C18: Economic participation opportunities for marginalized groups**, which emphasizes how CE frameworks can generate new types of economic involvement for underserved communities. The former Kamupak CEO explained how circular initiatives might generate chances for people to engage in activities such as collection, redistribution, and reuse. As one interviewee noted, *"if people can earn money within the system, it benefits everyone."* This kind of opportunity is valuable for immigrants and the unemployed, who are looking for chances to engage in economic activities while integrating into the local job market. When CE initiatives are also designed to provide income-generating opportunities, they can help meet both social and environmental goals.

The findings imply that whereas the Pantti deposit system demonstrates the successfulness of financial rewards in certain settings, similar processes have not yet been fully incorporated into broader CE engagement approaches. The fact that the economic value of waste products has been limitedly recognized, and the use of incentive-based participation models underdeveloped, is a critical structural gap of the existing system. Strength-enhancing financial incentives and raising awareness of the economic value vested in waste materials may contribute to boosting the participation of ordinary people in CE activities.

The evidence demonstrates that CE initiatives are currently taking place in the Vaasa area via formal waste management systems and informal community led reuse activities. However, these activities are highly fragmented and are not incorporated into a unified participation framework. Digital tools mainly serve to provide information instead of acting as platforms for participatory engagement. But more importantly, informal reuse activities largely operate outside formal waste management systems and people

frequently do not recognize the economic value embedded in waste materials. Overall, the system still does not fully maximize the potential of digital engagement, community participation, or incentive-based mechanisms. This is the motivation for the next section, which investigates how the CE framework might develop by addressing these structural constraints.

4.3 System Transformation Potential

The prior section identified some structural limitations that create barriers to inclusive participation in CE activities. However, interview findings highlight opportunities for system development within the existing CE system. Although the Vaasa region has well-developed waste management systems, institutional actors, and avenues for community participation, interview participants indicated that these elements do not yet operate as a fully coordinated system. Rather, CE activities are implemented in a fragmented manner by numerous actors and initiatives that operate independently.

This analysis, therefore, goes beyond merely noting structural limitations. It also takes into account how the CE system can be developed as a result of a more robust ecosystem coordination. The participants of the interviews pointed out that the essential actors and infrastructure are already involved in al-ready the Vaasa CE ecosystem. However, the absence of a system that coordinates the system prevents the ability of the system to combine these parts effectively. Therefore, the possibilities of wider participation, increased transparency of the data, and better collaboration between the parties are not fully exploited.

One of the themes that emerged as a result of the interviews is the possibility of a change at the system level: the loss of ecosystem integrity and the lack of a coordinating entity. This theme represents the role of different actors in the formation of the CE including the local governments, waste management companies, businesses, and community initiatives. However, their operations tend to be disjointed due to the differences in the institutional roles, system of governance, and operational duties. Improving the cooperation between these stakeholders could thereby indicate a significant move towards better participation, and more effective expansion of CE initiatives.

4.3.1 Ecosystem Fragmentation and Intermediary Potential

The interviews indicated that the major stakeholders play a role in contributing to the CE ecosystem in Vaasa. They include regional development entities, local governments, waste management companies, corporations, and community-based programmes. This observation corresponds to Code **C23: Multiple Actors Exist but Lack Coordination**, which reflects the presence of these stakeholders, the ecosystem still lacks strong operational coordination.

An ELY-Keskus representative described regional authorities as primarily strategic coordinators rather than operational implementers, stating that *"our role is like an orchestra coordinating regional development."* This metaphor suggests that regional stakeholders focus on setting and aligning regional development priorities that include sustainability initiatives. However, despite this strategic coordination, operational tasks continue to be fragmented among various stakeholders who mainly operate within their own institutional roles in CE efforts.

This issue is reflected in Code **C24: Institutional and Legal Constraints**, which emphasizes how legal and governance structures influence the functioning of CE initiatives. The Stormossen representative noted that the governance structure of municipal waste management clearly defines roles and responsibilities for household waste management, stating that "*household waste becomes the property of the municipal waste company."* Such frameworks are designed to ensure accountability in waste management systems, but they also shape the extent to which new circular initiatives may be integrated into existing systems. Therefore, it can be observed that legal frameworks are critical in defining how alternative participation models can operate within the system.

This issue corresponds to **Code C25: Operator Gap in the Circular Ecosystem**, which emphasizes the lack of a coordinating intermediary entity linking various stakeholders. While multiple actors participate in CE activities, there is currently no mechanism through which households, digital participation platforms, municipal waste operators, and community reuse initiatives are systematically connected. The former CEO of Kamupak noted this gap and stated, *"there is room for someone operating between*

ecosystem players." This observation highlights the absence of a coordinating intermediary in the ecosystem.

This finding is captured in **Code C26: Ecosystem Collaboration Needed for Implementation**, which emphasizes the significance of collaboration among municipalities, businesses, and community stakeholders when executing CE initiatives. The ELY-Keskus representative stated, *"practical implementation would require coordination with multiple stakeholders,"* emphasizing that municipalities, businesses, and community actors would need to work together. This observation underscores the absence of a coordinating intermediary in the ecosystem.

A variety of key elements of effective CE participation already exist in the Vaasa CE ecosystem. However, the absence of intermediary coordination mechanism limits the ecosystem ability to integrate existing actors, link fragmented act of circular activities, and collect complete participation data. In the absence of such coordination, circular activities within communities, digital systems, and municipal platforms remain partially disconnected.

The CE ecosystem in Vaasa includes several community initiatives, institutional actors, and infrastructure, but the evidence suggests that these elements currently operate in a fragmented manner. The absence of a coordinating intermediary limits the ecosystem's ability to integrate existing circular activities, strengthening collaboration among stakeholders, and expanding participation in the system. Thus, strengthening coordination among ecosystem actors is an important opportunity to enhance the CE system by enabling broader and more inclusive participation.

To synthesize the interrelationships among the identified themes and analytical layers, figure 2 illustrates the CE participation challenges, structural gaps, and system transformation opportunities identified in the Vaasa context.

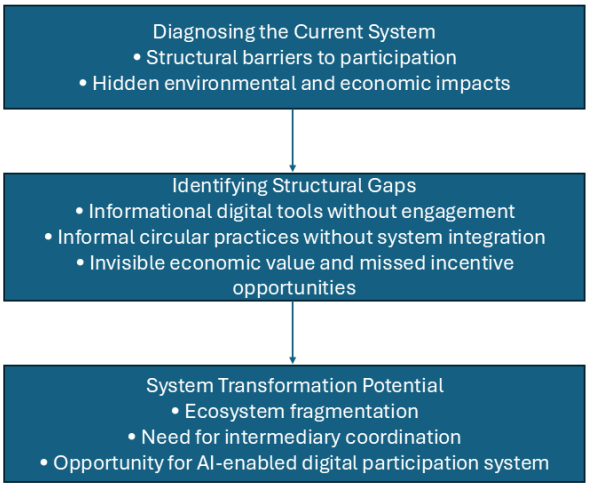

Figure 2. CE Participation Findings and Structural Gaps Identified in Vaasa

4.4 Synthesis of Findings

This chapter presents empirical findings from qualitative interviews with regional governance, municipal administration, waste management, and representatives from digital CE initiatives. The interviews and thematic analysis of the data yielded multiple interconnected findings regarding participation in waste management and CE activities. The findings point to three analytical layers: diagnosing the current system, identifying structural gaps, and examining system transformation potential.

The findings also suggest that the waste management system in the city of Vaasa is institutionally well developed and is supported by governance mechanisms and structured waste sorting practices. For instance, municipal waste management actors, such as Stormossen, operate organized systems that separate multiple waste fractions, and the city's sustainability strategies have positioned waste management as an important component of the city's climate policy. Nevertheless, despite this robust institutional framework, stakeholders reported differences in engagement among demographic groups. As a result of the interviews, a number of structural barriers have been identified as a basis for the gaps in the participation of citizens, encompassing language accessibility, visibility and clarity of instruction, cultural learning processes, and behavioral convenience. The

findings also suggest that these barriers are primarily informational and structural, rather than motivational. Many residents, even immigrants, have shown a strong willingness to follow societal norms.

Structural gaps identified in the findings indicate potential inefficiencies in existing CE initiatives. Although digital tools already exist within the waste management system, these systems currently serve informational rather than interactive purposes. Existing applications provide sorting guidance, but most lack engagement mechanisms, participation tracking, and feedback systems. Moreover, CE activities also occur informally within communities through second-hand markets and local reuse networks. This isolation of community-based reuse networks from municipal CE systems makes reuse behavior and citizen participation largely invisible within formal monitoring systems. Conversely, financial incentive mechanisms demonstrate how economic rewards can motivate circular participation, as evidenced by the Pantti deposit-refund system. Furthermore, similar incentive mechanisms are not implemented in other waste streams. Therefore, financial incentives can encourage broader participation by helping residents recognize the economic value of waste materials.

Lastly, the current CE ecosystem indicates opportunities for system transformation. The Vaasa region has a variety of actors involved in sustainability initiatives, such as municipal authorities, regional development organizations, waste management operators, digital platforms, and community initiatives. Unfortunately, these actors often operate within separate institutional structures, and coordination between them remains limited. Interviews reveal the absence of a coordinating intermediary mechanism capable of connecting households, digital platforms, waste management actors, and community reuse initiatives. Without such coordination, various CE initiatives remain fragmented and difficult to scale.

Taken together, for the system to change, new CE initiatives alone are not sufficient. Instead, better integration of existing actors, information systems, and incentive mechanisms is required. Improved communication, digital engagement tools, integration of informal circular practices, and incentive-based participation models can all collectively enhance citizen participation in the CE. There is promise in digital platforms to facilitate

coordination between stakeholders, while offering citizens accessible guidance, feedback, and economic incentives for their engagement.

Overall, the empirical results indicate that digital engagement mechanisms, especially those that utilize AI and incentives, may help address the participation barriers and structural gaps identified in the CE system. It is suggested that an online participatory ecosystem solution, which integrates guidance, participation monitoring, economic incentives, and ecosystem coordination in a single platform, could enhance participation in waste collection and CE activities among immigrants, unemployed individuals, and the broader public. The next chapter discusses these findings in the context of existing literature and evaluates how the proposed conceptual model contributes to CE participation strategies at the global and local levels.

5. Discussion

The research focused on the potential of AI-powered and incentive-based digital solutions to support the involvement of immigrant and unemployed populations in the Vaasa region in the waste management system and CE activities. While Finland has a highly advanced waste management system, stakeholders indicate that stakeholders indicate that there is uneven participation among various social groups in CE activities. As a result, the study focused on understanding citizen participation and the role of digital engagement solutions in supporting broader participation in CE activities.

The study employed a qualitative case study approach and conducted semi-structured interviews with stakeholders in municipal waste management, regional development, and digital CE initiatives. Thematic analysis presented in Chapter 4 identified several key factors contributing to participation challenges, such as communication barriers, inadequacy of existing digital participation mechanisms, incentive-based participation mechanisms and a fragmented CE system.

This chapter discusses the results in the context of the literature and the study's guiding theories, the TAM, and the TPB. The discussion explains the key findings, analyzes the implications from both practical and theoretical perspectives, and examines the relevance of the proposed conceptual model for supporting participation in CE initiatives. The chapter also analyzes how the findings address the research questions on how participation may be supported, how social inclusion is perceived in this context, and the potential relevance of the proposed model beyond the Vaasa region.

5.1 Discussion of Key Findings

This research highlights several interconnected factors influencing participation in the CE. These include structural barriers that limit citizen participation, the limitations of existing digital participation mechanisms, the motivational role of incentives, and the fragmentation among CE actors. Overall, the findings provide insights into the behavioral, technological, and institutional aspects of participation in municipal CE systems. Although the empirical data were collected in Vaasa, several of the identified challenges appear similar to those described in CE initiatives in other cities. For this reason, the

discussion interprets these findings from the viewpoint of the local context, as well as their potential relevance for facilitating participation in similar urban CE contexts.

5.1.1 Structural Barriers to CE Participation

The results show how involvement in the CE can be limited by a range of structural barriers, including barriers related to communication, information, digital accessibility, and cultural adaptation. Interviewees pointed out that, for immigrants who are still learning the local language, sorting instructions that are available in Finnish and Swedish pose an added challenge. Furthermore, unclear sorting instructions and the lack of visibility of information can lead to situations where residents are unable to access the information needed for correct sorting.

These results are consistent with previous studies which have identified that the accessibility, ease of use, and awareness of the recycling systems and related information are key factors in promoting recycling (Abila & Kantola, 2019; Iqbal et al., 2022). Previous studies have suggested that barriers to participation are often related to shortcomings in communication and system design, rather than a lack of willingness to engage in sustainable behaviors. Stakeholders in this study similarly indicated that many residents appeared willing to participate in sustainable practices but faced barriers due to limited understanding of the waste sorting system or lack of accessible information.

The TPB provides an explanation for the findings of this study. According to TPB, attitudes, social norms, and perceived behavioral control influence individuals' intentions to engage in a particular behavior. Although people have favorable views on sustainable practices, perceived behavioral control can diminish when structural barriers are present. For instance, unclear sorting instructions or language barriers might hinder people's understanding of the waste sorting system, thereby complicating participation.

These obstacles emerge clearly in the local context; however, similar findings have been observed in other multicultural urban environments. Communication barriers, multilingual guidance, and user-centered system design may therefore support greater participation in CE initiatives globally.

5.1.2 Role of Digital Facilitation in Circular Participation

The findings also show that while the Vaasa CE system includes several digital tools, these tools are mainly informational and lack interactive features. Interviewees mentioned that these digital tools provide instructions for waste sorting, but few residents use them. Moreover, existing digital tools do not provide participation tracking, environmental impact feedback, or other incentive-based features.

Existing research highlights the role of digital technologies within CE systems. Digital tools support communication, tracking waste and recycling activities, providing environmental feedback, and managing sustainability initiatives. However, previous studies indicate that digital tools are less effective when they provide only static information instead of actively engaging users.

The TAM suggests that individuals adopt new technologies when they perceive them as useful and easy to use. This applies to digital tools that support participation in the CE. If digital tools offer simple guidance, personalized feedback, or make the environmental impact of user actions visible, people may find the tools more useful and engaging. Without these features, systems may not provide strong motivation for users to interact with them regularly. This may be why many users did not interact with the digital tools in the Vaasa context.

The challenges that have been identified in the Vaasa context have also been observed in other urban sustainability initiatives involving digital tools. This suggests that without feedback mechanisms, engagement features, and incentive systems, digital tools are unlikely effectively support participation in the CE. These findings may also hold relevance for other cities facing similar participation challenges, demonstrating the importance of user-centered design in digital tools for supporting CE participation.

5.1.3 Incentive Mechanisms and Behavioral Motivation

The incentive mechanisms that encourage participation in CE practices were also highlighted in this study. Several interviewees mentioned the success of the Finnish Pantti deposit-refund system, where consumers receive money for returning beverage containers. Such systems show that financial incentives, regardless of size, can lead to increased

recycling. The interviews also uncovered that many residents lack awareness of the potential economic value contained in other waste streams. This lack of awareness can undermine the incentive to participate in recycling activities that generate economic value. Previous research supports these findings and shows that economic motivators affect recycling behavior. Mechanisms that promote financially motivated actions, including deposit-refund systems and reward programs, have been well documented as drivers of pro-environmental behavior. According to the TPB, incentives may strengthen positive attitudes toward recycling as well as reinforce social norms within a community. Incentivized recycling schemes can reinforce recycling as a socially accepted behavior as more people take part in the activity. These observations are based on the Vaasa case, but the implementation of such incentive mechanisms, to improve recycling, has been undertaken in other countries as well. Therefore, expanding incentive systems to other waste streams may support engagement in CE activities in other municipalities facing similar conditions.

5.1.4 Fragmented CE Ecosystem

The findings of this study reveal that in the Vaasa region's CE ecosystem, municipal bodies, waste management entities, companies, and community initiatives are key actors in this ecosystem. However, the independent operation of these actors contributes to the fragmentation of CE initiatives. Effective CE systems, as previous studies indicate, are a result of integrated and cohesive efforts by multiple stakeholders. Poorly integrated governance leads to circular activities, such as recycling, reuse, and resource recovery, remaining disconnected and difficult to scale. The findings indicate that the main obstacle in the Vaasa CE ecosystem is not a shortage of actors; it is the coordination deficit. One approach to this problem is the use of digital platforms that act as intermediaries and coordination tools between the community, waste management actors, and reuse initiatives. Although this problem was identified in the context of Vaasa, it is a governance problem that has been observed in many other regions implementing CE initiatives. Therefore, a combination of enhanced cooperation and digital participation systems in urban CE governance systems may be needed to address challenges in CE implementation.

Though this study is based on Vaasa, the factors of participation noted in this research are problems that are common in most multicultural cities, and therefore, the suggested model could be significantly applicable in various international settings facing comparable participation issues.

5.2 Theoretical Contribution

This research contributes to the CE literature by analyzing citizen participation in municipal waste management systems from both behavioral and technological perspectives. Previous research has focused primarily on the operational and technological aspects of CE systems while examining citizen participation to a lesser extent.

A key contribution of this study is the integration of the TAM and the TPB to analyze participation in CE initiatives. While TPB focuses on behavioral intentions related to sustainability practices, TAM focuses on the adoption of technological systems. The integration of TAM and TPB offers a broader understanding of technological adoption and behavioral motivations influencing participation in CE initiatives.

Another conceptual AI-facilitated model of citizen participation in municipal CE systems that incorporates digital facilitation, incentive systems and ecosystem coordination is also presented in the study. This theoretical framework visually describes how digital technologies could be used to support the involvement of citizens in CE initiatives by between citizens, digital systems, and institutional stakeholders.

The study expands the literature on the CE by addressing the social inclusion and citizen participation in the municipal waste management systems. The research emphasizes the importance of inclusive design of CE systems in different populations. This is examined through the viewpoints of stakeholders regarding the situations of immigrants and those without jobs. By doing so, the research contributes to a conceptual understanding of the interaction between behavioral motivation and digital system design in shaping participation in CE systems.

5.3 Practical and Managerial Implications

The results of this research provide a number of viable suggestions to policymakers, local administrations, waste management institutions, and the creators of digital platforms.

For municipal authorities, the findings of this study may be used to refine communication strategies to support more inclusive participation in waste sorting initiatives. In multicultural urban environments, the provision of multilingual communication channels and clear waste sorting instructions may help address communication barriers.

The adoption of digital platforms by waste management organizations that can facilitate waste sorting, provide feedback on waste sorting behavior, and monitor sorting practices may offer a deeper understanding of citizen behavior and how to engage citizens through behavioral engagement strategies.

The findings also suggest a more refined and focused approach for digital CE platform developers. AI-based tools may provide personalized sorting guidance, participation tracking, and participation-based engagement mechanisms.

Although the focus of this research was the Vaasa region, many urban areas face similar challenges of citizen engagement and digital participation in CE initiatives. Consequently, the conceptual model developed in this study may provide a conceptual basis for municipalities seeking to strengthen digital engagement and behavioral incentives.

5.4 Limitations of the Study

Several limitations should be acknowledged. First, the study is based on a limited number of qualitative interviews with key stakeholders in the Vaasa CE ecosystem. These interviews provide useful insights, but the results cannot be considered statistically generalizable. Second, the results are based on a single case study, which means they are shaped by the institutional and cultural context of the Vaasa region. Third, the conceptual participation model proposed in this study has not yet been empirically tested. Future research could focus on the model's practical implementation and examine this through pilot implementations or experimental research. Lastly, the study is largely limited to stakeholder perspectives, which are not direct accounts of citizens. Future

research should, for example, include survey-based or participatory research to capture how residents engage with CE systems.

5.5 Suggestions for Future Research

Further research could be conducted on other urban settings to test the suggested conceptual model. The effect of digital infrastructure and cultural issues on the involvement in CE initiatives in various cities or countries could be investigated in comparative studies. The potential effects of digital engagement tools and incentive mechanisms on citizen participation could be analyzed through quantitative studies. Additionally, studies on the use of AI-based waste management applications could further examine how digital systems support sustainability initiatives within municipal waste management systems.

5.6 Final Conclusion

The thesis highlights the potential of digital engagement mechanisms within CE activities in municipal waste management systems. The results indicate that stakeholders view the obstacles to participation as mainly structural instead of motivational. Therefore, the communication mechanisms, digital engagement tools, and incentive frameworks remain underutilized. The study develops a conceptual model of AI-based engagement that combines digital facilitation, behavioral incentives, and ecosystem coordination. The model conceptually connects citizens and institutional actors via digital platforms. Although the study focuses on the city of Vaasa, it also identifies similar participation challenges in other cities emphasizing the possible significance of the suggested conceptual framework in different contexts. Consequently, the combination of digital technologies and participatory design approaches may support more sustainable and circular urban systems. In this context, the proposed conceptual model provides analytical insights that can be applied to other municipalities that encounter similar participation barriers, indicating its potential significance in CE systems outside the specific situation at hand, especially in multicultural urban settings. These findings address the research questions by showing how the digitally facilitated approach, behavioral rewards, and system design inclusivity can increase the engagement in the CE.

AI Declaration

During the writing of this thesis, I relied on AI tools as a supplementary aid during the writing process. The AI applications were primarily used to proofread the text to improve clarity and fix grammatical issues as well. I also used AI at times to assist in structuring the overall layout of the chapters and helping find out the potentially useful academic literature. This thesis is my own work, and all the ideas, interpretations, analysis and conclusions were made by myself. I critically reviewed all AI-generated suggestions and edited them thoroughly to ensure that the final work presents my own academic knowledge and opinion. The research data, research analysis, and the primary findings of this study were not generated with the help of AI tools.

References

Ahmad, G., Aleem, F. M., Alyas, T., Abbas, Q., Nawaz, W., Ghazal, T. M., Aziz, A., Aleem, S., Tabassum, N., & Ibrahim, A. M. (2025). Intelligent waste sorting for urban sustainability using deep learning. *Scientific Reports*, *15*(1). https://doi.org/10.1038/s41598-025-08461-w

Ajzen, I. (1991). *The theory of planned behavior: Habit, perceived control, and reasoned action*.

Anne P.M. Velenturf, & Phil Purnell. (2021). Principles for a sustainable CE. *Sustainable Production and Consumption*. https://doi.org/10.1016/j.spc.2021.02.018

Armstrong Jan. (2010). *Naturalistic Inquiry* (1st ed.). SAGE. https://www.researchgate.net/publication/256294652_Naturalistic_Inquiry

Belle, J., Hirtz, D., & Sängerlaub, S. (2024). Expert survey on the impact of cardboard and paper recycling processes, fiber-based composites/Laminates and regulations, and their significance for the CE and the sustainability of the German paper industry. *Sustainability*, *16*(15), 6610. https://doi.org/10.3390/su16156610

Belyamani, I. (2025). AI in waste management systems: Applications, challenges, and prospects. *Waste Management Bulletin*, *3*(4), 100269. https://doi.org/10.1016/j.wmb.2025.100269

Blackburn, O., Ritala, P., & Keränen, J. (2022). Digital platforms for the CE: Exploring meta-organizational orchestration mechanisms. *Organization & Environment*, *36*(2), 253-281. https://doi.org/10.1177/10860266221130717

Bodislav, D. A., Nițu, R. M., Piroșcă, G. I., & Georgescu, R. I. (2025). The opportunity cost between the CE and economic growth: Clustering the approaches of EU member states. *Sustainability*, *17*(6), 2525. https://doi.org/10.3390/su17062525

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77-101. https://doi.org/10.1191/1478088706qp063oa

Bruno, J. M., Bianchi, E. C., & Sánchez, C. (2022). Determinants of household recycling intention: The acceptance of public policy moderated by habits, social influence, and perceived time risk. *Environmental Science & Policy*, *136*, 1-8. https://doi.org/10.1016/j.envsci.2022.05.010

C, K., I, T., K, K., P, J., K, M., & M, V. (2025). IoT and PLC enabled smart waste segregation and sustainable energy generation management system. *2025 3rd International Conference on Intelligent Cyber Physical Systems and Internet of Things (ICoICI)*, 1442-1448. https://doi.org/10.1109/icoici65217.2025.11252995

Cain, L. K., Williams, R. E., & Bradshaw, V. (2023). Establishing quality in qualitative research: Trustworthiness, validity, and a lack of consensus. *International Encyclopedia of Education(Fourth Edition)*, 336-350. https://doi.org/10.1016/b978-0-12-818630-5.11032-2

Calabrese, A., Costa, R., Di Pillo, F., Haqbin, A., Ghiron, N., & Tiburzi, L. (2025). Turning waste into value: A design strategy for sustainable deposit-refund systems. *Business Strategy and the Environment*, *35*(1), 1532-1548. https://doi.org/10.1002/bse.70247

Calisto Friant, M., Vermeulen, W. J., & Salomone, R. (2021). Analysing EU CE policies: Words versus actions. *Sustainable Production and Consumption*, *27*, 337-353. https://doi.org/10.1016/j.spc.2020.11.001

Chen, X. (2022). Machine learning approach for a CE with waste recycling in smart cities. *Energy Reports*, *8*, 3127-3140. https://doi.org/10.1016/j.egyr.2022.01.193

Chitti, S., Rinku, D. R., Juluru, T. K., P, R. R., B, R., & B, V. S. (2025). Smart IoT-enabled monitoring and adaptive waste collection system for sustainable urban management. *2025 7th*

International Conference on Inventive Material Science and Applications (ICIMA), 952-956. https://doi.org/10.1109/icima64861.2025.11073972

Ciulli, F., Kolk, A., & Boe-Lillegraven, S. (2019). Circularity brokers: Digital platform organizations and waste recovery in food supply chains. *Journal of Business Ethics*, *167*(2), 299-331. https://doi.org/10.1007/s10551-019-04160-5

Claudio-Quiroga, G., & Poza, C. (2024). Measuring the CE in Europe: Big differences among countries, great opportunities to converge. *Sustainable Development*, *32*(5), 4707-4725. https://doi.org/10.1002/sd.2925

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly*, *13*(3), 319-340. https://doi.org/10.2307/249008

Dey, P. K., Malesios, C., Chowdhury, S., Saha, K., Budhwar, P., & De, D. (2022). Adoption of CE practices in small and medium-sized enterprises: Evidence from Europe. *International Journal of Production Economics*, *248*, 108496. https://doi.org/10.1016/j.ijpe.2022.108496

Dragomir, V. D., & Dumitru, M. (2024). The state of the research on CE in the EU: A bibliometric review. *Cleaner Waste Systems*, *7*, 100127. https://doi.org/10.1016/j.clwas.2023.100127

Dubois, A., & Gadde, L. (2002). Systematic combining: An abductive approach to case research. *Journal of Business Research*, *55*(7), 553-560. https://doi.org/10.1016/s0148-2963(00)00195-8

Erlingsson, C., & Brysiewicz, P. (2017). A hands-on guide to doing content analysis. *African Journal of Emergency Medicine*, *7*(3), 93-99. https://doi.org/10.1016/j.afjem.2017.08.001

Finamore, M., & Oltean-Dumbrava, C. (2025). Emerging trends in the CE: Multidimensional perspective in the building sector. *CE and Sustainability*, *5*(4), 3017-3052. https://doi.org/10.1007/s43615-024-00485-0

Finns return a record 2.3 billion bottles and cans for recycling. (2025, March 18). News. https://yle.fi/a/74-20150204?utm

Fry, C., Boyd, E., & Connaughton, M. (2023). Migrants as sustainability actors: 'In between' nation, city and migrant discourses and actions. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.4508791

Gibovic, D., & Bikfalvi, A. (2021). Incentives for plastic recycling: How to engage citizens in active collection. Empirical evidence from Spain. *Recycling*, *6*(2), 29. https://doi.org/10.3390/recycling6020029

Henry, M., Bauwens, T., Hekkert, M., & Kirchherr, J. (2020). A typology of circular start-UPS: An analysis of 128 circular business models. *Journal of Cleaner Production*, *245*, 118528. https://doi.org/10.1016/j.jclepro.2019.118528

Henry, M., Schraven, D., Bocken, N., Frenken, K., Hekkert, M., & Kirchherr, J. (2021). The Battle of the buzzwords: A comparative review of the CE and the SE concepts. *Environmental Innovation and Societal Transitions*, *38*, 1-21. https://doi.org/10.1016/j.eist.2020.10.008

Hossain, M. A., Ferdous, N., & Ferdous, E. (2024). Crisis-driven disruptions in global waste management: Impacts, challenges and policy responses amid COVID-19, Russia-Ukraine war, climate change, and colossal food waste. *Environmental Challenges*, *14*, 100807. https://doi.org/10.1016/j.envc.2023.100807

Hosseinian, A., Ylä-Mella, J., & Pongrácz, E. (2021). Current status of CE research in Finland. *Resources*, *10*(5), 40. https://doi.org/10.3390/resources10050040

Iqbal, A., Yasar, A., Nizami, A., Haider, R., Sharif, F., Sultan, I. A., Tabinda, A. B., Kedwaii, A. A., & Chaudhary, M. M. (2022). Municipal solid waste collection and haulage modeling design for Lahore, Pakistan: Transition toward sustainability and CE. *Sustainability*, *14*(23), 16234. https://doi.org/10.3390/su142316234

Judl, J., Horn, S., & Karppinen, T. K. (2023). Towards a low-carbon plastic waste recycling in Finland: Evaluating the impacts of improvement measures on GHG emissions. *CE and Sustainability*, *4*(1), 755-776. https://doi.org/10.1007/s43615-023-00306-w

KATE HOOPER, & LAWRENCE HUANG. (2024). *The Role of Immigrant Workers in the Green Transition*. Migration policy institute. https://www.migrationpolicy.org/research/immigrant-workers-green-transition

Khanna, M., Gusmerotti, N. M., & Frey, M. (2022). The relevance of the CE for climate change: An exploration through the theory of change approach. *Sustainability*, *14*(7), 3991. https://doi.org/10.3390/su14073991

Kihila, J. M., Wernsted, K., & Kaseva, M. (2021). Waste segregation and potential for recycling - A case study in Dar es Salaam city, Tanzania. *Sustainable Environment*, *7*(1). https://doi.org/10.1080/27658511.2021.1935532

Kirchherr, J., Yang, N. N., Schulze-Spüntrup, F., Heerink, M. J., & Hartley, K. (2023). Conceptualizing the CE (Revisited): An analysis of 221 definitions. *Resources, Conservation and Recycling*, *194*, 107001. https://doi.org/10.1016/j.resconrec.2023.107001

Kirsiilmaranta. (2021, December 22). *CE success: Finland's recycling programme keeps bottles and cans off the streets*. thisisFINLAND. https://finland.fi/life-society/circular-economy-success-finlands-recycling-programme-keeps-bottles-and-cans-off-the-streets/?utm

Korsunova, A., Halme, M., Kourula, A., Levänen, J., & Lima-Toivanen, M. (2022). Necessity-driven CE in low-income contexts: How informal sector practices retain value for circularity. *Global Environmental Change*, *76*, 102573. https://doi.org/10.1016/j.gloenvcha.2022.102573

Kubanza, N. S. (2024). Analysing the challenges of solid waste management in low-income communities in South Africa: A case study of Alexandra, Johannesburg. *South African Geographical Journal*, *107*(2), 169-189. https://doi.org/10.1080/03736245.2024.2356563

Lab, B. G., & Douglas, B. (2020). Gamification to prevent climate change: A review of games and apps for sustainability. https://doi.org/10.31219/osf.io/3c9zj

Labour market forecast: Employment to pick up by the end of 2025. (2025, November 14). Työ- ja elinkeinoministeriö. https://tem.fi/en/-/labour-market-forecast-employment-to-pick-up-by-the-end-of-2025

Laubinger, F. (2022). *Deposit-refund systems and the interplay with additional mandatory extended producer responsibility policies*.

Laukkanen, M., & Tura, N. (2020). The potential of SE business models for sustainable value creation. *Journal of Cleaner Production*, *253*, 120004. https://doi.org/10.1016/j.jclepro.2020.120004

Lazarevic, D., Salo, H., & Kautto, P. (2022). CE policies and their transformative outcomes: The transformative intent of Finland's strategic policy programme. *Journal of Cleaner Production*, *379*, 134892. https://doi.org/10.1016/j.jclepro.2022.134892

Lazarevic, D., Salo, H., & Kautto, P. (2022). CE policies and their transformative outcomes: The transformative intent of Finland's strategic policy programme. *Journal of Cleaner Production*, *379*, 134892. https://doi.org/10.1016/j.jclepro.2022.134892

Liu, T., Wang, P., Cao, J., Weng, Z., & Stegmann, R. (2025). Implementing mandatory household waste sorting: Economic perspective and policy implications. *Journal of Cleaner Production*, *516*, 145795. https://doi.org/10.1016/j.jclepro.2025.145795

Lukka Kari. (2003). *The Constructive Research Approach*. Turku School of Economics and Business Administration. https://www.researchgate.net/publication/247817908_The_Constructive_Research_Approach

Marjamaa, M., & Mäkelä, M. (2022). Images of the future for a CE: The case of Finland. *Futures*, *141*, 102985. https://doi.org/10.1016/j.futures.2022.102985

Mykkänen, J., & Repo, P. (2021). Consumer perspectives on arranging CE in Finland. *Sustainability: Science, Practice and Policy*, *17*(1), 349-361. https://doi.org/10.1080/15487733.2021.1977500

Negrete-Cardoso, M., Rosano-Ortega, G., Álvarez-Aros, E. L., Tavera-Cortés, M. E., Vega-Lebrún, C. A., & Sánchez-Ruíz, F. J. (2021). CE strategy and waste management: A bibliometric analysis in its contribution to sustainable development, towards a post COVID-19 era. https://doi.org/10.21203/rs.3.rs-629171/v1

Nogueira, A. (2022). Are soft legal measures in CE action plans enough to permeate EU strong economic core regulations bringing systemic sustainable change? *CE and Sustainability*, *3*(3), 1545-1568. https://doi.org/10.1007/s43615-022-00227-0

Nordic council of ministers. (2025). *Policy framework for migrant integration in the nordic countries 2025 - an overview*. https://www.norden.org/en/publication/policy-frameworks-migrant-integration-nordic-countries-2025-overview

Novanda, R. R., Ependi Malau, L. R., & Yulni, T. (2026). A meta-analysis of waste sorting behavior: Examining the TPB(TPB) and the role of contextual factors. *Environmental Development*, *58*, 101426. https://doi.org/10.1016/j.envdev.2025.101426

Numata, D. (2016). Policy mix in deposit-refund systems – From schemes in Finland and Norway. *Waste Management*, *52*, 1-2. https://doi.org/10.1016/j.wasman.2016.05.003

Olawade, D. B., Fapohunda, O., Wada, O. Z., Usman, S. O., Ige, A. O., Ajisafe, O., & Oladapo, B. I. (2024). Smart waste management: A paradigm shift enabled by AI. *Waste Management Bulletin*, *2*(2), 244-263. https://doi.org/10.1016/j.wmb.2024.05.001

Outreach, R. (2023, November 8). *Waste management and transition to a CE*. Research Outreach. https://researchoutreach.org/articles/waste-management-transition-circular-economy/

Oyegoke, A. (2011). The constructive research approach in project management research. *International Journal of Managing Projects in Business*, *4*(4), 573-595. https://doi.org/10.1108/17538371111164029

Peura, P., Voutilainen, O., & Kantola, J. (2022). From garbage to product and service systems: A longitudinal Finnish case study of waste management evolution. *Waste Management*, *140*, 143-153. https://doi.org/10.1016/j.wasman.2022.01.025

Picuno, C., Gerassimidou, S., You, W., Martin, O., & Iacovidou, E. (2025). The potential of deposit refund systems in closing the plastic beverage bottle loop: A review. *Resources, Conservation and Recycling*, *212*, 107962. https://doi.org/10.1016/j.resconrec.2024.107962

Pilapitiya P.G.C. Nayanathara Thathsarani, & Ratnayake Amila Sandaruwan. (2024). The world of plastic waste: A review. *ELSEVIER*, *11*. https://doi.org/10.1016/j.clema.2024.100220

Ranta, V., Aarikka-Stenroos, L., & Väisänen, J. (2021). Digital technologies catalyzing business model innovation for CE—Multiple case study. *Resources, Conservation and Recycling*, *164*, 105155. https://doi.org/10.1016/j.resconrec.2020.105155

Reijonen, H., Bellman, S., Murphy, J., & Kokkonen, H. (2021). Factors related to recycling plastic packaging in Finland's new waste management scheme. *Waste Management*, *131*, 88-97. https://doi.org/10.1016/j.wasman.2021.05.034

Reijonen, H., Bellman, S., Murphy, J., & Kokkonen, H. (2021). Factors related to recycling plastic packaging in Finland's new waste management scheme. *Waste Management*, *131*, 88-97. https://doi.org/10.1016/j.wasman.2021.05.034

Rezaie, S., Vanhuyse, F, & André, K. (2022). Beyond closing the loop – integrating social considerations into CE transitions in cities. *Stockholm Environment Institute*. https://www.sei.org/wp-content/uploads/2020/01/rezaie-et-al.-2022-beyond-closing-the-loop.pdf

Riina Antikainen, Carl Dalhammar, Mikael Hildén, Jáchym Judl, Tiina Jääskeläinen, Petrus Kautto, Sirkka Koskela, Mika Kuisma, David Lazarevic, Ilmo Mäenpää, Jukka-Pekka Ovaska, Philip Peck, Håkan Rodhe, Armi Temmes, & Åke Thidell. (2017). *Renewal of forest based manufacturing towards a sustainable circular bioeconomy* (13). Finnish Environment Institute. https://helda.helsinki.fi/items/64706990-35d4-407d-b92e-d51f50d19b8b

Romano, G., & Masserini, L. (2023). Pay-as-you-throw tariff and sustainable urban waste management: An empirical analysis of relevant effects. *Journal of Environmental Management*, *347*, 119211. https://doi.org/10.1016/j.jenvman.2023.119211

Santti, U., Happonen, A., & Auvinen, H. (2020). Digitalization boosted recycling: Gamification as an inspiration for young adults to do enhanced waste sorting. *AIP Conference Proceedings*, *2233*, 050014. https://doi.org/10.1063/5.0001547

Saptaputra, E. H., Bonafix, N., & Araffanda, A. S. (2023). Mobile app as digitalisation of waste sorting management. *IOP Conference Series: Earth and Environmental Science*, *1169*(1), 012007. https://doi.org/10.1088/1755-1315/1169/1/012007

Saunders, M., Lewis, P., & Thornhill, A. (2019). *Research methods for business students* (8th ed.). Pearson Education. https://ebookcentral-proquest-com.proxy.uwasa.fi/lib/tritonia-ebooks/detail.action?docID=5139642

Seker, S. (2022). IoT based sustainable smart waste management system evaluation using MCDM model under interval-valued q-Rung orthopair fuzzy environment. *Technology in Society*, *71*, 102100. https://doi.org/10.1016/j.techsoc.2022.102100

Sosunova, I., Happonen, A., Wolff, A., & Porras, J. (2024). Towards a smarter waste management. *International Journal of Social Ecology and Sustainable Development*, *15*(1), 1-36. https://doi.org/10.4018/ijsesd.361770

Statistics – Employment. (n.d.). Vaasa. https://www.vaasa.fi/en/about-vaasa-and-the-vaasa-region/the-vaasa-region-in-numbers/statistics-employment/?utm

Ten Caat, S., Van Uffelen, N., & Cuppen, E. (2024). Revealing hidden injustice: Barriers to citizen participation among migrants in the energy transition of The Hague. *Environmental Research Communications*, *6*(7), 075006. https://doi.org/10.1088/2515-7620/ad431d

Trushna, T., Krishnan, K., Soni, R., Singh, S., Kalyanasundaram, M., Sidney Annerstedt, K., Pathak, A., Purohit, M., Stålsby Lundbog, C., Sabde, Y., Atkins, S., Sahoo, K. C., Rousta, K., & Diwan, V. (2024). Interventions to promote household waste segregation: A systematic review. *Heliyon*, *10*(2), e24332. https://doi.org/10.1016/j.heliyon.2024.e24332

Tuuli Leskinen. (2025). *Waste Management Companies as Institutional Actors: The Role of Finnish Municipal Waste Companies as CE Enablers* [Doctoral dissertation]. https://erepo.uef.fi/server/api/core/bitstreams/3ac597b8-5fc7-48e7-80d5-07a3de21305c/content

Vaasa's population exceeds 70,000 residents – immigration and employment are driving the growth. (2024, November 7). Vaasa. https://www.vaasa.fi/en/news/vaasas-population-exceeds-70000-residents-immigration-and-employment-are-driving-the-growth/?utm

Van Opstal, W., Borms, L., Brusselaers, J., Bocken, N., Pals, E., & Dams, Y. (2024). Towards sustainable growth paths for work integration social enterprises in the CE. *Journal of Cleaner Production*, *470*, 143296. https://doi.org/10.1016/j.jclepro.2024.143296

Walls, M. (2011). Deposit-refund systems in practice and theory. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.1980142

Wan, C., Shen, G. Q., & Choi, S. (2022). Pathways of place dependence and place identity influencing recycling in the extended theory of planned behavior. *Journal of Environmental Psychology*, *81*, 101795. https://doi.org/10.1016/j.jenvp.2022.101795

Watkins, E, & Meysner, A. (2022). *European CE policy landscape overview*. Institute for European Environmental Policy. https://ieep.eu/wp-content/uploads/2022/11/European-Circular-Economy-policy-landscape-overview.pdf

Wright, C. Y., Godfrey, L., Armiento, G., Haywood, L. K., Inglesi-Lotz, R., Lyne, K., & Schwerdtle, P. N. (2019). CE and environmental health in low- and middle-income countries. *Globalization and Health*, *15*(1). https://doi.org/10.1186/s12992-019-0501-y

Xia, W., Jiang, Y., Chen, X., & Zhao, R. (2021). Application of machine learning algorithms in municipal solid waste management: A mini review. *Waste Management & Research:*

The Journal for a Sustainable CE, *40*(6), 609-624. https://doi.org/10.1177/0734242x211033716

Yin, R. K. (2017). *Case study research and applications: Design and methods*. SAGE Publications.

Zavos, S., Lehtokunnas, T., & Pyyhtinen, O. (2024). The (missing) social aspect of the CE: A review of social scientific articles. *Sustainable Earth Reviews*, *7*(1). https://doi.org/10.1186/s42055-024-00083-w

Zhang, X., Deng, G., Nketiah, E., & Shi, V. (2024). Enhancing recycling participation: Behavior factors influencing residents' adoption of RVMs. *Behavioral Sciences*, *14*(11), 1071. https://doi.org/10.3390/bs14111071

Zhang, Z., Chen, Z., Zhang, J., Liu, Y., Chen, L., Yang, M., Osman, A. I., Farghali, M., Liu, E., Hassan, D., Ihara, I., Lu, K., Rooney, D. W., & Yap, P. (2024). Municipal solid waste management challenges in developing regions: A comprehensive review and future perspectives for Asia and Africa. *Science of The Total Environment*, *930*, 172794. https://doi.org/10.1016/j.scitotenv.2024.172794

Zhou, J., Jiang, P., Yang, J., & Liu, X. (2021). Designing a smart incentive-based recycling system for household recyclable waste. *Waste Management*, *123*, 142-153. https://doi.org/10.1016/j.wasman.2021.01.030

Zickgraf, C., Jolivet, D., Fry, C., Boyd, E., & Fábos, A. (2024). Bridging and breaking silos: Transformational governance of the migration–sustainability nexus. *Proceedings of the National Academy of Sciences*, *121*(3). https://doi.org/10.1073/pnas.2206184120

Zohrabi, M. (2013). Mixed method research: Instruments, validity, reliability and reporting findings. *Theory and Practice in Language Studies*, *3*(2). https://doi.org/10.4304/tpls.3.2.254-262

Zota, R. D., Cîmpeanu, I. A., Dragomir, D. A., & Lungu, M. A. (2024). Practical approach for smart and circular cities: Chatbots used in waste recycling. *Applied Sciences*, *14*(7), 3060. https://doi.org/10.3390/app14073060

Ögmundarson, Ó., Kalweit, L. S., Venkatachalam, V., Kristjánsdóttir, R., Endres, H., & Spierling, S. (2022). Plastic packaging waste management in Iceland: Challenges and opportunities from a life cycle assessment perspective. *Sustainability*, *14*(24), 16837. https://doi.org/10.3390/su142416837

Appendices

Appendix 1. Interview Questions

1. **Storemossen representative**

1. What types of waste are currently collected and accepted at Stormossen?
2. Is there a price or compensation per kilogram for sorted waste (e.g., metal, electronics, plastics)? If so, could you share the current rates?

   Scrapped
3. Does the pricing or acceptance vary by waste type or season?
4. Does the volume or type of waste collected change across the four seasons in Vaasa?
5. Are there specific challenges during winter or summer in waste logistics?
6. Has Stormossen previously collaborated with community groups or immigrants in any waste collection or sorting initiatives?
7. Why do you think some Finnish citizens hesitate to sort waste or bring it to waste centers like Stormossen?
8. Have you ever considered including or educating immigrants in waste sorting practices as part of your strategy?
9. What are your thoughts on involving unemployed immigrants or students as intermediaries in community waste collection?
10. Are there any legal or practical barriers in engaging individuals as part-time waste collectors or intermediaries?
11. Has Stormossen previously implemented or tested any digital or AI-based solutions (e.g., smart bins, route optimization)?
12. Are there plans or interest in expanding AI integration within your waste collection and logistics processes?
13. What kind of data is currently collected about waste sources, routes, or sorting accuracy?
14. Do you currently use or share any apps/web platforms with households to encourage participation?
15. How do you feel about the idea of developing a mobile app that connects households with local “intermediaries” who collect properly sorted waste and deliver it to Stormossen?
16. What challenges or risks do you foresee with such a model?

17. What type of support or cooperation would Stormossen be able to offer if such an initiative were tested or piloted?
18. What would be the most important things to consider if we aim to increase citizen participation—especially among migrants—in CE practices?
19. Are there any internal priorities at Stormossen (logistical, environmental, educational) that my thesis should align with?

2. ELY-Keskus representative

1. From your perspective, what are the key challenges immigrants face when integrating into the labor market in Ostrobothnia?
2. How do you see immigrants and unemployed groups contributing to the region's sustainability and CE goals?
3. Are there existing regional strategies that connect integration, employment, and environmental sustainability?
4. In your view, what are the biggest challenges households face in participating in waste sorting and recycling in Vaasa?
5. How important is community-level participation (especially from diverse groups) for achieving regional CE targets?
6. Do you think there are gaps in current waste collection systems where new digital or social innovations could make a difference?
7. Based on the app idea I shared, do you see potential for this type of solution in Vaasa?
8. What benefits could such a model bring for both waste management companies and immigrant/unemployed groups?
9. What barriers do you foresee — for example, cultural, technological, financial, or institutional?
10. In your opinion, what would be important to ensure this app is accepted and trusted by both households and immigrants?
11. From your expertise in regional development, how do you think such a solution could be integrated into broader local or regional strategies?
12. Are there examples of successful digital or social innovations in Ostrobothnia that could inspire this type of initiative?
13. What role do you see public organizations (like municipalities, ELY-keskus, TE Office, or the Regional Council) playing in supporting such an initiative?
14. Do you think a pilot project of this type could be feasible in Vaasa?

15. What advice would you give me to make this model practical, relevant, and aligned with regional priorities?
16. Finally, are there other stakeholders or organizations you recommend I should contact for further insights?

3. City of Vaasa representative

1. From the City of Vaasa's perspective, what challenges do immigrant or unemployed residents face in participating in waste sorting and CE activities?
2. Are there identifiable gaps in awareness, access, communication, or motivation among these groups?
3. How does the city currently address participation inequalities in waste management or sustainability programs?
4. Does the city collaborate with integration services, community groups, or NGOs to promote sustainability participation among immigrants?
5. In what ways can sustainability actions (like waste sorting) contribute to the social or economic integration of immigrants or unemployed residents?
6. Have you observed cases where participation in environmental activities has supported inclusion, skill development, or community engagement?
7. Has the City of Vaasa implemented digital tools or platforms to engage residents in environmental or CE activities?
8. In your view, how could AI-driven tools or incentive-based digital models help increase participation among low-engagement groups?
9. What types of incentive mechanisms (e.g., financial rewards, gamification, recognition) do you think could motivate higher participation?
10. Based on the concept I shared, how suitable or realistic do you find an AI-driven, incentive-based participation model in Vaasa?
11. What benefits do you think this model could bring for marginalized populations such as immigrants and unemployed residents?
12. What risks or concerns should be considered (e.g., fairness, data use, accessibility, behavioral barriers)?
13. How could the city support or collaborate in implementing such a model (e.g., awareness campaigns, partnerships, data availability)?
14. Are there infrastructure or policy limitations that could affect implementation?

15. Do you believe a model developed in Vaasa could be transferable to other cities or countries facing similar participation challenges?
16. What conditions must be met for international scalability (e.g., political support, societal readiness, digital maturity)?
17. What key elements must be included to make this model credible, workable, and aligned with municipal sustainability goals?
18. Are there existing examples (local or international) that could inspire or benchmark this solution?
19. Is there anyone else in the city's sustainability or inclusion networks whom you think I should speak with?

4. Former CEO of Kamupak oy

1. Could you briefly describe Kamupak's digital reuse system and how it promotes CE participation?
2. What behavioral patterns have you observed among users when adopting deposit-based or incentive-based circular systems?
3. In your experience, what are the barriers people face when adopting circular practices such as reusables or digital return systems?
4. Do you think immigrant or unemployed groups might face unique challenges in engaging with circular digital services?
5. How can digital platforms empower marginalized or lower-income groups to participate more actively in CE behaviors?
6. What types of incentives (financial, gamification, convenience, recognition) have been most effective in encouraging user participation?
7. How important is real-time feedback or reward visibility in motivating users?
8. Does Kamupak currently use AI, data analytics, or predictive behavior modeling in improving user engagement or operations?
9. How do you think AI could enhance participation, personalization, or optimized communication in circular platforms?
10. What kinds of data are most valuable for understanding user participation patterns?
11. Based on the concept I shared, do you think an AI-driven, incentive-based citizen participation model could work in the waste sector?
12. What potential benefits do you see for immigrants, unemployed groups, or other marginalized residents?

13. What risks or challenges (data ethics, adoption barriers, operational issues) should be considered?
14. In your view, what partnerships or ecosystems (municipalities, waste companies, NGOs) are necessary for implementing such a model?
15. What infrastructure or digital readiness factors must be in place for adoption?
16. Based on Kamupak's experience in different environments, what factors determine whether a circular digital model can be replicated internationally?
17. Which types of markets or regions would be more receptive to this kind of AI-incentive model?
18. What advice would you give for developing a citizen-focused digital CE model that is both effective and inclusive?
19. Are there case examples or best practices (in Finland or globally) that I should explore for benchmarking?
20. Finally, are there other professionals you recommend I contact for further insights?

Appendix 2. Code table

Theme	Code	Statement	Interpretation	Link to AI Model
Structural Barriers to Inclusive Circular Participation	**C1 – Multilingual Communication Gap**	**Stormossen:** "All the sorting information was written only in Finnish." **City of Vaasa:** "Vaasa has more than 100 spoken languages." **ELY:** "Learning how the Finnish waste system works may be difficult if instructions are only in Finnish or Swedish." **Kamupak:** "Language can become a barrier if the application is not available in multiple languages."	Waste sorting participation is strongly influenced by language accessibility and communication design.	AI multilingual interface and adaptive instructions

	C2 – Instruction Visibility & Accessibility Failure	**Stormossen:** "Sometimes instructions exist but are placed in a drawer and people do not see them." **Stormossen:** "Information must be visible and understandable to work." **City of Vaasa:** "I am not sure whether instructions are always clearly provided or visible in apartment buildings."	Information exists but is often invisible at the moment when residents make sorting decisions.	Context-based AI guidance and visual prompts
	C3 – Behavioral Friction & Inconvenience	**Kamupak:** "The biggest barrier to adoption was inconvenience." **Kamupak:** "Even a small additional effort can discourage people." **Stormossen:** "Sorting requires repetition, monitoring, and continuous reinforcement."	Circular systems require additional effort compared to simple disposal, discouraging participation.	Friction-reduced user journey and AI nudging
	C4 – Digital Onboarding & Trust Barriers	**Kamupak:** "Users needed to provide credit card details." **Kamupak:** "Not everyone owns a smartphone or knows how to use applications."	Digital solutions may unintentionally exclude certain groups due to onboarding complexity or trust issues.	Simplified onboarding and inclusive platform design
	C5 – Cultural Adaptation &	**City of Vaasa:** "People come from countries with very different waste systems."	Waste sorting practices are culturally	AI micro-learning and

	Learning Curve	**Stormossen:** "Communication works differently across cultures."	learned behaviors requiring adaptation and education.	contextual guidance
	C6 – Structural Information Gap (Not Motivation)	**Stormossen:** "Sorting issues arise due to lack of information rather than lack of willingness." **Stormossen:** "Many immigrants are motivated to follow societal norms."	Participation barriers are mainly informational and structural rather than motivational.	Empowerment-based engagement model
Informational Digital Tools Without Engagement Mechanisms	**C7 – Informational Digital Tools Without Behavioral Engagement**	**Stormossen:** "We already have a phone application that provides sorting instructions in three languages, but people do not use it."	Digital tools exist but function only as passive information sources rather than engagement platforms.	AI interactive guidance and engagement prompts
	C8 – Lack of Participation Tracking Systems	**Stormossen:** "The challenge is that people who need the information most do not engage."	Current systems cannot track which groups participate or fail to participate in circular practices.	AI participation monitoring and analytics

	C9 – Absence of Feedback and Impact Visibility	**Kamupak:** "People want to understand what impact their actions create."	Without visible feedback, individuals feel their participation has little impact, reducing motivation.	Impact dashboards and feedback loops
	C10 – Untapped Potential of Digital Incentive Systems	**City of Vaasa:** "There has been discussion about creating competitions between districts based on sorting performance, but it remains conceptual."	Digital engagement strategies are discussed but not implemented in current systems.	Gamification and incentive mechanisms
Informal Circular Practices Without System Integration	**C11 – Informal Reuse Platforms Already Exist**	**City of Vaasa:** "Residents already use Facebook groups - Roskalava, Tori, Minimosan, Kirrpis and other second-hand platforms."	Circular reuse behavior already occurs informally within communities.	Centralized digital circular platform
	C12 – Fragmented Circular Participation Channels	**City of Vaasa:** "These systems are fragmented."	Circular activities are dispersed across multiple platforms with no integration.	Integrated ecosystem platform
	C13 – Lack of CE Measurement	**Stormossen:** "Informal reuse channels such as Roskalava already exist."	Current reuse activities are invisible to	Measurable circular

			municipal data and CE statistics.	contribution tracking
	C14 – Missing Data for Strategic Decision Making	**Stormossen:** "We need better dashboards and visibility tools."	Without integrated data, CE strategies cannot be optimized.	Data-driven CE analytics
Invisible Economic Value and Missed Incentives	**C15 – Pantti System Demonstrates Incentive Success**	**City of Vaasa:** "Many immigrants and students are familiar with the Pantti system."	Financial incentives clearly motivate circular participation.	Micro-incentive mechanisms
	C16 – Waste Value Awareness Gap	**City of Vaasa:** "Most people are unaware that other waste fractions may also have value."	Economic value exists in waste streams but remains invisible to residents.	AI-based value visibility
	C17 – Financial Incentives Drive Behavior Change	**Kamupak:** "Financial incentives are the most important factor."	Monetary benefits strongly influence adoption of circular practices.	Incentive-based behavioral nudging
	C18 – Economic Participation	**Kamupak:** "If people can earn money within the system, it benefits everyone."	CE systems can create economic opportunities for	Gig-based circular

	Opportunities for Marginalized Groups		immigrants and unemployed groups.	participation model
Hidden Costs of Improper Waste Behavior	**C19 – Waste Management as Major Emission Source**	**City of Vaasa:** "Waste management is the third-largest emission source in the city."	Waste sorting directly influences environmental sustainability outcomes.	Environmental impact feedback
	C20 – Financial Costs of Improper Sorting	**Stormossen:** "Improved sorting reduced mixed waste and saved nearly 2,000 euros annually."	Poor sorting increases operational costs for housing communities.	Cost transparency dashboard
	C21 – Citizens Lack Awareness of System-Level Costs	**Stormossen:** "Residents must see the benefit in reduced monthly costs."	Financial consequences of waste behavior are rarely visible to households.	AI cost awareness feedback
	C22 – Waste Governance Influences Behavior	**Stormossen:** "Countries like Germany impose graded penalties."	Policy mechanisms shape waste behavior but Finland relies more on voluntary participation.	Data-driven policy insights

Ecosystem Fragmentation and Intermediary Potential	**C23 – Multiple Actors Exist but Lack Coordination**	**ELY:** "Our role is like an orchestra coordinating regional development."	CE involves many actors but lacks operational coordination.	Platform orchestration model
	C24 – Institutional and Legal Constraints	**Stormossen:** "Household waste becomes the property of the municipal waste company."	Legal frameworks shape how circular systems can operate.	Structured intermediary model
	C25 – Operator Gap in Circular Ecosystem	**Kamupak:** "There is room for someone operating between ecosystem players."	A coordinating intermediary actor is missing in the system.	AI-enabled intermediary platform
	C26 – Ecosystem Collaboration Needed for Implementation	**ELY:** "Practical implementation would require coordination with multiple stakeholders."	Effective circular solutions require collaboration between municipalities, businesses, and communities.	Scalable ecosystem coordination