



**ENHANCING SUSTAINABLE COMMUTING STRATEGIES FOR LAHTI CITY:
INTEGRATING MULTI-THEMATIC INTERVENTIONS FOR EFFECTIVE
URBAN MOBILITY**

Lappeenranta–Lahti University of Technology LUT

Master's Program in Sustainability Science and Solutions, Master's Thesis

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ABSTRACT

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Enhancing sustainable commuting strategies for Lahti city: Integrating multi-thematic interventions for effective urban mobility

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This master thesis investigates sustainable commuting practices within the urban context of Lahti, Finland, aiming to identify effective interventions for enhancing urban mobility and achieving the city's carbon neutrality goals by 2025. Employing a qualitative research approach, this study critically examines the interconnectedness of sustainable commuting practices through an extensive literature review and a detailed case study of Lahti. It introduces a holistic framework that categorizes interventions into main themes, highlighting their dynamic interrelationships and mutual reinforcement. Key findings reveal that the innovation required for sustainable commuting extends beyond the discovery of new solutions to the strategic implementation of existing, proven interventions. The study demonstrates how Lahti's specific challenges and infrastructure act as a filter to identify and prioritize strategies that are both viable and tailored to the city's unique context. Through this focused analysis, the research offers a comprehensive guide for policymakers, urban planners, and community stakeholders, emphasizing the need for a holistic and adaptable approach to sustainable urban mobility.

The study provides suggestions for both organizational and city-level decision-makers, underscoring the importance of flexible strategy in advancing sustainable urban mobility. It also offers updated insights for Sustainable Urban Mobility Plan in Lahti, enhancing their relevance and effectiveness in fostering sustainable commuting practices. Conclusively, the thesis argues that sustainable commuting is a multifaceted endeavour, crucial for fostering healthier, more liveable urban environments. It underlines the significance of strategic execution and contextual adaptation in employing sustainable commuting interventions, presenting a blueprint for Lahti and similar urban settings to advance towards sustainable mobility objectives. This thesis contributes to the field by providing a scaffolded approach to sustainable urban planning, enriching the discourse on environmental sustainability and urban resilience.

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As I write this thesis, I am reminded of Voltaire's wise counsel, "The best is the enemy of the good." This work, while not without its flaws, is a culmination of earnest effort and the pursuit of knowledge.

For language refinement in this thesis, AI-based tools were utilized with limitations strictly to grammar and clarity enhancements.

Lappeenranta, February 2024

Hanieh Alimohamadi

SYMBOLS AND ABBREVIATIONS

Abbreviations

| | |
|-------|------------------------------------------|
| AR | Augmented Reality |
| BSP | Bike Sharing Program |
| DSB | Danish State Railways |
| EMRC | Electric Mobility Research Centre |
| EU | European Union |
| EV | Electric Vehicle |
| GEM | Green Electrification of Mobility |
| GIS | Geographic Information Systems |
| ICT | Information and Communication Technology |
| ITS | Intelligent Transportation Systems |
| LADEC | Lahti Regional Development Company |
| LSL | Lahden Seudun Liikenne |
| MaaS | Mobility-as-a-Service |
| MOD | Mobility-Oriented Development |
| PCP | Personalized Commuter Plan |
| PCT | Personal Carbon Trading |
| PMS | Parking Management Systems |
| RQ | Research Question |
| SC | Sustainable Commuting |
| SDG | Sustainable Development Goal |
| SUMP | Sustainable Urban Mobility Plan |

| | |
|-----|--------------------------------|
| TOD | Transit-Oriented Development |
| UN | United Nations |
| VDI | Virtual Desktop Infrastructure |
| VPN | Virtual Private Network |

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1 Introduction

1.1 Background

The pressing demand for sustainable mobility solutions has become increasingly apparent in our collective efforts to address environmental challenges, improve public health, and cultivate liveable cities (Gallo & Marinelli, 2020). As urban areas continue to expand and deal with the detrimental effects of congestion, noise, land use, and pollution, a paradigm shift toward sustainable commuting modes that reduce reliance on fossil fuel-powered vehicles is crucial (United Nations, 2021). These issues have far-reaching consequences for the planet and its ecosystems, posing threats to biodiversity and ecological balance (Potter, 2007).

As commuting remains a fundamental aspect of daily life for many, linking their personal lives to their work environments, it is accompanied by adverse effects on the socio-ecological landscape, including health implications, time constraints, and contributions to climate emissions (Stein et al., 2022). The dominance of car use persists even in cities renowned for their bike-friendly infrastructure despite worldwide efforts by cities to mitigate these challenges (Cass and Faulconbridge, 2016). “Sustainable commuting (SC) usually refers to environmentally friendly travel modes, such as public transport (bus, tram, subway, light rail), walking, cycling, and carpooling” (Molina et al., 2020a).

The significance of commuting extends beyond individual choices, and it is influenced by overarching transport policies and urban planning. According to Dujava & Kališ, (2021) transport policy can shape commuting patterns, underscores this by describing how specific policies can either encourage or prevent certain commuting behaviours. For instance, Copenhagen’s transport policies prioritize cycling, with investments in dedicated bike lanes, cyclist-friendly traffic lights, and exclusive bridges (State of Green, 2017). As a result, over 49% of its resident’s cycle for daily commutes (Sitra, 2019). Conversely, cities like Los Angeles, historically designed around automobiles with extensive freeway systems, face challenges of congestion and a car-centric culture (Novak, 2013).

Transportation, as a cornerstone of urban development, significantly influences the sustainability path of modern cities. Its impact is complex, touching upon economic, environmental, social, and cultural aspects of sustainable development (EESC, 2018).

Within this broad spectrum, commuting stands out as a crucial subset. The daily movement patterns of urban residents provide a unique lens through which we can understand the intricate relationship between transportation choices and their sustainability implications (Mosaberpanah & Khales, 2013).

The choices individuals make regarding their daily commute can have profound economic implications. Efficient public transport systems or shared mobility solutions can lead to significant economic savings, both on a personal and societal level (Mårtensson, 2015). From an environmental perspective, the carbon footprint of people's commuting choices varies widely; while walking, cycling, or electric-powered public transport contribute minimally to emissions, fuel-driven vehicles cast a much larger shadow (Pazhuhan et al., 2022).

Giles-Corti et al. (2016) highlight that these patterns also resonate with social equity and well-being. Efficient and inclusive commuting options reflect a city's commitment to social justice, while also promoting healthier lifestyles. In Bogotá, the Ciclovía program reserves streets for non-motorized activities on Sundays, promoting both social equity by providing inclusive urban access and health through encouraging physical activity (Sarmiento et al., 2010).

Additionally, commuting decisions influence a city's cultural character. Cities like Amsterdam, known for their cycling emphasis, not only prioritize environmental considerations but also establish a unique urban identity. As Gatersleben and Uzzell (2007) point out, reshaping a city's commuting culture might necessitate behavioural changes, underlining the need for campaigns that shift societal norms.

In response to this critical need, policy landscapes worldwide are increasingly aligning with a sustainable agenda, as reflected in the United Nations Sustainable Development Goals (SDGs). These global goals, adopted by UN member states in 2015, comprise 17 interconnected objectives that address socio-economic and environmental challenges. The relevance of goal 11 lies in its emphasis on the creation of inclusive, safe, resilient, and

sustainable cities and human settlements, particularly in relation to sustainable mobility (Chalmers University of Technology, 2022).

1.2 Statement of the Problem

Green mobility has become a key focus in urban planning and development across Europe. The European Union (EU) has set ambitious targets to reduce climate-altering emissions and promote sustainable commuting among its member states. To support these goals, the EU has implemented Sustainable Urban Mobility Plans (SUMP), which provide strategic frameworks for cities and regions to encourage sustainable commuting options (European Commission, 2019). Finland, on a national level, has undertaken the initiatives to foster sustainable mobility and mitigate the environmental impact of transportation and these endeavors are guided by the National Transport System plan. The Finnish Transport Agency plays a pivotal role in this context, focusing on integrated mobility solutions. National climate strategies set emission reduction targets, aligning with broader European commitments (Future Mobility Finland, 2023).

Through this transition from a national perspective to a city-level context, Lahti city embraces sustainability as a core value and has set an impressive objective of achieving carbon neutrality by 2025. This determined goal drives the implementation of advanced interventions aimed at promoting sustainable commuting practices. Addressing urban mobility planning effectively calls for bridging gaps in expertise and resources. Constructive collaboration among employers, community entities, and residents is vital to enrich the planning process with diverse perspectives and shared commitments.

This investigation delves into the influence of urban design interventions and SUMP in steering Lahti city towards sustainable commuting practices. A key observation is the important role which organizations play in this process. Their deeper involvement and expertise are crucial elements that, if enhanced, could significantly bridge the current gaps in urban mobility planning. Understanding the interplay of various factors like local dynamics, political commitment, stakeholder participation, and financing is crucial for the effective execution of SUMP (Smeds and Jones, 2020).

To address the multifaceted aspects of sustainable urban mobility, particularly focusing on the transition towards sustainable commuting practices, this study is guided by the following research questions:

RQ1. How can the existing literature be mapped and consolidated to identify most effective interventions that can be implemented in the transition towards sustainable commuting?

RO2. How can a holistic framework, utilizing the dynamic relationships between interventions, effectively guide and advance sustainable commuting?

RQ3. What are the most effective strategies and measures that can be implemented to improve sustainable commuting in the city of Lahti?

1.3 Research Objectives

The objective of this study is to analyze the existing mobility systems and technologies to identify opportunities for improving sustainable commuting options in the city of Lahti. Through an extensive investigation, progressive interventions, policies, and innovative solutions will be explored to promote eco-friendly traveling alternatives. The aim is to find areas for refinement and develop strategies that contribute to a more sustainable and efficient transportation network.

The study will also focus on creating a comprehensive list of activities and interventions categorized by different themes and commuting methods. This grouping of interventions and behaviors will lay the foundation for a structured framework that enhances sustainable commuting and drives the widespread adoption of sustainable commuting practices. This framework can act as a guide for decision-making, resource allocation, and policy formulation. Additionally, it aids in facilitating the transition towards sustainable commuting. It can help to foster a more environmentally conscious society and catalyse positive impacts on the environment and social well-being.

1.4 Structure of the Thesis

This study employs a comprehensive literature review to evaluate the existing body of knowledge, drawing from diverse fields such as transportation and urban planning, infrastructure systems, sustainability, and emerging transportation technologies and mobility solutions literature. By synthesizing information from a wide range of secondary data sources such as articles, reports, and relevant websites, the literature review method enables an inclusive examination of the subject matter. Through this review, a panoramic overview of sustainable mobility concepts, definitions, and strategies will be presented. By critically evaluating state-of-the-art interventions across various themes aimed at promoting sustainable commuting and other methods, this research seeks to gain valuable insights into their effectiveness, potential positive impacts, and contributions to the transition towards a more sustainable system in urban mobility. Additionally, it aims to identify challenges related to the implementation of sustainable practices.

The city-level analysis will evaluate the current commuting landscape in the city of Lahti, identifying the existing barriers and unlocking underlying possibilities for enhancing the city's transportation network. It integrates qualitative insights from interviews with city transport specialists and statistical data on transportation modalities. The analysis delves into Lahti's transportation infrastructure, the commuting behaviors of its residents, supportive policies for sustainable mobility, and collaborative efforts within city departments. This comprehensive approach provides a critical evaluation of Lahti's journey towards sustainable commuting, underlining the city's unique context within the broader framework of sustainable urban mobility.

The Results chapter provides an insightful narrative across three main sections, each addressing a distinct research question. Initially, it synthesizes literature to identify and map effective sustainable commuting interventions, uncovering dynamic interrelationships and illustrating the interconnected strategies within urban mobility. This approach ensures that the transition towards sustainable commuting is not only conceptually robust but also intricately tailored to meet the specific demands and change of different cities with diverse characteristics. Subsequently, a holistic framework derived from the thematic literature review is introduced, elucidating its role as a guiding tool for facilitating the transition towards sustainable commuting. The chapter then focuses on Lahti, offering a practical

application of theoretical constructs. Here, Lahti's unique commuting challenges are analysed, proposing modified strategies to enhance its sustainable commuting practices. This chapter concludes by applying the framework to Lahti's context, showcasing a theoretically grounded approach translating into practical, actionable strategies.

In the discussion section, each research question is individually addressed, integrating findings into the existing body of knowledge, comparing the work with other studies, and critically analysing results to identify future research areas. For RQ₁, the study's contribution to sustainable commuting literature is explored, highlighting new insights and perspectives, and comparing methodologies with other key studies. The uniqueness of the holistic framework addressing RQ₂ is discussed, contrasting it with other models and reflecting on its limitations. For RQ₃, strategies for Lahti are critically evaluated, emphasizing their innovative aspects and feasibility while contrasting them with similar initiatives in other urban settings.

In conclusion, this master's thesis will integrate the key findings, shed light on their contributions to the existing understanding. It bridges theoretical concepts with real-world applications, particularly in Lahti, contributing to a broader understanding of sustainable urban mobility. Through its nuanced examination of various interventions and strategies, the research illuminates pathways towards environmentally conscious, socially equitable, and economically practical urban transport solutions, positioning itself as a foundational work for future endeavours in sustainable commuting and urban planning.

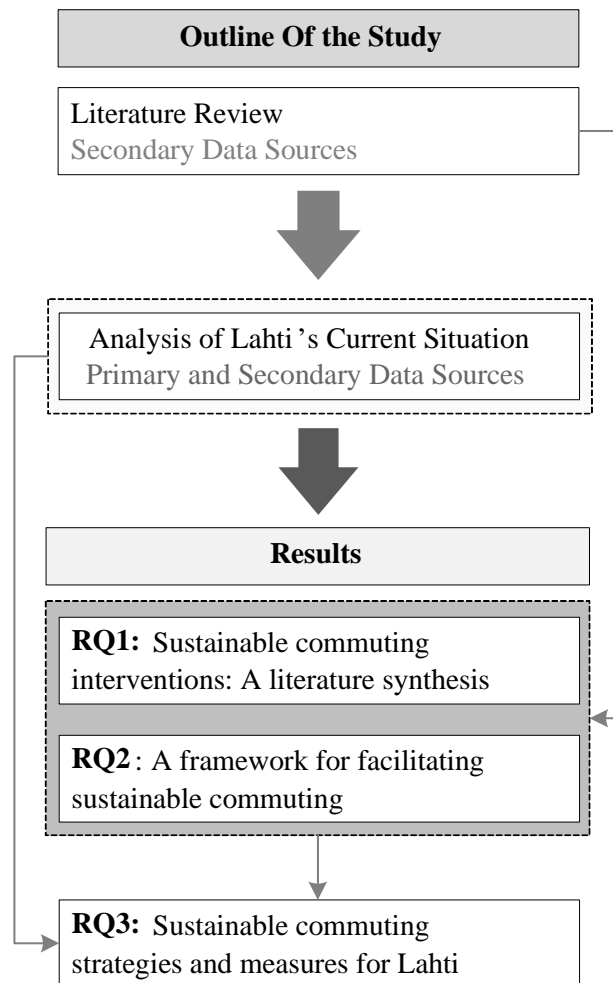


Figure 1 Outline of the Study Visualization

2 Theoretical Background

In this chapter, the theoretical foundation of this study is established, focusing on the extensive literature concerning sustainable mobility. The literature review encompasses a comprehensive exploration of sustainable mobility, including its definition, and complexities in advancing sustainable mobility. Moreover, it delves into the domain of intervention design for achieving sustainable mobility, drawing insights from emerging themes such as, public transport, infrastructure enhancement, behaviour change campaign, technology for seamless commuting and mobility management.

2.1 Sustainable Urban Mobility

2.1.1 Concepts and Definitions

Sustainable mobility is a concept profoundly intertwined with the principles of sustainable development. To fully grasp what sustainable mobility is, it is essential to understand both of its foundational elements: mobility and sustainable development. These two concepts are not only complex in their nature but also vary significantly in how they are perceived and understood. These variations often stem from the diverse perspectives and traditions inherent in different scientific disciplines (Høyer, 1999).

Sustainable development refers to the organized progress of society in a manner that improves economic growth, environmental protection, and social equity. This concept emphasizes meeting current needs without compromising the ability of future generations to meet their own needs. (Richardson, 2005)

Mobility, in the context of urban development and planning, refers to the ability and ease of movement across different spaces. It includes various forms of transportation like walking, cycling, public transit, and private vehicles. Mobility is not just about physical movement; it also incorporates access to essential services and activities, such as work, education, healthcare, and recreation (Høyer, 1999).

Bridging the concepts of sustainable development and mobility “Sustainable mobility” represents a transformative urban development paradigm centered on the creation of cities with distinct characteristics and features that address the evolving needs of modern societies (Berger et al., 2014). It entails implementing infrastructure investments and travel policies that pursue multiple objectives, and these developments also should align with the needs of service and information-based economies (Goldman and Gorham, 2006).

Sustainable mobility also involves connecting the cities to form clusters of polycentric urban centers, enabling proximity to everyday facilities and ensuring high accessibility to higher-order activities (Banister, 2008). A range of influential factors affects the progress of sustainable development. They include spatial and land-use planning, government policy, economic forces, technology, social and behavioral trends, and environmental considerations that must be collectively addressed in a dynamic process (Enoch, 2018; Mcfadden, 2007). This process involves the adaptation to changing societal needs and the operation within resources, ecological constraints, and environmental limitations. (Zietsman et al., 2002).

In the field of sustainable urban mobility, a paradigm shift is taking place, focusing on four key strategies: travel substitution, modal shift, distance reduction, and efficiency enhancement (Banister, 2008). These strategies are the basis of efforts to reduce unsustainable travel practices and address the negative impacts caused by current mobility systems. Moreover, an extensive range of interventions has been introduced and implemented to curb the demand and mitigate these issues. These interventions consist of several aspects, from the creation of eco-friendly infrastructure to the alteration of consumer preferences, in pursuit of adopting innovative approaches and executing them in an effective way to encourage sustainable commuting (Stephenson et al., 2018). This perspective acknowledges that sustainable mobility interventions operate across different levels, encompassing individual behaviors, corporate strategies, city-wide initiatives, and national policies (Nijkamp et al., 2001, p. 173).

According to the research by Dimitropoulos et al. (2018), effective intervention design is a complex task that necessitates the simultaneous influence of various aspects of the transport system. It also requires careful consideration to avoid unintended consequences, such as rebound effects that might inadvertently encourage increased driving, underscoring the importance of considering a holistic approach. (Stephenson et al., 2018). This approach in

sustainable urban mobility aligns with the need for an extensive assessment in the context of large-scale projects and it ensures that assessments and decisions encompass a broader range of impacts and benefits (Hüging et al., 2014.) Through the dynamic interplay of these factors, the urban mobility landscape adapts to meet evolving societal needs while respecting ecological and resource limitations, ultimately culminating in a more efficient and sustainable mobility system (Sato and Lan, 2007.) For the vision of sustainable mobility to become a reality, it critically hinges on the generation of expertise specific to this domain, which diverges from traditional transport knowledge primarily drawn from engineering and planning disciplines. Contemporary mobility expertise increasingly incorporates economic perspectives, underscoring the interdisciplinary nature of sustainable mobility knowledge. Environmental assessments assume a central role, complemented by insights into spatial and regional development and decision-making processes (Giorgi, 2003).

2.1.2 Challenges

The intricate and systemic nature of the mobility system poses a significant challenge. Over the past century, the growth in both population and mobility has been remarkable, with motorized travel expanding exponentially. However, this growth has raised concerns due to its considerable consumption of energy and material resources, emission, and the occupation of substantial land areas.

Despite the shared objective of mitigating the negative effects associated with mobility, persistent inquiries continue to arise. These inquiries revolve around the improvement of a sustainable commuting system that can accommodate the beneficial aspects of mobility, such as enriched human interaction and activity, without inhibiting or suppressing them. (Loo and Tsoi, 2018).

The primary challenge of sustainable mobility lies in striking a balance between the resource consumption of all transportation users and the ecosystem's capacity for regeneration. Furthermore, accessibility to mobility services remains unequal, leading to instances of social exclusion (Berger et al., 2014). Addressing sustainable mobility requires the consideration of different approaches, each with its own set of constraints. One of the central challenges in sustainable mobility revolves around public transportation. While it represents a key component of reducing individual car usage and associated emissions, there are

numerous obstacles, include funding issues, maintaining affordability, ensuring reliability and accessibility, and fostering a shift in public perception and preference towards public transit. Upgrading and expanding transit networks and bridging the gap between public transit stations and commuters' final destinations also requires larger investment and advanced urban planning (Kisor, 2021.)

Developing and upgrading infrastructure to support sustainable mobility is another challenge which entails financing for large-scale projects, minimizing disruptions and emissions during construction, and adapting to evolving urban landscapes (Thibault, 2021).

Now, utilizing technology to upgrade commuting for enhanced sustainability is a key area of focus. Nevertheless, this endeavor also brings forth several concerns. These include the need to guarantee fair access to technology, data privacy and dynamic, designing technology that is easy for users to navigate, addressing issues related to cybersecurity, and preventing a digital divide that might exclude certain individuals or communities from these technological advancements (D'Alberto and Giudici, 2023).

In the context of behavior change, encouraging individuals to switch from private car use to alternatives like biking, walking, carpooling, or using public transit demands significant effort and intervention. Encounters here include addressing ingrained habits, providing incentives for change, and ensuring that these campaigns reach diverse demographic groups including different gender identities, age, and socioeconomic backgrounds (Hyvärinen, 2021).

Efficiently managing urban mobility to alleviate congestion, emissions, and inefficiencies is a critical undertaking. Challenges emerge on multiple fronts, such as fostering collaboration and engagement among multiple stakeholders, ranging from government to private enterprises and community organizations, all of whom may have disparate priorities and perspectives. For instance, the formulation of effective strategies to genuinely reduce carbon footprints within the transportation sector proves intricate, requiring the promotion of low-carbon options like electric vehicles and overcoming existing infrastructure and policy barriers (Famoso and Lanzafame, 2013).

The role of political culture in transportation planning cannot be overlooked when identifying barriers to achieving sustainable mobility. According to Irish (2017), the fabric of political culture profoundly impacts the connections and collaborations involved in

mobility planning. This culture steers a city's aptitude to forge strong ties, which are crucial for innovative urban mobility development.

To overcome these challenges, it necessitates a blend of advanced solutions and strategies, policy adjustments, active public engagement, and collaboration among diverse stakeholders, including government entities, private enterprises, and local communities.

2.2 Intervention for Improving Sustainable Mobility

2.2.1 Public Transport Enhancements

Public transport shapes the core of urban mobility in all cities and offers a cost efficient and eco-friendly means of commuting for people across the globe. (ECMC, 1999). Cutting the expenses on parking and fuel and engaging with your community is also something that is attainable with utilizing public transport. (Hulkkonen et al., 2020). Moreover, it is frequently more time-efficient than solo driving, allowing individuals to engage in various activities during their journey. Public transportation can be an affordable choice for commuting more sustainably because it offers flexible timings and routes in many cities (O'Connell, 2023).

Green Transportation Policies and Regulations

Green transportation policies and regulations align closely with the public transportation enhancement theme, forming the foundation of sustainable commuting. These policies restrict certain mobility practices and implicate a range of measures designed to reduce emissions (Gonzalez et al., 2022).

One of the primary interventions in the public transport improvement category is the green transportation regulations and its principles revolve around the development of policies that actively promote the use of low emission in transportation. These policies include different forms, such as providing financial incentives for individuals who choose low-emission options, like buses or trains, over private cars (Hulkkonen et al., 2020).

Establishing and enforcing strict emission standards for public transport vehicles is another imperative intervention within this subtheme. These standards impose the maximum allowable level of pollutants that these vehicles can release, thus encouraging the adoption

of cleaner technologies. By mandating lower emissions, municipalities not only contribute to their sustainability ambitions but also foster innovation within the transportation industry. This intervention often requires collaboration with vehicle manufacturers to ensure compliance with these standards and may include financial incentives or penalties for adherence or disobedience, respectively (Eamonn Mulholland, 2023).

Renewable Energy Integration in Public Transportation Systems

Renewable energy integration involves harnessing green power sources like solar and biofuels to operate public transport systems, decreasing their reliance on fossil fuels. As part of the effort to incorporate renewable energy, can be conducting extensive research to evaluate the feasibility and benefits of utilizing biofuels in the transport sector. Biofuels are derived from organic materials and can be used as replacement to traditional fossil fuels. Research in this area assesses factors such as production scalability, cost-effectiveness, and the reduction of greenhouse gas emissions. It also explores the potential for local biofuel production, which can stimulate regional economies (Börjesson et al., 2014).

The EU's allowance for certain exemptions based on local conditions should be expanded to consider the existing low-emission fleet. Financial backing for new zero-emission buses and the necessary infrastructure must be strengthened, ensuring cities can fully leverage EU funds for sustainable mobility. It is crucial for the European Investment Bank and other EU instruments to support these local investments, ensuring a coherent and supportive framework for cities to meet decarbonization goals (Eurocities, 2023).

A new and significant intervention in renewable energy integration field is the electrification of bus transit systems, often referred to as trolleybuses or electric buses. These vehicles are powered by electricity, which can be generated from renewable sources (Kühne, 2010). Moreover, establishing partnerships with renewable energy providers ensures a sustainable energy supply for these electric transit systems. In this type of partnerships, it is possible to purchase green energy directly from providers or investing in local renewable energy infrastructure like solar panels or wind turbines that can be also profitable (Vehviläinen et al., 2022).

Transdev, as a mobility company, in its initiative to champion clean transport solutions, has been entrusted to oversee and operate Europe's largest fleet of electric buses in the Amstelland-Meerlanden region of Amsterdam. Since March 2018, these 100 electric buses,

predominantly powered by wind energy, have seamlessly catered to passengers, especially in routes serving the Amsterdam Schiphol airport. With solar panels adorning the bus depots, the vision is to achieve a fleet that is 90% electric by 2021 and fully emission-free by 2025 (Transdev is moving zero emission, 2023).

Accessible and Inclusive Public Transport Services

The concept of making public transport services more accessible and inclusive to a diverse range of users indicates providing for those who have special needs and varying mobility requirements. This approach seeks for creating a public transport system that can accommodate everyone, regardless of physical ability, age, or socioeconomic background (Saif et al., 2019). User surveys play a vital role in understanding passengers' needs and identifying gaps in intermodal connectivity. By gathering information from users, transport authorities can determine areas that require improvement and tailor their services to better serve the community based on their feedback (Morozov et al., 2023).

One of the most central interventions associated with this subtheme is the advancement of intermodal urban mobility. Intermodal transportation offers passengers to use multiple forms of transport for a single journey, seamlessly transferring from one mode to another. This approach improves the efficiency and convenience of public transport by integrating various modes such as buses, trams, trains, and bicycles. Passengers can easily switch between these modes during their journeys, reducing travel times and enhancing accessibility (Gebhardt et al., 2016).

In the bustling city of Copenhagen, the Danish State Railways (DSB) has pioneered an innovative approach to intermodal transportation, seamlessly integrating bike and train commutes. Recognizing the dual benefits of cycling and train travel, DSB redesigned its carriages, implementing a one-way system to facilitate easy entry and exit for bicycles. This modification has not only bolstered daily commuting but also ensured no compromises on passenger experience. The intermodal solution offers commuters the flexibility of combining the speed of train travel with the convenience of cycling, and alleviating city congestion. By allowing and encouraging travelers to bring their bikes aboard, DSB has effectively bridged the first and last-mile connectivity gap, emphasizing the importance and efficiency of integrated transport solutions (state of Green, 2017).

Multi-modal hubs are strategic locations and they have been planned in a way different modes of transportation converge. These hubs act as central points for transfers and connections between different commuting options. Implementing multi-modal hubs simplifies the transit experience for users, making it easier for them to switch between modes, whether it's from a bus to a train or from a bicycle to a tram (Yuan and Yu, 2018).

In 2016, the Lahti Travel Centre was inaugurated, consolidating various modes of transport by relocating the operations of the Lahti bus station to the vicinity of the train station (Lahti YIT, 2017). This centralized hub was established to ease transitions between trains and buses, addressing the prior inconvenience where commuters had to traverse a distance of one and a half kilometers between stations (netMAGmedia, 2016). The design of the center, featuring a 60-meter-long canopy, and an underground road tunnel, demonstrating the city's devotion to enhancing its infrastructure for residents. The move aimed not only to streamline transportation but also to reduce regional traffic in the city's central area, with the former bus station area being repurposed into a residential zone (Nordic Investment Bank, 2014).

Park-and-ride facilities are designed to encourage commuters to switch from private cars or bicycles to public transport. They provide convenient parking spaces at transit hubs, allowing individuals to park their personal vehicles and continue their journeys via public transport, such as buses or trains. This integration between modes of transportation enhances the overall commuting experience for those who are trying to switch to more sustainable modes of traveling rather than being driving alone all the time (Parkhurst, 2000).

In a concerted effort to enhance urban mobility, the Metropolitan Area Transport, in collaboration with its partners, has refurbished the park-and-ride services in Helsinki catering to both car drivers and cyclists. Key improvements include the replacement of outdated bike racks with safer frame-lock-supporting racks, enhancing guidance and visibility, and planning for weather-protected parking. These efforts align with Helsinki's aim to boost cycling's transport share to 20% by 2035. Ensuring quality bicycle parking is central to this strategy (Kaupunkiliikenne Oy, 2021).

Optimizing bus routes as a crucial part of making public transportation more available comprises reassessing and redesigning bus networks to enhance efficiency and accessibility. Cities may conduct studies to determine optimal routes, taking into account factors like passenger demand, traffic congestion, and geographic coverage.

By redesign bus tracks, public transport has more potential to become more accessible to a wider population (Chien et al., 2003).

Real-time information systems provide passengers with up-to-the-minute information about public transport schedules, delays, and service disruptions (Lu et al., 2018) These systems are accessible through many channels, such as mobile apps, websites, and digital displays at transit stops. Real-time information enhances the overall passenger experience, specifically for those who have busy or tight schedules (MacEdo et al., 2021).

The "EcoInfo" real-time information system marks a transformative approach in enhancing urban transit with its deployment of solar-powered, energy-efficient digital displays at bus stops and metro stations. Designed to operate under direct sunlight without compromising visibility, these displays utilize a fraction of the energy required by traditional real-time passenger information systems, significantly reducing the carbon footprint associated with urban commuting. (E-Tela, n.d.).

Besides, targeted design involves customizing public transport services to meet the specific needs of a variety of population segments. for instance, it can be include designing accessible vehicles, offering priority seating for seniors and people with disabilities, or ensuring that schedules align with the needs of different user groups, such as students or shift workers (Stephenson et al., 2018).

2.2.2 Infrastructure Enhancements

Infrastructure enhancements stands as a focal theme, anchoring the foundation of transformative change in mobility systems. The very essence of sustainable commuting, characterized by environmentally conscious practices that require the development and optimization of the infrastructure. This fundamental theme explores the tangible facets of our daily commute, encompassing the physical elements that facilitate and shape the transportation choices (Utilities One, 2023).

Enhancing Bicycle and Pedestrian Infrastructure

An integral part of sustainable urban mobility is developing the proper bicycle and pedestrian infrastructure in cities and rural areas. The major goal of these interventions linked with this subtheme is to promote and support active modes of commuting, reduce traffic congestion,

and improve the overall quality of urban life. By investing in well-designed infrastructure, cities can encourage more people to walk and cycle, thereby reducing their carbon footprint while enhancing public health (Todd Litman et al., 2006). Dedicated bike lanes and pedestrian walkways are essential components of structure enhancement for zero emission modes of transportation like cycling and walking. They provide safe and separate spaces for cyclists and pedestrians, that reduce the risk of accidents and making active transportation more appealing and enjoyable. These lanes are often physically separated from vehicular traffic, offering a sense of security to users (Cervero et al., 2009).

Moreover, public bike-sharing programs (BSP) are gaining popularity in urban areas worldwide. Bike-sharing systems typically consist of a network of self-service bicycle stations strategically placed throughout a city or urban area (dell'Olio et al., 2015). These programs make bicycles instantly available for short-term use, allowing customers to easily access bikes when they need it (Macioszek et al., 2020). This initiative not only promotes cycling as an easier mode of commuting but also contributes to reducing the number of cars on the road (Zhang et al., 2015).

However, strategically locating bike-sharing stations within urban areas is decisive for the success of these programs, but this task has often lacked a robust methodology. Geographic Information Systems (GIS) can serve as a valuable tool in this context (Caliskan, 2021). They allow the development of location-allocation models that consider several factors like demand, connectivity with public transport, and network structure. These simulations, integrated with GIS, provide a data-driven approach to determine optimal station locations (García-Palomares et al., 2012).

Understanding ridership patterns during cold seasons is crucial for promoting year-round cycling and walking. Cities need to adapt their infrastructure and maintenance strategies to ensure safety and convenience in cold and snowy conditions. By studying how people use these commuting modes in winter, cities can tailor interventions to meet their specific demands during that period (Singhal et al., 2014).

In the Finnish city of Oulu, winter cycling is not just an extreme activity but a mainstream commuting choice. With a notable modal share of 20% for cycling, even in cold climates, Oulu stands as a testament to effective urban planning. Oulu's approach is multi-faceted, combining both "hard" policies, such as an extensive and winter-friendly pathway network

carefully maintained for safety and convenience, and “soft” policies, including efforts and education to nurture a supportive cycling culture. Oulu’s success also underscores the importance of a supportive cycling culture. Studying such exemplars can offer invaluable insights for cities aiming to promote year-round cycling, even in challenging weather conditions (Pratte, 2011).

In regions with cold winters, maintaining pedestrian and cycling paths is challenging but essential. Effective winter maintenance ensures that these routes remain accessible year-round. This includes snow removal, de-icing, and maintaining proper lighting for safety of commuters (Aasvik and Bjørnskau, 2021; Turunen, 2023).

Street design measures such as developing and maintaining sidewalks to ensure safe and accessible pedestrian pathways. This involves features like wheelchair ramps and adequate lighting. Bicycle lanes and pedestrian pathways must be physically separated or marked with paint to provide clear routes for cyclists. Utilizing share-the-road signs and markings to inform all road users about common roadways, promoting safe interactions between different commuting modes (CDC, 2011). Providing streetscape amenities like benches, landscaping, lighting, public art, and first aid stations contribute to the overall attractiveness and functionality of pedestrian and cycling infrastructure.

For example, public art plays an important role in humanizing these spaces and connecting them with their surrounding communities. It also can transform transit stations from mere waiting areas into engaging spaces that contribute to the overall quality of life for commuters (Amundsen and Board, 1995). Public art such as installation art or street wall painting can convey the identity and cultural significance of a neighborhood, fostering a sense of connection between the transit system and the community it serves. Moreover, collaboration with local artists in the design process helps express community values and instills a sense of ownership and stewardship among residents and contribute to aesthetically pleasing visual experience of commuters (Cross River Partnership, 2018).

Keran Hallit, located in the former Inex Partners logistics centre in Helsinki, serves as a prime example of how urban art can transform public spaces into pedestrian-friendly areas. This area is also a hub for diverse events, ranging from flea markets and live music to community art projects (My Helsinki, n.d.).

Improving bus station infrastructure is also essential for ensuring serviceability and convenience. This can include upgrades like constructing wheelchair ramps, installation of seating areas, and using digital information displays. These improvements create a more comfortable and user-friendly environment for commuters. In regions with challenging weather conditions, such as heavy rain, snow, or extreme temperatures, it becomes even more critical to focus on enhancing bus station infrastructure. Adverse weather can pose significant obstacles for passengers, particularly those with mobility challenges (Rocha et al., 2020).

The Brighton Central Bus Hub improvement project, located at the heart of Brighton, entailed a £10 million investment. This encompassed a redesigned, stronger weather protection bus station with advanced digital signage, modern seating arrangements. Post-completion assessments marked 25% improvement in passenger satisfaction. The updated security features have significantly reduced incidents, ensuring passenger safety (Greener Journeys - Arup, 2018).

Sustainable Urban Planning

Green and sustainable urban planning plays a critical role in shaping cities that are conducive to sustainable commuting. By implementing the intervention associated with this subtheme it is possible to create environments where walking, cycling, and other sustainable transportation modes are not only feasible but also entertaining. Particularly, when urban planning integrated into broader transportation strategies, it contributes to the development of livable, environmentally responsible, and people-centric cities.

Mixed-use zoning is a planning strategy that intends to reduce the need for extensive travel by integrating diverse functions and activities within proximity. Its purpose is to minimize unnecessary commutes by allowing residents to access essential services, work, and entertaining opportunities within their immediate neighborhoods. By creating mixed-use zones, cities promote walking and cycling as practical alternatives to car-dependent commuting (Kusumastuti and Nicholson, 2016).

To create an attractive environment for pedestrians and cyclists, urban planners can prioritize the development of street-level shops, flea markets, cafes, and restaurants along their routes. It can motivate residents to walk or cycle for both practical and leisure purposes, as they can

easily access amenities and services during their commutes. It also contributes to the vibrancy and economic vitality of neighborhoods (Yoshimura et al., 2022).

Transit-Oriented Development (TOD) and Mixed-Use Land Use Planning

Interventions within this subtheme are centered on strategies and measures that facilitate mixed-use development around transit hubs. Such interventions encompass zoning regulations that encourage higher-density development near these hubs, as well as incentives for developers and architects to engage in transit-oriented projects. Furthermore, the integration of public spaces and pedestrian-friendly infrastructure in these areas is vital for fostering vibrant and accessible transit-oriented communities. Moreover, Mobility-Oriented Development (MOD) practices play a significant role in this context, emphasizing the creation of urban environments that seamlessly integrate various transportation modes into daily life. These modes include public transit, cycling, and walking, all working in harmony to reduce reliance on private vehicle (RTA Michigan, 2019).

Transit-Oriented Development (TOD) and Mixed-Use Land Use Planning are design approaches that underscore the importance of promoting mixed-use development near transit hubs. In essence, these policies support urban planning that integrates diverse land uses, such as residential, commercial, and recreational, around public transportation nodes (Shamskooshki, 2012).

Electric Vehicle Charging Infrastructure

To encourage the use of electric vehicles (EVs), cities can strategically install EV charging stations in public areas and within buildings such as parking garages, shopping centres, and office complexes. These charging points should be conveniently located to address the concerns of EV users regarding charging availability. Installing them in public places ensures that EV owners have the confidence to use their vehicles without the fear of running out of power (Luo and Qiu, 2020). Promoting business engagement in the expansion of the EV charging network is essential. Cities can incentivize commercial entities by providing benefits like tax breaks or financial subsidies to install EV charging stations in their parking facilities or on their premises. This dual benefit not only improves the accessibility of charging infrastructure but also aids businesses in attracting environmentally conscious customers who own electric vehicles (Sierzchula et al., 2014).

The collaboration between Kempower, a recognized EV charging solutions provider, and LUT University in Lahti, Finland, stands as a testament to the transformative potential of public-private partnerships in the realm of e-mobility. Through their joint venture, the Electric Mobility Research Centre (EMRC), the synergy between industry innovation and academic prowess is manifestly evident. Moreover, the global implications of this partnership are far-reaching. With Kempower poised to scale its production facilities, beginning with an expansion to Durham, North Carolina, the ripple effects of this Finnish collaboration are set to resonate on international shores (Kempower, 2023).

While EVs are lauded for their reduced carbon emissions compared to internal combustion engines, the experience of Norwegian cities highlights a critical oversight in the overarching strategy of transport decarbonization. EV incentives, as applied in Norway, have inadvertently perpetuated car-centric urban models that run counter to the efforts of cities like Oslo, Bergen, and Trondheim, which aim to foster denser neighbourhoods and prioritize transit, cycling, and walking. The prioritization of EVs, with subsidies making them cheaper to operate, has not only diminished the competitiveness of public transportation by making car travel relatively less expensive but has also indirectly depleted funds for transit development due to lost toll revenues. This paradoxical situation raises critical questions about the holistic benefits of EVs in urban settings and suggests that a successful transition to a greener transport future requires a more nuanced approach that balances the promotion of EVs with robust support for alternative transport modalities (Yang et al., 2023).

2.2.3 Behaviour Change Campaigns

Behaviour change campaigns as the main theme embodies a complex approach to encourage people to choose healthier and more sustainable ways of mobility. It is about restoring our connection with our surroundings, enhancing physical well-being, and reducing the carbon footprint of our daily commutes.

Promoting Active Modes of Transportation

Cities and organizations can promote walking and cycling by organizing events and campaigns that raise awareness of the benefits of these modes. For instance, “Bike to Work” campaigns have gained popularity in many urban areas. These events often include group

rides, safety workshops, and community-building activities. Research has shown that such campaigns can effectively encourage people to try cycling for their daily commute (Scheepers et al., 2014).

Encouraging employees to use bicycles for their work commute can be achieved through various incentives (Wardman et al., 2007). Companies can offer benefits such as subsidized bike purchases, secure bike storage facilities, and even financial rewards for employees who consistently choose cycling (Rérat, 2019). Recognizing this, many companies provide showers and cooling lockers. This not only makes it convenient for employees to freshen up but also ensures these showers are well-ventilated and maintained to the best standards (Baltatzi, 2017).

Companies can implement Eco-Mobility Rewards Programs to change the commuting habits of their employees in their daily lives. These programs often provide points or rewards to workers who choose eco-friendly modes of transportation, including walking and cycling. These points can be redeemed for wide range of incentives, from gift cards to extra vacation days (Mobility Behaviour Change, 2019). A notable perk includes subscription access to popular apps like Spotify, YouTube, and Audible. This allows eco-commuters to enjoy music, podcasts, and audiobooks, transforming their journey to work. For instance, the tech company “HubSpot” in Dublin offers a “Bike to Work” scheme, allowing employees to get tax savings on new bikes and equipment (HubSpot Careers, 2022). Another example is Pave Commute represents a key intervention for companies aiming to foster sustainable commuting among employees. Pave Commute stands out by seamlessly integrating into corporate structures. It offers a hassle-free, hands-on management experience, with pricing tailored to company size and inclusive of turn-key rewards. Priced affordably, starting at €455 per year for small businesses, and it aligns with the increasing demand for environmentally responsible workplace practices. For larger organizations, Pave Commute offers an “Enterprise” option tailored to meet diverse company needs and scales. This version expands on the “Small Business” package, adding features like optional custom rewards, a personalized launch program, and a custom marketing kit with a dedicated landing page. (Pave Commute, 2023).

Active transportation not only benefits the environment but also individual health as an excellent form of physical exercise. Promoting the advantages associated with personal well-being of these modes can inspire people to walk or bike for short or even longer trips (Sallis

et al., 2004). Organizations and companies can play an important role by organizing events or educational sessions offering insights into the benefits of active commuting, cycling safety, and even basic bike maintenance. Collaborative efforts, such as partnerships with local businesses, can further incentivize active mobility by providing discounts or perks to those who choose eco-friendly commuting methods (Hyvärinen, 2021). At the broader city level public campaigns, through advertisements and community events, can amplify the message, spotlighting the numerous benefits, from health to environmental conservation, associated with walking, cycling, and other active transport methods. By publishing data on the positive impacts of active mobility and creating platforms for citizen feedback, cities can maintain transparency and continually refine their initiatives to better serve their residents (Dons et al., 2015).

Facilitating Carpool and Ridesharing Matching Services for Commuters

In the quest for sustainable mobility, carpooling and ridesharing initiatives have potential to combat traffic congestion and reducing the number of single-occupancy vehicles on the road by efficient use of transportation resources (Xia et al., 2015). Large tech campuses, for instance, often provide internal shuttle services for employees or have partnerships with rideshare services like “BlaBlaCar” or other carpooling services to promote carpooling.

In the digital era, smartphone apps and online platforms can connect like-minded commuters who share similar travel routes (Ferrero et al., 2018). These platforms utilize algorithms to match potential carpoolers, making it easier for individuals to find suitable ride-sharing partners. Some studies even have indicated that these services not only increase carpooling rates but also foster a sense of community among participants (Molina et al., 2020b). Some corporations take a practical stance by launching dedicated carpooling and ridesharing programs. They provide a structured framework for commuters to share rides, complete with scheduling tools and incentives for participants. By formalizing the process, these initiatives lead to overcome some of the barriers to carpooling, such as concerns about reliability and trust (Parezanović et al., 2017).

Offering preferential parking for carpool vehicles as an inducements matter, and one powerful motivator is preferential parking. Cities and workplaces often reserve prime parking spaces for carpool vehicles. These conveniently located spots serve as a reward for commuters who choose to share rides. additionally, the visible nature of these parking spaces

also serves as a constant reminder of the benefits of carpooling, encouraging more people to give it a try (Kelly, 2007).

2.2.4 Technology for Seamless Commuting

Technology for Seamless Commuting arises as a transformative force. This theme navigates the digital landscape, where innovation merges with practicality to create efficient and eco-conscious travel solutions. It revolves around the deployment of technology to streamline mobility experiences and it makes sustainable commuting not just accessible but also appealing in our fast-paced, technology-driven world.

Mobility-as-a-Service (MaaS) Platforms

MaaS platforms are designed to simplify and enhance the urban commuting experience by seamlessly integrating diverse transportation options into a unified, user-friendly system (Musolino et al., 2022).

These platforms streamline urban mobility by offering a one-stop solution for planning, booking, and completing trips that involve different commuting modes. They enable users to effortlessly transition between buses, trains, trams, subways, bike-sharing, and ride-sharing services through a single, cohesive platform. This integration minimizes the complications of multi-modal commuting, promoting efficiency and accessibility (Butler et al., 2021).

A core feature of MaaS is the integration of ticketing and payment systems. commuters can access and pay for a multitude of transportation services, from buses to ferries, within the MaaS app or platform. This consolidation streamlines fare payments, ensuring a hassle-free experience while providing more transparency in pricing (Kamargianni et al., 2016).

Sometimes MaaS platforms are not limited to transactional functions; they are increasingly incorporating gamification strategies to influence commuting behaviours positively. By analysing users' daily transportation choices, these platforms can identify opportunities for sustainable urban mobility. Residents who chose eco-friendly modes, such as walking, cycling, or using public transport, are rewarded with virtual points, discounts, or other incentives. This gamified approach not only motivates users but also fosters a sense of collective environmental responsibility (Kazhamiakin et al., 2021).

Many believed it would reshape urban mobility, with platforms like Whim, Mobility-X, and Ubi-Go leading the charge, backed by popular mobility service providers like Uber, Lyft, and Lime. Cities worldwide began to see the merit of a harmonious blend of public and private mobility solutions. This transformation suggests a future where cities organize MaaS strategies, emphasizing collaboration over competition (Taylor, 2020).

Several forward-thinking cities are taking the concept of gamification a step further by introducing city-wide gamification apps. These applications encourage entire communities to make environmentally conscious commuting choices. People are motivated to participate in eco-friendly modes, contributing to broader urban sustainability goals while earning rewards (Manca et al., 2022).

For example, “Metropia” serves as a quintessential example of a MaaS platform aiming to redefine urban mobility. It integrates various transportation services, from real-time transit data to bike routing solutions that emphasize rider safety. The application not only provides real-time information but also integrates a “Mobility Wallet,” introducing a dual currency system, facilitating ease of payments across services. Additionally, by incorporating gamification elements and loyalty programs, Metropia promote eco-friendly commuting behaviours. This integration of transportation service providers with user incentives encapsulates the potential of MaaS platforms to transform urban commuting dynamics (Metropia, 2023).

In today’s digital era, personalized user experiences are key for customer engagement. A Personalized Commuter Plan (PCP) is a custom guide, often emailed, that offers tailored travel routes and relevant promotions based on a commuter’s habits and preferences. The goal is to promote sustainable, efficient, and cost-effective transport choices (Behavioural Insights Team, 2017).

Furthermore, examples from Baltic Sea port cities highlight the adaptability and potential of minipilots in addressing diverse urban challenges. For instance, Tallinn, recognizing the congestion woes of its urban core, explored the use of adaptive traffic lights as a means to optimize and streamline vehicular flow. On the other hand, Turku leveraged license plate recognition technology to analyse through traffic patterns, aiming to inform decisions on effective traffic redirection and city planning. In Hamburg, the focus shifted to sustainability and efficient cargo movement. Each of these cities, while united in their adoption of the

minipilot framework, tailored their approach to the unique challenges they faced, seamlessly integrating local decision-making, stakeholder collaboration, and cutting-edge technological innovation (Soe et al.,2022).

Shared Micro Mobility Solutions

Shared electric micro-mobility, including e-bikes and e-scooters, has emerged as a valuable addition to sustainable commuting possibilities (Mouratidis, 2022). It bridges the gap between traditional public transportation and final destinations. Travelers can easily access these services at transit hubs or designated areas, that provide a convenient and eco-friendly solution for covering the last part of their journey (Hosseinzadeh et al., 2021). By encouraging the use of shared e-micro mobility, cities can reduce the number of short car trips. Shared e-micro mobility services are designed to be inclusive and accessible to a wide range of users (Ignaccolo et al., 2022).

They offer individuals varying mobility needs and it counts as an affordable mode of transportation for most segments of the population. Electric micro-mobility options have a lower environmental impact compared to traditional vehicles, as they produce zero emissions and reduce air pollution. The adoption of shared e-micro mobility also presents an opportunity for data collection and analysis. Cities can use data from these services to better plan and optimize their transportation systems, ensuring that infrastructure development meets the evolving needs of commuters (Lin & Wells, 2023).

Amidst the transformative potential of micro-mobility in reshaping urban transportation towards sustainability, the challenges it presents are multifaceted and demand significant attention. A predominant challenge lies in ensuring safety.

As micro-mobility platforms replicate, cities witness a surge in accidents involving e-scooters and other micro vehicles, often due to the lack of dedicated infrastructure, clear usage guidelines, and user education. Such safety concerns are often intertwined with logistical issues (how these vehicles are parked or scattered post-use) can lead to cluttered sidewalks, impeding pedestrian movement and exacerbating urban congestion. The behaviour of riders remains unpredictable; from reckless driving to bypassing designated parking zones, these individual actions cumulatively damage the urban fabric (Olabi et al., 2023).

Intelligent Transportation Systems (ITS) for Traffic Management

One of the foundational elements of ITS is the deployment of smart traffic signals and congestion management systems. These advanced traffic signals are equipped with real-time data collection and communication capabilities. They can dynamically adjust signal timing based on traffic conditions, thus optimizing traffic flow. By reducing unnecessary stops, they mitigate congestion, enhance fuel efficiency, and minimize greenhouse gas emissions. Additionally, ITS can enable adaptive traffic control, where signals respond in real-time to changing traffic patterns, reducing travel time (Mandhare et al., 2018).

The main feature of ITS lies in data analytics and big data utilization. By harnessing a vast range of data sources, including traffic cameras, vehicle sensors, and GPS devices, cities can gain deep insights into traffic behaviour. Advanced algorithms process this data to predict traffic patterns, identify congestion hotspots, and suggest optimal routes for commuters. These data-driven insights empower traffic management authorities to make informed decisions, such as adjusting signal timing or deploying resources to alleviate bottlenecks (Zhu et al., 2019).

ITS extends beyond congestion management; it plays a vital role in enhancing road safety. For instance, intelligent traffic signals can prioritize emergency vehicles by in advance clearing intersections. Vehicle-to-vehicle and vehicle-to-infrastructure communication systems can provide real-time warnings to drivers about potential hazards, such as accidents or adverse weather conditions. This proactive approach to safety significantly reduces the risk of accidents and their associated human and economic costs (Bowman and Miller, 2016). As the first city in Northern Europe, Odense has implemented a brand-new rain sensor in a traffic light along their super bike highway. This sensor allows the intersection to detect rain, resulting in up to 20 seconds longer green light periods for cyclists during wet conditions. This ensures less idle time for cyclists, thus improving the commuting experience during rainy days. This system combines with motion detectors to identify approaching bicycles, further optimizing the traffic flow. Such integrative ITS solutions not only promote cycling but also make daily commuting more efficient and enjoyable for the citizens (State of green, 2017).

Ensuring road safety for cyclists is crucial to encourage sustainable commuting by two-wheelers (Belin et al., 2012). Augmented Reality (AR) technology can be integrated into

urban planning to enhance cyclist safety. AR systems can provide real-time information about traffic conditions, potential hazards, and safe routes for cyclists (Matviienko et al., 2022). Improving cyclist safety, cities can motivate more residents to choose bicycles as their preferred mode of commuting. Copenhagen has initiated the installation of intelligent traffic lights across all its intersections, being the first major city in Scandinavia to undertake such a venture. Investing in 380 new, adaptive traffic signals, the city aims to reduce travel time for both bus passengers and cyclists by optimizing green waves and traffic control digitally. This modern approach to ITS focuses on making the traffic system more digital, responsive, and intelligent. Key arteries leading to the city centre have green waves for bicycles, encouraging steady cycling speeds and reducing stops. With advanced sensors, these lights can even gauge the number of cyclists approaching an intersection and adapt accordingly, prioritizing groups of cyclists. Such endeavours showcase Copenhagen's commitment to using ITS for promoting sustainable commuting and enhancing the urban transport experience (State of green, 2017).

In the evolving domain of ITS, adapting to new innovations and their ability to implement and validate in practical settings is important. One method that offers promise in this context is the integration of "minipilots". It characterized by its agility, real-world experimentation, and cost-efficiency, stands out as a beacon of participatory governance. By fostering a collaborative environment that bridges cities, stakeholders, and residents, minipilots emphasize the focus on tangible urban challenges. The collective design of minipilot programs, combined with streamlined procurement and diversified risk, enables rapid feedback loops, and point out swift, impactful execution. Consequently, this integration promises not only accelerated innovation cycles but also a heightened potential for scalable, holistic solutions that resonate with real-world needs and ambitions (Soe et al.,2022).

2.2.5 Mobility Management

This theme represents the orchestration of diverse transportation modes and resources to achieve unified, eco-conscious mobility. It involves collaboration, innovation, and strategic planning to optimize commuting patterns, and reduce emissions.

Multi-Stakeholder Collaboration and Engagement

Multi-stakeholder collaboration and engagement play a significant role as it involves the active participation of various stakeholders, including government bodies, private sector entities, experts, retailers, and local communities, in the decision-making process and the implementation of transportation initiative (Cascetta & Pagliara, 2013).

Public-private partnerships can be structured in numerous ways, such as joint ventures, concession agreements, or service contracts. These collaborations can help in financing and operating transportation projects, leveraging the expertise and resources of both public and private sectors. For example, private companies may invest in public transportation infrastructure, like bus rapid transit systems, in exchange for revenue-sharing arrangements or other incentives (Le Pira et al., 2016).

Initiated as an inter-municipal collaboration, the Cycle Superhighways project aims to enhance sustainable mobility by expanding a network of bike paths across the Capital Region of Denmark. Since its inception, there's been a notable 52% increase in bike commuters on certain routes. This initiative not only seeks to motivate more people to choose bicycles for commuting but also anticipates a potential 30% surge in bike commuters. Beyond improving transportation, the Cycle Superhighways also boast a significant socio-economic return of 19%, highlighting its value in fostering both sustainable commuting and economic growth (State of green, 2017).

The active involvement of local communities and citizens is essential for designing transportation initiatives that meet their needs and preferences. This engagement helps transportation planners make informed decisions and ensures that projects align with the priorities of the community. In the context, the advent of social media and micro-participation of public presents an evolving opportunity, and many cities are now developing strategic approaches to involve the public through these platforms (Evans-Cowley and Griffin, 2012).

In the city of Tallinn, this principle of community engagement is prominently showcased through the Bicification project. The city invited its residents, particularly cyclists, to participate in an international mobility survey to map their journeys and offer insights into daily cycling routes. This initiative was not only aimed at collecting data but also at empowering the city to enhance its cycling infrastructure based on genuine user feedback.

By integrating technology such as the Pin Bike kit and introducing a reward system, Tallinn effectively motivated citizens to participate actively. Such strategies reflect how modern cities are turning to innovative tools and direct community interaction to ensure their transportation projects genuinely serve the needs of their residents (Tallinn, 2022).

Carbon Footprint Reduction Strategies

Among the strategies and policies for reducing carbon footprints in transportation, one approach is to encourage the use of fuel-efficient vehicles, which can significantly contribute to emissions reduction. It promotes the adoption of vehicles that offer better fuel efficiency, such as hybrid or electric cars or it may include providing incentives like tax credits or rebates for purchasing them (Litman, 2013).

Personal Carbon Trading (PCT) as one of the innovative approaches in this context involves individuals monitoring and managing their carbon emissions associated with transportation. It typically utilizes an ICT platform and a mobile phone application to track emissions. Participants are allocated a specific carbon allowance, and they can earn rewards (in a voluntary system), or face consequences (in a mandatory system) based on their emissions compared to this allowance (Uusitalo et al., 2022).

Moreover, it provides external motivation through economic benefits, triggers intrinsic motivation through improved carbon awareness, and can change social norms related to carbon consumption. While carbon pricing, whether through PCT or other mechanisms, is considered an effective tool, there are ongoing debates about the best approach, including cap-and-trade versus carbon taxes. Both approaches have their merits, with carbon pricing influencing decision-making, stimulating innovation, and potentially achieving environmental and economic efficiency (Kuokkanen et al., 2020).

An illustrative example is the CitiCAP project in Lahti, carried out between 2018 and 2021. The cornerstone of this project was the world's first citywide PCT pilot. With a mobile application that recognized different mobility modes, users were incentivized for making sustainable transport decisions. Despite the challenges of the Covid-19 pandemic, the pilot witnessed reduced mobility distances and emissions. While most users earned just a few virtual euros, the concept gained traction, with 79% understanding its mechanism and 36% successfully reducing their mobility emissions (CitiCAP, 2021).

Encouraging businesses or companies to invest in local eco-friendly transportation projects can be an effective way to offset their carbon emissions. This involves businesses supporting initiatives that reduce emissions, such as public transportation improvements, bicycle infrastructure, or electric vehicle charging networks. In return, businesses can compensate for their emissions and demonstrate environmental responsibility (Eloranta, 2021).

For instance, in New York City, the Citi Bike program, sponsored by Citibank, serves as a prime example of businesses investing in local eco-friendly transportation projects. This bike-sharing initiative not only encourages residents and tourists to opt for bicycles over cars for short trips, thereby reducing carbon emissions, but also strengthens Citibank's image as a socially responsible entity committed to sustainability (Skyler, 2023).

Travel Demand Reduction

Travel Demand Reduction strategies aim to minimize the need for commuting and travel, thus reducing the associated carbon emissions and traffic congestion. Encouraging flexible work hours among employers and employees can include options like flexitime, compressed workweeks, or staggered start and end times. By allowing employees to adjust their work hours within certain limits, it reduces the need for everyone to commute during peak traffic hours (Chakrabarti, 2018). This leads to less congestion on the roads, smoother traffic flow, and lower emissions from idling vehicles. Furthermore, it can enhance work-life balance for employees, potentially boosting job satisfaction and productivity (Wöhner, 2022).

Telecommuting, also known as remote work, enables employees to work from home or other remote locations using technology to connect to their workplace. Employers can provide the necessary technological support, such as secure internet connections and virtual meeting platforms. Telecommuting not only reduces the need for daily commuting but also lowers the demand for office space and associated energy use (Ye, 2012).

In the Nordic countries, telecommuting infrastructure thrives with widespread use of high-speed fibre-optic networks and e-learning platforms like Miro facilitate virtual brainstorming and collaboration, and Virtual Desktop Infrastructure (VDI) enables employees to access their work systems from any location. Key communication tools such as Slack and Zoom facilitate team interactions, while cybersecurity measures, including VPNs, ensure data protection. Region-specific solutions tailored to Nordic needs complement these global platforms, making remote work seamless and efficient (Nordic Council of Ministers, 2022).

Land Use Management

Parking management systems (PMS) and policies are crucial components of effective land use management strategies, particularly in urban planning, to mitigate the environmental impact of transportation and optimize land utilization. One key approach is to limit the availability of parking spaces, especially in dense urban areas like city centre. By reducing the number of parking spots or imposing stricter regulations, cities can make people to seek alternative commuting methods such as public transit, cycling, or walking. Fewer parking spaces discourage car use, alleviate traffic congestion (Litman, 2006).

Implementing pricing mechanisms for parking, such as congestion pricing or dynamic pricing, can help manage demand. By charging higher rates during peak hours or in high-demand areas, cities can encourage carpooling, shared rides, or the use of public transportation (Mingardo et al., 2022.) The revenue generated from these fees can be reinvested in sustainable transportation infrastructure.

Utilizing technology, cities can implement smart parking systems that help drivers find available parking spaces efficiently (Mangiaracina et al., 2017). These systems can reduce the time spent searching for parking, which in turn reduces fuel consumption and emissions associated with idling vehicles (Ramaswamy, 2016).

In recent years, technological advancements in parking management have led to the development of sophisticated Parking Management System (PMS) apps. For example, “EasyPark”, widely adopted in several European cities, facilitates users in locating, reserving, and paying for parking spaces using a simple interface. Similarly, “Parkopedia” provides detailed information on parking availability, pricing, and hours in numerous countries. These PMS apps exemplify the integration of technology in urban planning, easing the traditionally complex task of parking for drivers and promoting efficient use of urban spaces (Hiner, 2023).

3 City-Level Commuting Analysis in Lahti

This chapter provides a detailed analysis of Lahti's current commuting landscape and a critical assessment of the barriers the city faces in achieving sustainable mobility. It synthesizes insights from a qualitative interview with a city transport specialist and statistical data on the distribution of transportation modes. Additionally, the chapter examines the various transport modes used by Lahti's citizens. The discussion encompasses an exploration of Lahti's infrastructure, the behaviours of its residents, the policies supporting sustainable mobility, and the collaborative efforts among different city departments.

3.1 Understanding Lahti's Commuting Dynamics

Lahti, a progressive mid-sized Finnish city with a population of approximately 120,000, is taking strides towards sustainable commuting to align with its green city ethos and its target of carbon neutrality by 2025. The urban planning initiatives have been particularly focused on transforming the city centre into a pedestrian-friendly zone, fostering a conducive environment for walking, and cycling, and reducing vehicular traffic and associated environmental impact (Lahti -Municipality, Finland, 2023). The city's approach includes rerouting car traffic to the outskirts and consolidating parking into specific zones to discourage car usage within the central areas. These measures support the growth of the Travel Centre, a central hub in Lahti's transportation network, providing convenient rail links to Helsinki and beyond (Green Lahti, 2021). Lahti's public transportation network is comprehensive, featuring an extensive network of streets totalling 665 kilometres, 543 kilometres of dedicated bicycle paths (including 166 kilometres for non-motorized traffic), and a bike-sharing program with 500 bikes across 62 locations launching in April 2023 (Lahti, 2023-a).

The city is also investing in the transformation of the Niemi district from an old industrial zone into a bustling educational campus. This development is expected to bring together students and professionals who can take advantage of short-distance travel within the city, thus bolstering the city's sustainable mobility objectives (Lahti, 2023-b).

3.1.1 Different Modes of Commuting in Lahti

Public Transport

At the heart of Lahti's transportation network lies the Lahti Travel Centre, a pivotal junction uniting long-distance, regional, and local bus transport with rail services. This center serves as a vital link, offering a comprehensive range of services within the area, catering to both local and regional commuters.

Lahti features commuter trains, including the Helsinki-bound Commuter Train Z, ensuring an efficient one-hour journey from the capital city. The city also boasts regional trains connecting to Riihimäki, Helsinki, Kouvola, and various intermediate stations. For long-distance travel, all passenger trains, including those to St. Petersburg and Moscow, have Lahti as a designated stop. Quick access to Helsinki, St. Petersburg, and beyond positions Lahti as a significant transportation hub. Lahti offers convenient connections to the Helsinki-Vantaa airport, with regular bus services taking approximately 1 hour and 20 minutes to reach the airport. Train connections to the airport, originating from Tikkurila, further enhance accessibility. In addition, numerous long-distance buses link Lahti to the Port of Helsinki's passenger terminals, providing further convenience (Lahti, 2023).

Lahti's local bus transport system, operated by Lahden seudun liikenne (LSL), stands as an integral part of the city's commuting framework. The comprehensive network of bus routes evident in the city's transport map exemplifies a well-thought-out urban mobility solution. This network is particularly designed to connect residential areas, business districts, educational institutions, and key public spaces, thus promoting urban livability and economic efficiency. The map of Lahti's bus routes reveals a color-coded representation of various bus lines, each serving as a key connector, ensuring residents can reach their destinations with ease. The central nodes, such as the Travel Center, Market Square, and Päijät-Häme Central Hospital, function as important interchange points. Here, passengers can effortlessly transition between different bus lines, enhancing the system's flexibility and convenience. LSL's dedication to serving the community is reflected in the strategic placement of routes to cover expansive geographical areas, offering inclusive access to the city's amenities. The frequent services to high-demand areas like the city center, education centers, and healthcare facilities underscore the role of public buses in facilitating essential daily commutes. Furthermore, Lahti's local buses are synchronized with the broader regional

and national transport systems, including commuter trains and long-distance buses. This integration allows for seamless intermodal transfers, crucial for those commuting to and from the outskirts or neighboring cities (Lahti, 2023).

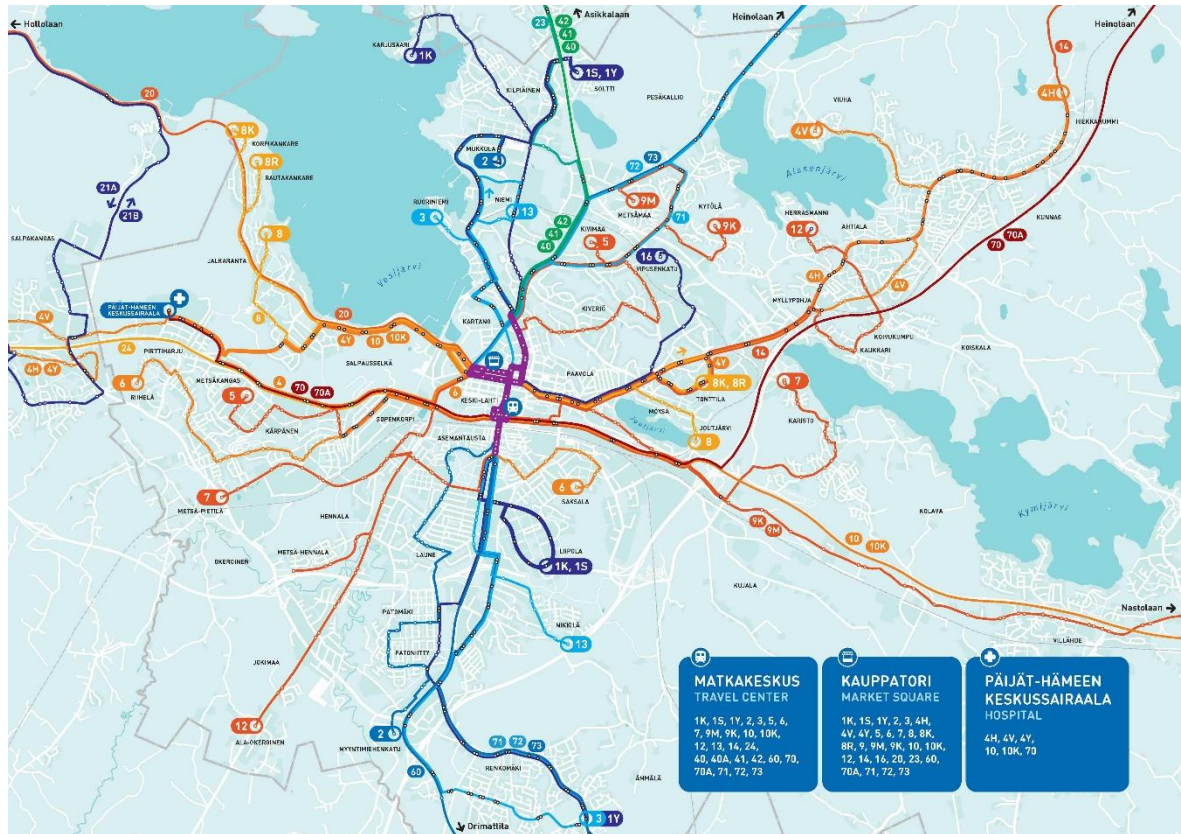


Figure 2 LSL Bus line map template (Lsl, 2023)

Shared E- Mobility

The city offers shared electric scooters to enhance mobility for everyone. Tier is the company that provides electric scooter services in Lahti, taking responsibility for its maintenance, customer support, and overall service operation. Using electric scooters follows the same traffic rules as bicycles. Ensuring traffic safety is essential, and riders must utilize the scooters' safety features, including turn signals, helmets, and double-standing support. Electric scooters represent a relatively new mode of transportation, and Lahti has established guidelines to govern their operation. These guidelines aim to seamlessly integrate this innovative mode of small mobility with existing transportation options, fostering a common understanding among all stakeholders. In these guidelines, “means of transport” refers to shared transportation accessible through an electronic smartphone application, ID card,

password, or other identification methods provided by the service provider, known as the “operator.” The term “service” denotes the offering provided by the operator, enabling customers to use shared transportation within the service’s defined limitations for a fee. A “user” is a customer utilizing the operator’s service. The City of Lahti reserves the right to update and modify these guidelines as necessary for the city’s well-being. These e-scooters are accessible during snow-free periods, typically becoming available around April, though the exact timing may vary depending on the year. They are withdrawn from service when winter arrives (Lahti, 2023).

Cycling

Lahti’s urban landscape showcases a strong commitment to sustainable transport, evidenced by the well-established cycling infrastructure that crisscrossed the city. Mapped out by distinctive purple lines, this network of cycling paths is designed for safety, efficiency, and directness, facilitating travel between residential areas, commercial centres, and green recreational zones. It reflects a holistic approach to urban planning, with cycling positioned as a key transportation alternative. The city’s bike-sharing program, which typically operates for seven months each year, launched in April 2023 and is accessible through 500 city bikes stationed at 62 locations across the city. Travelers can acquire licenses for various durations, from a day to a full season, facilitating flexible and sustainable commuting (Lahti, 2023).

These Mankeli stations, visible as green icons on the city map figure 3, ensure that bike-sharing is convenient and accessible, uniting seamlessly with other transportation modes for both locals and visitors. With licenses available for periods ranging from a single day to an entire season, and the Freebike 2.0 app to assist in locating bikes and stations, Lahti is equipping its residents with the tools for flexible, eco-friendly commuting. This expansive network of paths, in unison with the Mankeli stations, signals a shift in the city’s mobility culture. Cycling is actively promoted as a viable daily commute option. By placing the majority of residents within easy reach of both the paths and the bike-sharing facilities, the initiative is a strategic move to lessen the city’s reliance on private vehicles. Such measures resonate with Lahti’s broader environmental objectives, targeting emission reduction and traffic decongestion, while also advocating for the community’s health through increased physical activity (Lahti Map Service, 2023).

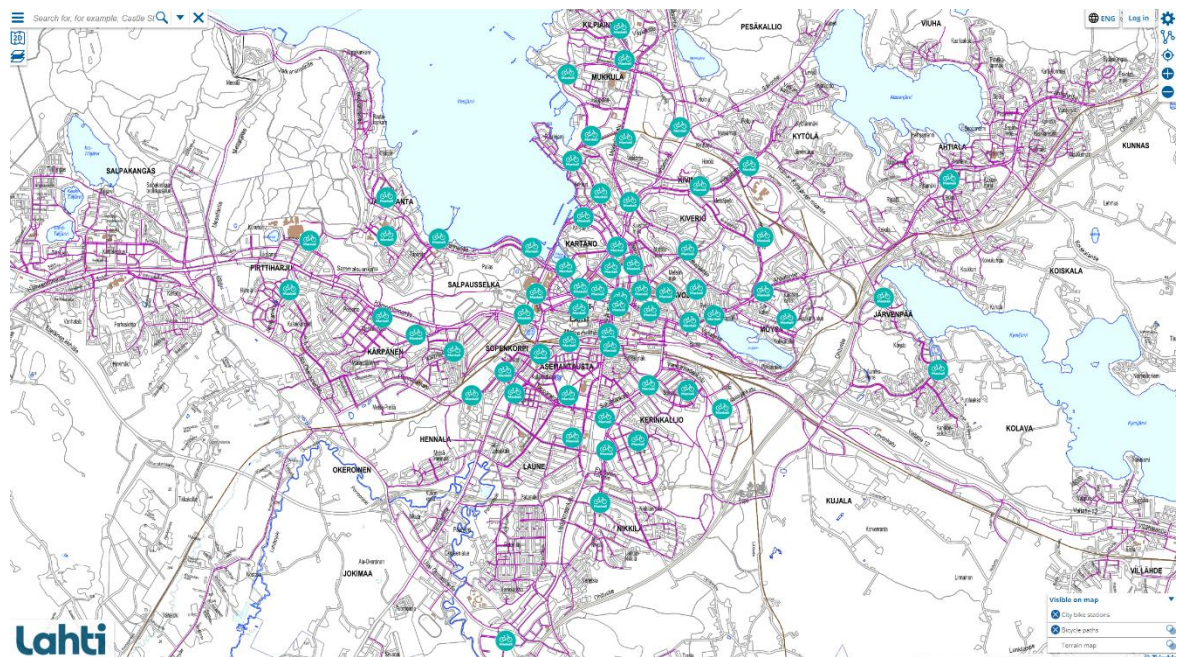


Figure 3 Mankeli stations and bicycle routes (Lahti Map Service, 2023-a)

Walking

Analyzing the walking infrastructure in Lahti from figure 4, it is clear that the city has established a comprehensive network designed to encourage and support pedestrian movement. The map shows a multitude of green areas, likely representing parks and recreational spaces, which are interconnected by pathways that accommodate walking. These pathways serve as green corridors within the urban fabric, promoting a healthy lifestyle and providing residents with accessible options for leisure and exercise. The presence of water bodies adds to the appeal of walking in Lahti, as they often have accompanying trails that offer scenic vistas and tranquil environments for pedestrians. Such features not only enhance the walking experience but also connect different parts of the city, creating a cohesive network of pedestrian routes. The map details “17 Counters” distributed across the network, indicating Lahti’s investment in monitoring pedestrian traffic.

This data is essential for understanding the frequency and patterns of foot traffic, which is crucial for the ongoing assessment and improvement of the pedestrian infrastructure. Despite the evident green spaces and scenic routes, the map suggests that the city center could benefit from targeted enhancements to address areas that are currently perceived as uncomfortable or noisy. Efforts are underway to improve these conditions, with a focus on differentiating pedestrian paths from those used by cyclists and micro-vehicles (Heinäaro, 2023).

By clearly establishing walking areas and implementing design elements that prioritize pedestrian comfort and safety, Lahti is taking steps to transform its city centre into a more inviting and walkable environment. The current state of pedestrian pathways in Lahti reflects a city that values sustainable transport and the well-being of its citizens. With strategic planning and continuous improvements, Lahti is fostering an urban landscape that encourages walking as a primary mode of transport, contributing to the city's vision of an engaging and environmentally conscious community (Lahti, 2023-a).

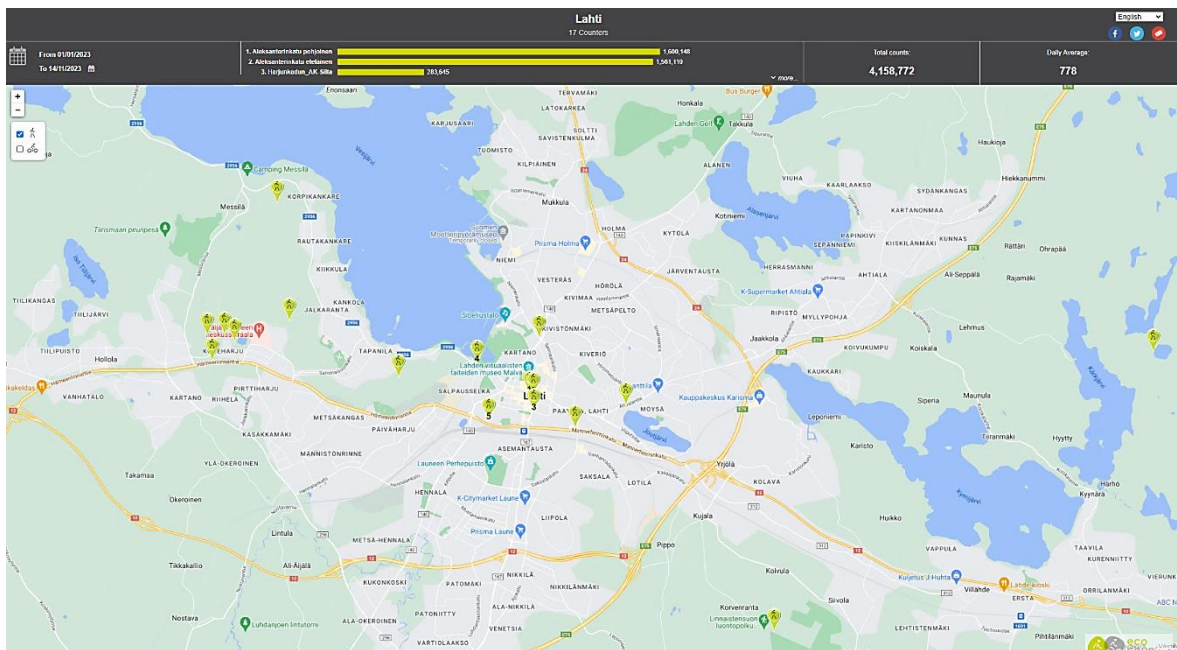


Figure 4 cycling and pedestrian encounter map (Lahti, 2023-b)

Private Car and Car Sharing

The map of Lahti reveals a city with a comprehensive road network, and the density of roads in Lahti's center is indicative of a high demand for vehicular access, with public transport seemingly taking a back seat to the attraction of private car convenience. However, this has led to significant drawbacks; traffic bottlenecks are a common sight, and the air quality is compromised by emissions from the steady stream of cars, as evidenced by the concerns of noise and pollution within the city's core. However, Lahti also recognizes the importance of sustainable alternatives and has facilitated car-sharing as a flexible option for residents. Carsharing in Lahti enables registered users to access vehicles at various locations, providing the convenience of a car without the obligation of ownership.

The city supports car-sharing by issuing general parking permits to car-sharing companies, allowing their vehicles to utilize resident parking spaces without the typical charges. This incentive aims to integrate carsharing into the daily mobility mix of the city, offering an alternative that could mitigate some of the traffic and environmental challenges associated with private car use. Car-sharing vehicles in Lahti are easily accessible through digital platforms and are available for all registered users, reflecting a modern approach to urban mobility.

In Lahti, car-sharing companies like 24 Rental Network Oy have been granted these general parking permits. The permits are electronic, streamlining the parking process and control through vehicle registration numbers. This system demonstrates Lahti's commitment to reducing the barriers to carsharing and making it an attractive option for residents (Lahti, 2023).

3.1.2 Analysis of Transportation Modalities

In Lahti, the modal split of transportation reflects a city at a crossroads of sustainable mobility and traditional commuting patterns. As figure 5 shows, over half of the journeys are made by drivers of passenger cars, accounting for 51% of the transport mode choice. This predominant use underlines the challenges ahead in shifting behaviours towards more sustainable options.

Walking, a cornerstone of sustainable urban mobility, represents a significant 23% of the modal split, indicating a healthy inclination towards non-motorized transport among the residents.

Cycling and bus usage, at 6% and 3% respectively, although modest, are crucial indicators of the city's developing sustainable mobility framework. Passenger car ridership, distinct from drivers, makes up 15% of the modal share, when considering those not behind the wheel, accounts for a notable portion of the modal share. (Traficom, 2021).

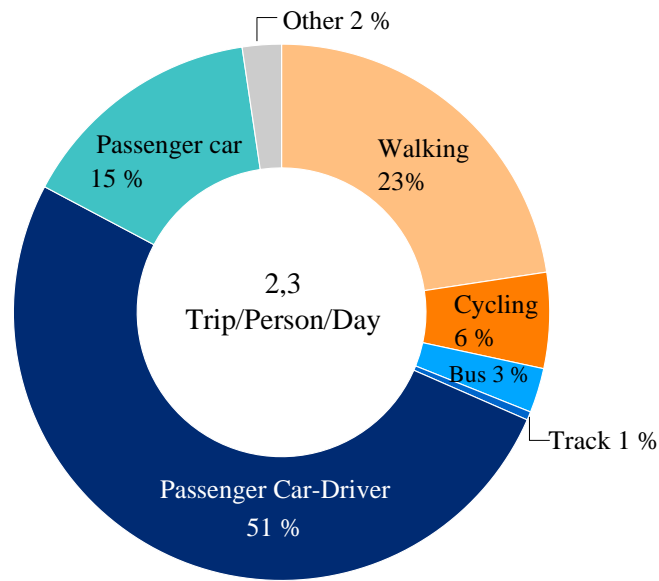


Figure 5 Modal split of transportation (percentage)

As it is evident in figure 6, 52.7% of households with no car primarily rely on walking, indicating a strong pedestrian culture in car-less demographics. Public transport is used by 19.1% of the no-car group, which could reflect the accessibility and convenience of Lahti's public transport system for those without personal vehicles.

Households with one car show a balanced dependency, with a significant 52.5% still opting for the car as drivers, suggesting that even with access to a car, there is an inclination towards driving. However, there is a modest use of public transport and non-motorized modes like cycling and walking, at 4.6% and 2.4% respectively, hinting at the potential to encourage multi-modal transport options among this group.

For households with two cars, reliance on driving increases dramatically to 64.7%, while public transport use drops to 1.6%. This trend indicates that as car availability increases, the propensity to use alternative transportation modes decreases, which presents a challenge for the city's sustainable transport initiatives.

The most car-abundant households, those with three or more cars, show the highest levels of car use for driving at 78.8%. This suggests a strong correlation between the number of cars a household owns and the likelihood of driving as the primary mode of transportation. Walking, cycling, and public transport use are minimal among this group, reflecting a significant challenge in shifting behaviours towards more sustainable commuting habits.

These statistics highlight a clear opportunity for Lahti to focus on strategies that address the different needs and habits of residents based on car ownership levels. For households without cars, improving and promoting public transport could further reduce the reliance on walking for longer distances. For those with one or more cars, incentivizing the use of public transport and cycling could be key to reducing the high rates of car usage for driving, thus aligning with Lahti’s sustainable mobility goals (Traficom, 2021).

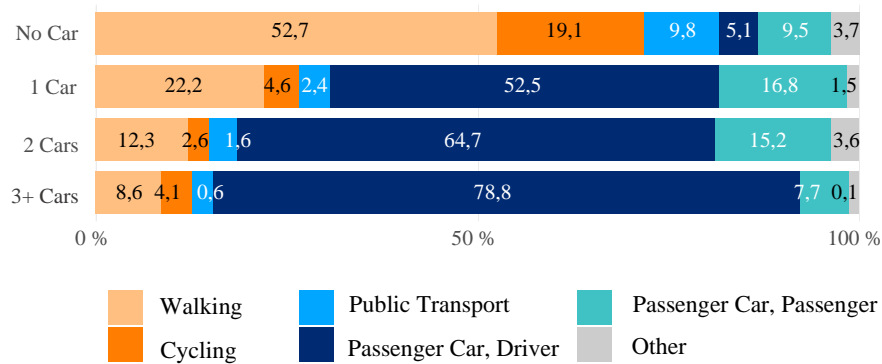


Figure 6 The use of residents’ modes of transportation according to the cars owned by households

The data on household car ownership which is shown in figure 7 across different regions reveals Lahti as a city with a distinctive pattern. Lahti stands out with 30% of households without a car, which is remarkably higher compared to nearby Orimattila-Asikkala, Kärkölä-Iitti, and Padasjoki-Sysmä-Hartola. This could indicate a more robust public transportation network or a more walkable city structure, suggesting a potential for Lahti to further enhance non-car-dependent mobility options. In Lahti, households with one car make up 54%, aligning with the overall regional trend, which shows a majority of households owning a single car. This consistency across the regions reflects a common lifestyle choice or necessity, potentially driven by the urban-rural spread and the availability of public transport services.

Furthermore, the proportion of households with two cars in Lahti is lower than the entire region and some nearby areas, at 14%. This might suggest a successful penetration of sustainable transport policies or the influence of urban living constraints on car ownership.

Households owning three or more cars are the least in Lahti at 2%, which is lower than the regional average. Overall, Lahti’s car ownership profile, with a significant portion of no-car

households and lower rates of high car ownership, positions the city favourably for pushing its sustainable mobility agenda forward. The data suggests opportunities for Lahti to capitalize on its existing public transport utilization and further discourage multi-car vehicle dependency (Traficom, 2021).

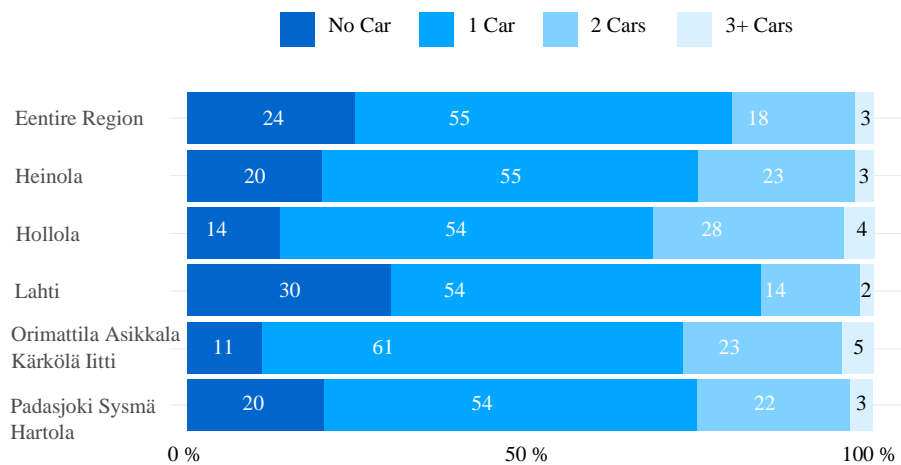


Figure 7 Car ownership of households by region

The figure 8, illustrates a clear gradient in car ownership across the urban-rural spectrum within the region encompassing Lahti. In the inner urban area, a substantial 36% of households do not own a car, which likely reflects the high accessibility to public transportation and urban amenities that reduce the dependence on personal vehicles. Moving outward to the outer urban areas, the proportion of households without a car decreases to 20.6%, with a corresponding increase in one-car households. This shift suggests that as we move away from the city centre, the reliance on private cars begins to grow, possibly due to less dense public transport networks. In the suburban areas and city outskirts, the percentage of households with two cars rises to 27.4%, indicating a greater dependence on private vehicles, likely due to limited transportation options and increased travel distances to urban centres. Rural local centres and areas near the city have an even lower percentage of no-car households, at 17.3% and 8% respectively. The significant presence of two-car households in these areas, 17.2% and 31.5% respectively, highlights the necessity of private vehicles for connectivity and mobility in less urbanized areas. The core rural areas and sparsely populated rural zones show the highest rates of two-car households, at 21.2% and 31.3% respectively, with three-plus car households also being more common in these regions. This trend highlights the essential role of cars in rural living where public transport services are

often scarce. The entire region, when viewed as a whole, has 24.4% of households without a car and a dominant 55.1% with one car, reflecting a mix of urban accessibility and rural dependence on private vehicles for transportation (Traficom, 2021).

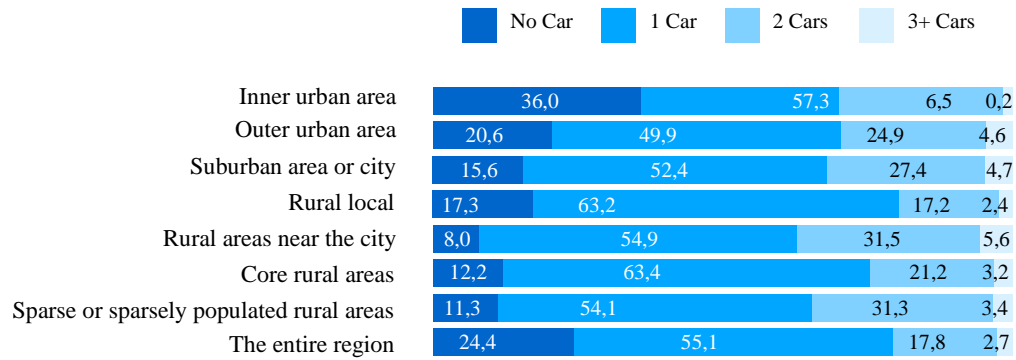


Figure 8 Household car ownership by urban-rural classification

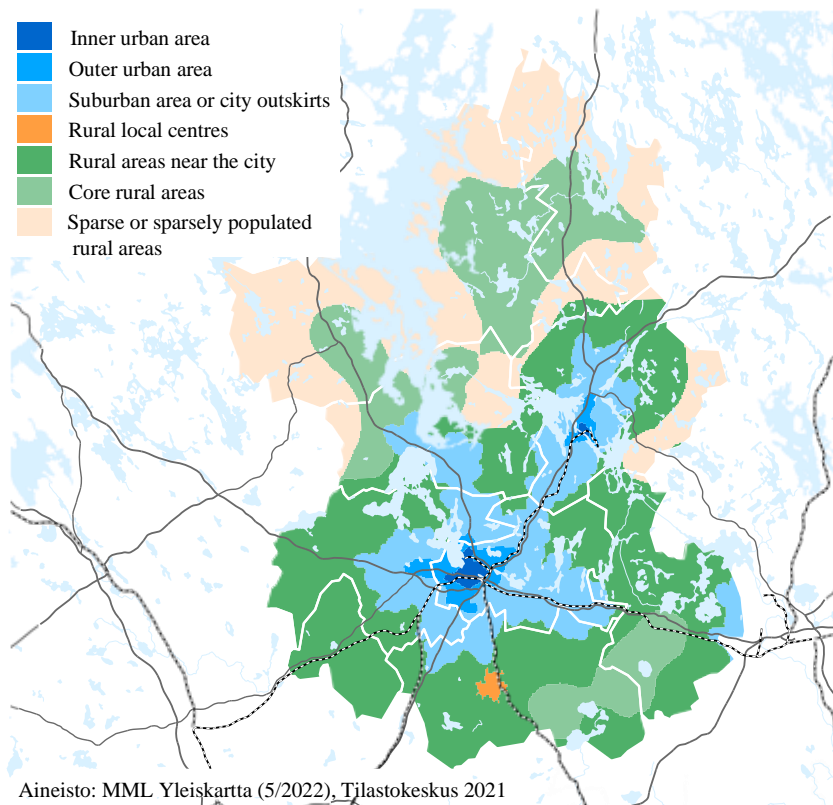


Figure 9 Data Source: MML General Map (5/2022), Statistics Finland 2021

The figure 9 is a visual representation of a study or analysis regarding transportation patterns in a specific region, showing how land use correlates with transportation modes used by residents.

The focus can shift from a broad overview of commuting patterns to a specific element within Lahti's transportation matrix: the Mankeli bike-sharing system. As a focal feature of the city's sustainable transit framework, the utilization statistics of the Mankeli system offer valuable insights. The number of rentals and rental time both show a similar trend over the given period, indicating that they are likely connected. There is a noticeable peak in July, suggesting that July might be the most popular month for bike rentals. This could be due to favourable weather conditions during the summer. Post-July, there is a gradual decrease in both rentals and rental time, reaching the lowest point in November. This could be attributed to the onset of colder weather, making biking less appealing. These insights suggest that weather could be a significant factor influencing bike rentals in Lahti. The Mankeli bike program seems to be a popular commuting method during warmer months. However, alternative commuting methods might be needed during colder months. Further analysis could include comparing these trends with weather data or exploring other factors that might influence bike rentals (Mankeli, 2023).

The number of new customers fluctuates over time, with a lot of peaks and valleys. This suggests that there might be specific events or factors that attract new customers at different times. There is a noticeable peak in new customers in August 2023. This could be due to specific events or promotions during that month. The total number of customers shows a more gradual increase over time, reaching the highest point in November 2023. This indicates a steady growth in the customer base of the Mankeli bike program (Mankeli, 2023).

These insights suggest that the Mankeli bike program is successful in attracting new customers and maintaining a growing customer base. Further analysis could include exploring the factors that contribute to the fluctuations in new customers and strategies to maintain the growth of the total number of customers.

3.2 Insights from Lahti's Sustainable Mobility Implementation

Lahti's sustainable mobility landscape is characterized by a complex mix of advancements and challenges. The infrastructure for sustainable transport is in place, but its effectiveness is limited by persistent car-centric attitudes and behaviours. The city's efforts in policy formulation and interdepartmental collaboration are noteworthy, but the real test lies in translating these into tangible, community-accepted practices. While there are positive trends, particularly among younger residents, the transition to a more sustainable commuting culture in Lahti is an ongoing process requiring continuous effort, strategic communication, and community engagement.

A critical barrier in Lahti's pursuit of its 2025 carbon neutrality goal is the management of transient traffic a significant number of drivers pass through Lahti without contributing to local sustainable initiatives. Compounding this issue is the prevalent mindset favouring car use. Despite available sustainable options, many residents' defaults to private vehicles due to ingrained habits and perceived conveniences (Heinäaro, 2023).

The challenge extends beyond the mere availability of sustainable infrastructure; it involves raising awareness and changing deep-rooted behaviours and attitudes towards mobility. Lahti's endeavours in constructing infrastructure for walking, cycling, and public transportation face the hurdle of low public awareness and utilization. Even with adequate facilities, convincing residents to shift from cars to more sustainable modes remain a significant challenge (Heinäaro, 2023).

Integral to Lahti's sustainable commuting are efforts to make alternatives like walking, biking, and public transport more attractive. This involves not only infrastructure improvement but also enhancing convenience and user-friendliness. Translating conceptual support for eco-friendly commuting into tangible actions in Lahti has presented a unique set of challenges. While residents generally favour a healthier living environment, a noticeable gap exists between this aspiration and the actual willingness to adopt environmentally friendly practices. This gap was evident in the initial reception of the CitiCap project. The project, initially met with scepticism over concerns about costs and its overall necessity, eventually experienced a significant shift in public perception. Despite most users earning only a few virtual euros through the project's PCT system, it became well-received. By the end of the project, 79% of participants had a clear understanding of how the PCT worked,

and 36% had successfully reduced their mobility emissions. This indicates a growing potential for acceptance and understanding of sustainable practices among the locals, highlighting a positive shift towards eco-friendly commuting in Lahti. This transition from doubt to appreciation underscores the prospective for changing mindsets towards eco-friendly commuting solutions, with proven practical benefits. (Heinäaro, 2023)

The larger obstacle is not in policy formulation but in the execution and public acceptance of specific actions to promote sustainable mobility. Lahti's recognition as the European Green Capital in 2021 has been decisive in advancing sustainable mobility initiatives. The city navigates the complexities of inter-departmental requirements, balancing diverse needs while advancing its sustainability agenda. Collaborations with external partners, though essential, are often strained by differing operational paces and bureaucratic procedures (Heinäaro, 2023).

Lahti employs a dynamic approach to integrate and apply knowledge from external projects. This strategy involves regularly updating organizational entities and stakeholders on project progress, ensuring a unified understanding across the city's management framework. Key to this process is the use of detailed reports and presentations, which effectively disseminate findings and outcomes from external engagements. Crucially, insights and strategies gleaned from these projects are not just shared but are integrated into Lahti's urban planning system, aiding in the development of innovative and responsive mobility initiatives. This approach establishes a valuable feedback loop within the city's governance, enabling continuous learning and adaptation. One example of this approach is the "Year-Round Active Transportation Project" which is launched to encourage citizens to walk or cycle throughout the year, including during the challenging winter months, this project adopts an innovative crowdsourced data collection method. By gathering feedback directly from the public about winter conditions, city planners aim to evaluate if this approach is a viable method for monitoring and improving winter maintenance of paths (Heinäaro, 2023).

Additionally, these routes will be given priority for snow removal, and stricter rules for snow clearance will be enforced. Chemical anti-skid treatment will be implemented on these routes, with gritting only permitted in exceptional cases (Lahti SUMP, 2020).

In Lahti, the integration of micro-mobility solutions like e-scooters into the urban infrastructure presents some encounters, particularly concerning safety and speed management and seasonal and operational tests. The city is strategically addressing these by redesigning pathways for safe scooter use, establishing clear vehicle parking protocols, and considering the introduction of dedicated scooter parking areas and specific speed zones. Additionally, there are efforts to clarify ownership and administrative responsibilities for these initiatives (Heinäaro, 2023).

The city center also faces major problems due to heavy traffic flow, including noise pollution and air quality degradation caused by exhaust emissions and fine particles. To address these issues, Lahti is implementing a comprehensive circulation plan aimed at revitalizing the city center, reducing traffic congestion, and enhancing road safety. This plan involves creating a more pedestrian-, cyclist-, and public transport-friendly environment through optimizing street space, parking, and traffic control systems (Lahti SUMP, 2020).

In certain areas of the city center, the need for segregation of different modes of transportation has become increasingly apparent, particularly as bicycle traffic and shared-use micro-vehicles gain popularity. Consequently, the city is actively planning to expand dedicated lanes for cyclists, integrating these lanes into the existing road infrastructure with a focus on safety and aesthetic appeal. One significant development area is near the harbor, where separate paths for cycling and walking are planned. This project not only prioritizes functional design but also incorporates greenery to create environmentally conscious and visually appealing urban spaces (Heinäaro, 2023).

Furthermore, this initiative includes innovative water management techniques, using run-off water to enhance ecological sustainability. A significant change in this redevelopment is the rerouting of vehicle roads to bypass these new cyclist and pedestrian areas, reflecting a strategic shift towards prioritizing non-motorized transport. This approach represents Lahti's commitment to transforming its city center into a more sustainable and livable urban area, where the movement of pedestrians and cyclists is facilitated, and the environmental impact of vehicles is minimized (Heinäaro, 2023). Lahti is enhancing its public transport system by developing park-and-ride facilities across the city. This initiative aims to expand these facilities, particularly along the trunk route network and in sub-regions, to encourage seamless travel. Key efforts include increasing park-and-ride capacity at the Travel Centre and improving bicycle storage security. Additionally, the city plans to establish new park-

and-ride options for both bicycles and cars at various public transport hubs and at the endpoints of major routes, fostering greater convenience and accessibility for public transport users (Lahti SUMP, 2020). The city's efforts to promote sustainable commuting among its staff reveal an encouraging trend, with a significant number already utilizing bus benefits. However, historical data from past surveys about staff mobility behaviours, while informative, may no longer fully capture the current commuting patterns or employee preferences (Heinäaro, 2023). This suggests a gap in understanding the present-day dynamics of sustainable commuting among city employees. The city, in its role as an organizational role model, faces the task of not only encouraging but also accurately assessing and responding to its staff's commuting preferences and habits in the context of an evolving urban mobility environment. This situation indicates the need for an updated and continuous assessment of commuting behaviours to effectively foster a more sustainable commuting culture within the workforce (Lahti SUMP, 2020).

In Lahti, the advancement of sustainable mobility is multifaceted, encompassing public transport, business development, and collaborative research. Lahti Region Transport, primarily financed by the city, exemplifies this commitment with a fleet that increasingly relies on alternative propulsion systems, including 32 electric and 37 renewable biodiesel buses. In 2021, of all buses in operation, 17% were powered by electricity, 41% utilized biodiesel, and the remaining 42% ran on fossil diesel (Halonen et al., 2023). This shift towards greener mobility is boosted by substantial funding dedicated to promoting public transport and innovative projects like the upcoming pilot for autonomous electric buses. In the field of business development, Lahti regional development company (LADEC), notably backed by the city, plays a vital role. It has successfully established the Green Electrification of Mobility (GEM) cluster, fostering a network of companies engaged in sustainable mobility solutions. This synergy between the city and the business sector extends to academia through projects like "The Lahti Last Mile," a collaborative effort with LAB University of Applied Sciences aimed at revolutionizing goods transport, and partnerships with LUT University, which is making strides in green mobility education and research. The upcoming Kempower EMRC at LUT University, a joint initiative with Kempower, is set to become a hub for cross-disciplinary research and education in electric transportation, further setting Lahti's position as a leader in sustainable mobility solutions (Ojala, 2023).

4 Research Design and Method

This chapter outlines the methodological structure employed in this study, which adopts a qualitative approach to explore sustainable commuting in the urban context of Lahti. It details the strategies used for collecting and analysing both primary and secondary data, emphasizing the in-depth exploration of diverse factors influencing urban commuting behaviours and intervention effectiveness. This section also discusses the validation process for the research findings, ensuring their credibility and relevance in the field of sustainable commuting.

4.1 Methodological Approach

This study employs a qualitative research approach, a methodology that excels in capturing the complexity of social phenomena. Qualitative methods are particularly adept at exploring in-depth the perceptions, experiences, and interactions of individuals within their natural settings (Yin et al., 2011.) This approach is instrumental in providing rich, descriptive insights into the nuanced facets of urban sustainable commuting, which quantitative methods may overlook.

For this thesis, a qualitative approach was deemed most suitable due to its ability to explore the interconnectedness and dynamism inherent in sustainable commuting practices. Such an approach allows for an understanding of the holistic and multi-faceted nature of interventions, which is essential when addressing the research questions posed. It enables the capture of contextual details and the subjective complexities of stakeholder experiences, thereby facilitating a more informed analysis of the strategies and measures that can be implemented in Lahti for sustainable commuting.

The qualitative nature of this research promotes an iterative process of inquiry, allowing for a gradual emergence of insights through a thorough analysis of the data. The intent is to unravel understandings, going beyond surface-level data to uncover deeper layers of meanings and narratives that shape the realm of sustainable commuting.

4.2 Data Sources

Secondary Data

Central to this research lies its extensive literature review, crafted by weaving together diverse sources. The foundation is primarily built upon scientific articles extracted from various journals, encompassing disciplines that range from urban planning and infrastructure to green transportation and innovative mobility solutions. In addition to scholarly contributions, official sustainability reports provided valuable data, enhancing the depth of the research. Moreover, master's theses, specifically those delving into facets of mobility, commuting, and transportation, were instrumental in adding granularity to the analysis. Seminal books were consulted for their historical context and broad overviews of the field, while reputable websites offered current perspectives and updates on trends in sustainable commuting. Lastly, reputable websites enriched the study, offering up-to-date, real-world insights and trends in the sustainable commuting landscape.

Primary Data

Parallel to the literature review, the city of Lahti was chosen as a focal case study, symbolizing an urban space grappling with sustainable commuting challenges and opportunities. To paint a vivid picture of Lahti's current commuting landscape, the research tapped into two data streams: secondary sources offering a macro perspective on the city's commuting attitude and a primary, semi-structured interview with a city specialist in Lahti. This interview was instrumental in grounding the research, offering ground-level insights, challenges, success stories, and visions shaping Lahti's sustainable commuting narrative.

4.3 Data Analysis

Initially, a comprehensive review of the literature was conducted, during which extensive information on sustainable mobility interventions was gathered. The selection of keywords for the literature review was strategically aligned with the overarching purpose of the study, which aimed to explore the broad spectrum of sustainable commuting. "Sustainable Commuting" was the primary term, capturing the essence of eco-friendly commuting patterns. To encompass broader aspects of movement within cities, "Sustainable Mobility"

was included, addressing the efficiency and environmental impact of various transportation modes. “Sustainable Transportation Mode” further narrowed the focus to specific sustainable options like cycling, walking, and public transit. “Sustainable Commuting Practices” guided the search towards practical, real-world applications of sustainable commuting concepts. Finally, “Sustainable Mobility Intervention” was chosen to explore active strategies, policies, and initiatives that promote sustainable urban mobility, rounding out the comprehensive approach to the literature search.

The search extended across various disciplines to capture the multifaceted nature of urban living where elements such as urban planning, infrastructure, and transportation policy are intricately linked and impact commuting patterns. Through iterative rounds of reading and cross-referencing, a robust list of interventions was assembled. This data was then subjected to qualitative coding, leading to the identification of nuanced sub-themes based on shared objectives.

The qualitative coding process was guided by a conceptual approach that sought to identify patterns and commonalities among the various interventions. This approach was rooted in the idea of thematic analogy, where interventions were examined for shared characteristics and overarching goals.

The initial phase of the coding process, representing the first-order coding, involved a detailed examination of each intervention identified in the literature. This step was essential for laying the groundwork for the analysis. Each intervention was individually assessed to understand its specific contribution to sustainable mobility. This part of the process was about staying close to the data, labeling interventions with codes that accurately reflected their content and purpose.

As the first-order coding progressed, patterns began to emerge. It was noted that certain interventions shared common characteristics or goals, marking the beginning of a alteration from first-order to second-order coding (Bell et al., 2022)

These conceptual similarities then informed the second-order coding process. Here, the focus shifted from individual interventions to broader conceptual categories or sub-themes. This step was more analytical and interpretive, as it involved synthesizing the first-order codes into a more abstract understanding of the data (Adu, 2019).

By examining the interconnections and collective contributions of these grouped interventions, a richer, multi-dimensional view of sustainable commuting strategies emerged. This second-order coding process was not just about categorizing data; it was about understanding how different interventions collectively worked towards the broader aim of sustainable commuting.

Finally, from this nuanced, multi-layered analysis, five main themes emerged, representing the culmination of the coding process. These main themes were the product of an in-depth interpretation of the data, moving beyond the specifics of individual interventions to a thematic understanding that encapsulated the essence of the research findings. Each main theme represented a key strategic area in the realm of sustainable urban mobility, distilled from the examination of interventions and their thematic associations.

The primary data collection, integral to addressing the third research question, involved conducting a semi-structured interview with a sustainability specialist in Lahti. This interview was designed to complement the city analysis, providing deeper insights into Lahti's commuting landscape and mobility challenges. The interview questions were structured across three layers – city level, organizational level, and infrastructure-oriented – to ensure a comprehensive understanding of the various aspects influencing sustainable commuting in Lahti. This multi-layered approach was crucial in capturing the complexity of the city's commuting dynamics from different perspectives.

To systematically analyse the interview data, a coding process was employed, similar to the approach used for the literature review. This involved first-order coding, where direct observations and statements from the interview were assigned descriptive labels. For instance, a comment about individuals preferring cars due to convenience and habit was coded as “car-centric attitude”.

This coding provided a way to distil specific points from the interview into identifiable and meaningful categories. The insights gleaned from the interview were then examined in relation to the sub-themes identified in the first-order coding of the literature and the overarching themes that emerged in the second-order coding. This process involved interpreting the coded interview data to see how it aligned with and supplemented the broader themes of sustainable commuting.

The methodological approach ensured that the interview data not only enriched the understanding of Lahti's specific challenges but also guided the selection of suitable sustainable commuting strategies for the city. The patterns identified in the interview were directly used to filter and tailor interventions, ensuring they were contextually relevant to Lahti's unique commuting landscape.

To this end, the research process involved an in-depth examination of interventions across themes, revealing the overlap and interconnectedness of actions within the sustainable commuting landscape. It became evident that the success of any single intervention could be influenced by related strategies across different themes, highlighting the need for an integrated approach to urban mobility planning. Consequently, the dynamic relationships between these themes were classified into three distinct types: synergistic, where combined interventions create greater overall effects; catalytic, where one intervention significantly enhances the impact of another; and enabling, where one intervention lays the groundwork for others to succeed. This classification illuminated how intertwined and interdependent sustainable commuting practices are.

By outlining how different interventions are interlinked, the framework serves to guide the design and implementation of effective sustainable commuting measures. It emphasizes the importance of considering the broader network of influences in urban mobility.

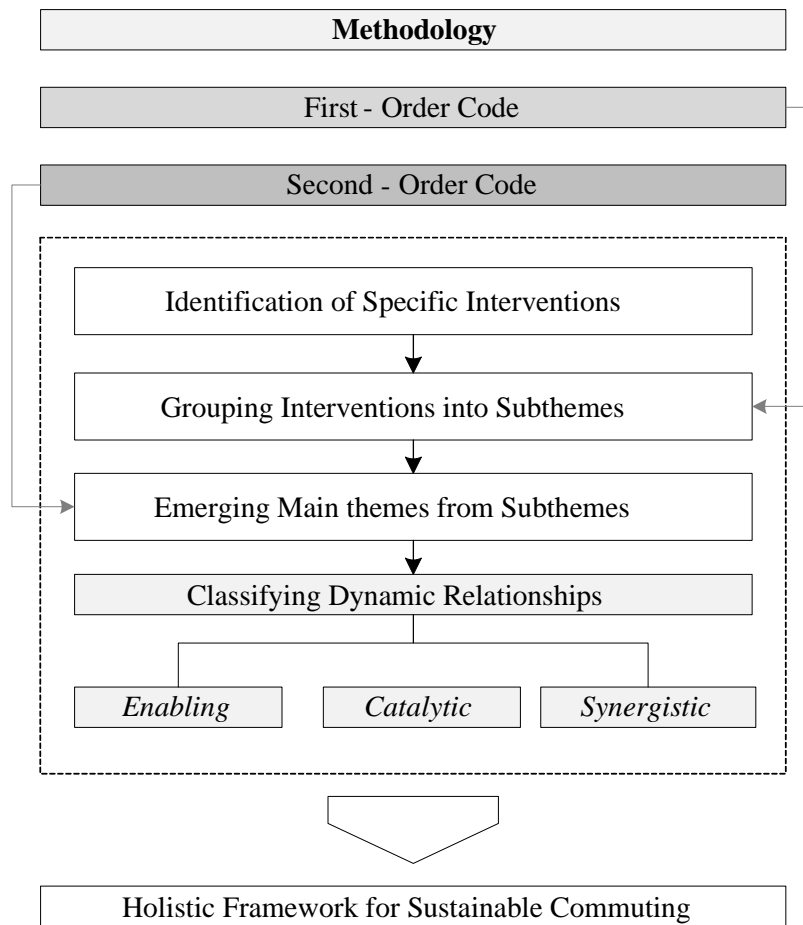


Figure 10 The methodology visualization

5 Results

This Results chapter is structured to provide an insightful narrative through its three main sections, each corresponding to a specific research question. The chapter commences with a synthesis of the literature, where sustainable commuting interventions are identified and mapped. This synthesis not only highlights the effective interventions but also uncovers the dynamic relationships between them, illustrating the interconnectedness of various strategies within the broader context of urban mobility.

Following this synthesis, the chapter introduces a holistic framework that is built upon these relationships. It elucidates how the framework, derived from a thematic literature review, can function as a guiding tool for transition towards sustainable commuting. By articulating the synergies and dependencies among interventions, the framework serves as a decision-making instrument, aiming to optimize resource allocation, strategic planning, implementation of sustainable commuting practices.

The narrative then converges on Lahti, a case study that serves as a practical application of the theoretical constructs developed earlier. In this section, the city's unique commuting challenges are analysed, and strategies are proposed to enhance its transition towards sustainable commuting. The chapter culminates by applying the previously outlined framework to Lahti's specific context, demonstrating how a theoretically grounded approach can translate into practical, actionable strategies.

5.1 Sustainable Commuting Interventions: A Literature Synthesis

In the quest for sustainable commuting, the study has adopted a novel approach that draws from established interventions documented in literature rather than focusing on the allure of untested innovations. This strategic choice is rooted in a belief that the innovation lies not necessarily in the novelty of new solutions, but in the execution and implementation of existing ones (Medina-Molina & Rey-Tienda, 2022).

According to Goldman and Gorham, (2006b) interventions serve as critical instruments for guiding cities toward sustainable mobility. Recognizing the need for a structured approach

in navigating the vast and diverse fields of urban planning, infrastructure systems, sustainability, emerging transportation technologies and mobility solutions, a thematic approach was employed. It is centred around five main themes: Public Transport Enhancements, Infrastructure Enhancements, Behaviour Change Campaigns, Technology for Seamless Commuting, and Mobility Management. These themes were identified and defined after a comprehensive exploration of literature across different disciplines.

Each theme encompasses a set of subthemes, representing specific domains that require more attention. This thematic architecture acts as a facilitator for a meaningful analysis, enabling policymakers to navigate the multi-layered landscapes of urban mobility with a holistic perspective. The mapping of literature within these themes forms a foundation upon which a framework for transition towards sustainable commuting practices. It is through this lens that the study addresses RQ1, revealing a unique approach that not only categorizes interventions but also interweaves them into the fabric of city planning and policymaking.

Table 1 Sustainable mobility interventions include (subthemes and main themes)

| <i>Theme</i> | <i>Subtheme</i> | <i>Interventions</i> |
|----------------------------------------------|----------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>Public Transport Enhancements</i> | Green Transportation Policies and Regulations | Develop policies to incentivize the use of low-emission public transit Setting emission standards for public transport vehicles |
| | Renewable Energy Integration in public Transportation Systems | Conduct research on biofuels' feasibility and benefits in the transport sector Bus transit systems with electric traction and establish partnerships with renewable energy providers |
| | Accessible and Inclusive Public Transport Services | Intermodal Urban Mobility Multi-Modal Hubs Optimization of Bus Route Conduct user surveys to identify gaps in intermodal connectivity Implementing real-time public transport information systems Targeted design of transport for the needs of different segments of the population Development of park-and-ride |
| <i>Infrastructure Enhancements</i> | Bicycle and Pedestrian Infrastructure Development | Building dedicated bike lanes and pedestrian walkways Creating bike-sharing programs in urban areas Studying ridership patterns in winter Development of the winter maintenance of pedestrian and cycling paths Street design measures including sidewalks and share-the-road signs Provide streetscape amenities (benches, landscaping, lighting, public art and first aid) |

| | | |
|------------------------------------------|---------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| | | Enhancing Bus Infrastructure (bus station) Optimizing the location of stations in bike-sharing programs |
| | Sustainable Urban Planning | Implementing mixed-use zoning to reduce travel distances development of street-level shopping and restaurants along pedestrian and bicycle route |
| | Electric Vehicle Charging Infrastructure | Installing EV charging stations in companies, public places, and buildings Providing incentives for businesses to install charging points |
| | Transit-Oriented Development (TOD) and Mixed-Use Land Use Planning | Encouraging mixed-use development around transit hubs Mobility-Oriented Development (MOD) practices |
| <i>Behavior Change Campaigns</i> | Promoting Active Modes of Transportation | Organizing walking and cycling events and campaigns Implement workplace incentives for employees who use bicycle for work trip Cyclist-friendly amenities in company's premises Leveraging health benefits to encourage people to walk Eco-Mobility Rewards Program in companies |
| | Carpooling and Ridesharing Initiatives | Facilitating carpool matching services for commuters Carpooling and Ridesharing Initiative Offering preferential parking for carpool vehicles |
| <i>Technology for Seamless Commuting</i> | Mobility-as-a-Service (MaaS) Platforms | Invest in the development of user-friendly MaaS platforms that integrate various transport modes Ticket and payment integration A gamification platform to analyze and influence citizens' daily transportation choices Create a city-wide gamification app that rewards residents for choosing eco-friendly commuting options Personalized commuter plan (PCP) tailored journey information and information about discounted |
| | Shared Micro Mobility Solutions | Shared e-micro mobility, (shared e-bikes and shared e-scooters) |
| | Intelligent Transportation Systems (ITS) for Traffic Management | Installing smart traffic signals and congestion management systems Using data analytics and big data to optimize traffic flow Implementation of the road safety plan (using Augmented Reality for Cyclists) Holistic urban mobility planning using (ITS) mini pilots (with experimental approach) |
| <i>Mobility Management</i> | Multi-Stakeholder Collaboration and Engagement | Forming partnerships between public and private sectors (Foster collaboration between governments, private businesses operators, experts) Engage local communities and citizens in the decision-making process for transportation initiatives (Such as, tax reduction and funding) |
| | Carbon Footprint Reduction Strategies | Encouraging the use of fuel-efficient vehicles Personal carbon trading Encourage businesses to invest in local eco-friendly transportation projects as a carbon offset, compensating for emissions |

| | |
|--------------------------------|------------------------------------------------------------------------------------------------------------|
| Travel Demand Reduction | Promoting flexible work hours Supporting telecommuting programs for employees and technological support |
| Land Use Management | Parking Management and Policies Implementing Pricing Mechanisms Smart Parking System |

The set of interventions in sustainable commuting, as detailed in table 1, are organized under distinct thematic areas, each central to the broader objective of sustainable urban commuting. These interventions are not standalone solutions; instead, they interact dynamically within and across these thematic areas. Such interplay is intricately represented in table 2, which outlines the cross-theme dynamic relationships. For instance, “Infrastructure Enhancements” like the development of bike lanes not only serve their direct purpose but also bolster “Behavior Change Campaigns” by fostering safer and more attractive environments for cycling. This complex web of interactions underscores the importance of a holistic approach in the planning and execution of sustainable mobility strategies. It’s crucial to recognize that the success of intervention within one thematic area can be significantly influenced by supportive actions in others. Such understanding enables a more efficient allocation of resources and efforts, ensuring that interventions collectively contribute to a cohesive and effective sustainable commuting ecosystem. The dependency and sequence of these actions reveal a nuanced landscape where each intervention, while important on its own, gains additional significance through its contribution to the larger goal of sustainable urban mobility.

Figure 11 serves as a schematic representation of table 2, describes how interventions across various sub-themes not only target distinct aspects of sustainable commuting but also exhibit interactions across thematic boundaries. The arrows signify the cross-theme dynamic relationships. It is a precursor to the detailed classification of these relationships into three types, which will be elaborated upon in the subsequent chapter. In this figure, solid arrows depict direct influences between themes, demonstrating how interventions within one area can directly impact another. Dotted arrows indicate a synergistic interplay, where themes interact reciprocally, enhancing each other in a mutually reinforcing network of sustainable urban development.

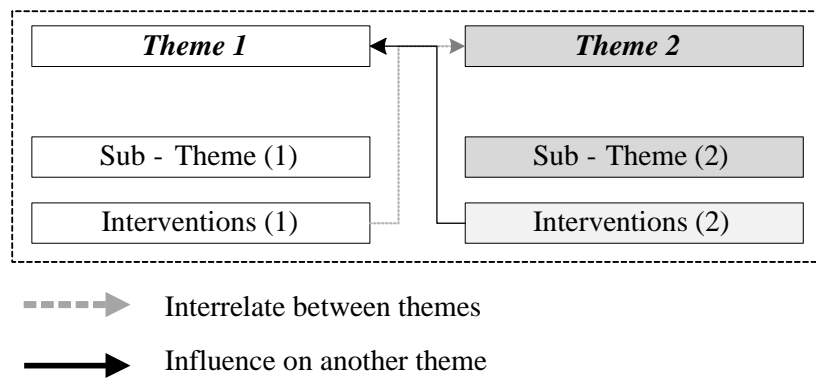


Figure 11 Visualization on dynamic relationship between themes

Table 2 Interpretation of dynamic relationship between main themes

| <i>Theme</i> | <i>Cross Theme Dynamic Relationship</i> |
|--------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>Infrastructure Enhancements</i> | Behavior Change Campaigns: Safe infrastructure encourages more people to choose walking, cycling and e-shared mobility, thereby fostering a shift in commuting behavior. |
| | Public Transport Enhancement: EV charging infrastructure can power renewable energy integration. |
| | Mobility Management: Mixed-use zoning reduces travel distances leading to reduction of dependence on private car use. |
| <i>Public Transport Enhancements</i> | Mobility Management: Supports the implementation of sustainable mobility strategies by improving non-motorized transport options (such as parking management). |
| | Mobility Management: Enhances the efficiency of urban mobility systems through strategic land use and transport planning. : Enhances the first-last mile connectivity to public transport hubs and facilitates the integration of public transportation with community planning. |
| | Behavior Change Campaigns: TOD development fosters multi-modal transportation and encourages people to use active modes of transport. |
| <i>Behavior Change Campaigns</i> | Infrastructure Enhancements: Encourages the integration of public transport facilities into urban planning, like bus rapid transit lanes and improved train stations. |
| | Infrastructure Enhancements: Adoption of Green Transportation drives the need for EV charging infrastructure as part of public transport electrification. |
| | Behavior Change Campaigns: Provides a reliable and efficient public transport system, motivating individuals to shift from personal vehicle use to public transit. |
| <i>Behavior Change Campaigns</i> | Technology for Seamless Commuting: Supports the integration of public transport data into MaaS platforms, improving route planning and scheduling for commuters. |
| | Mobility Management: Green transport policies contribute to carbon footprint reduction strategies in transportation. |
| | Technology for Seamless Commuting: Carpooling and ridesharing platforms, integrated with MaaS, facilitate more efficient travel planning and matching. |
| <i>Behavior Change Campaigns</i> | Mobility Management: Initiatives like carpooling and eco-mobility rewards reduce carbon emissions and encourage collaborative efforts among different stakeholders for sustainable mobility. |

| | |
|-------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| | <p>Infrastructure Enhancements: Promoting alternative modes of transportation like biking and walking can lower the overall demand on transport infrastructure, reducing the need for extensive road networks and parking spaces.</p> <p>Mobility Management: Campaigns that encourage the adoption of electric vehicles indirectly support the development of EV charging infrastructure, contributing to overall carbon footprint reduction.</p> <p>Public Transportation Enhancement: Awareness campaigns about the benefits of public transport can lead to increased ridership, justifying further investments in public transport systems.</p> |
| <p><i>Technology for Seamless Commuting</i></p> | <p>Public Transport Enhancements: MaaS platforms encourage the use of diverse public transport options by integrating various modes into a single user-friendly system.</p> <p>Public Transport Enhancements: Real-time updates for public transport systems, integrated into MaaS platforms, improve the reliability and attractiveness of public transport by providing passengers with accurate and timely information.</p> <p>Behavior Change Campaigns: Real-time updates and convenient payment options embedded in MaaS platforms and mobile applications motivate users to adopt active transportation modes.</p> <p>Mobility Management: Shared mobility services, part of MaaS ecosystems, reduce the overall need for private car ownership, leading to less traffic and lower emissions.</p> <p>Infrastructure Enhancements: Technologies like ITS (Intelligent Transportation Systems) enable efficient use of existing infrastructure through optimized traffic flow and reduced congestion.</p> <p>Infrastructure Enhancements: The use of data analytics in MaaS systems can inform urban planning and transport policy, leading to smarter, more responsive infrastructure development.</p> <p>Mobility Management: MaaS platforms contribute to sustainable urban mobility by streamlining the use of various transport modes, reducing reliance on single occupancy vehicles.</p> <p>Mobility Management: ITS optimizes traffic flow, reducing congestion and emissions.</p> <p>Mobility Management: Collaboration can lead to the development of innovative MaaS platforms.</p> <p>Public Transport Enhancements: Collaborations can enhance the efficiency of public transport services.</p> <p>Behavior Change Campaigns: Eco mobility reward programmes facilitate the use of ecofriendly commuting mode.</p> <p>Behavior Change Campaigns: Integration of eco-mobility rewards within MaaS platforms encourages sustainable travel choices, supporting behaviour change campaigns.</p> |
| <p><i>Mobility Management</i></p> | <p>Infrastructure Enhancements: Multi-stakeholder engagement in Mobility Management initiatives can lead to more effective and comprehensive infrastructure development and also it drives the implementation of sustainable urban planning.</p> <p>Technology for Seamless Commuting: Collaboration can lead to the development of innovative MaaS platforms.</p> <p>Public Transport Enhancements: Mobility management strategies can play a pivotal role in enhancing the efficiency and accessibility of public transport services through coordinated planning and policy alignment.</p> <p>Behavior Change Campaigns: Effective mobility management involves the collaboration of various stakeholders (public), which can significantly amplify the impact and reach of campaigns promoting behaviour change.</p> |

5.2 A Framework for Facilitating Sustainable Commuting

Addressing research question 2 involves understanding how the sustainable commuting framework functions as a tool, particularly for those shaping urban transport policies and interventions. This section delves into the analytical justification of the model developed, focusing on its utility in guiding and implementing sustainable commuting strategies.

The intricate web of interactions among various sustainable mobility themes, as identified in the analysis, is not merely a collection of independent elements. Instead, it represents a dynamic and interconnected system where themes interact in various ways to collectively shape the trajectory of sustainable urban mobility.

These relationships are classified into three categories: synergistic, catalytic, and enabling. Each category highlights unique aspects of how these themes interrelate and influence one another, thereby shedding light on the elaborate dynamics at play in the transition towards sustainable urban mobility.

Synergistic Relationship: Themes in a synergistic relationship work together to create outcomes that are greater than the sum of their individual impacts. For example, the collaboration between infrastructure enhancements and mobility management results in a more comprehensive approach to sustainable urban development, surpassing the potential of each theme alone (Knoll, 2008).

Catalytic Relationship: One theme acts as a catalyst, accelerating the effectiveness of another theme. An illustration is seen in how Technology for Seamless Commuting catalyses behaviour change campaigns. The integration of innovative technologies, such as real-time updates and mobile applications, directly facilitates the acceleration of sustainable commuting behaviours. By enhancing user experience and offering incentives, such technologies can shift daily commuting patterns towards more sustainable practices.

Enabling Relationship: A theme may enable or facilitate the implementation and success of another theme. The development of robust infrastructure, such as dedicated bike lanes and pedestrian walkways, lays the groundwork for more effective and widespread use of public transport systems like bike sharing program.

The categorization of interactions as synergistic, catalytic, and enabling within this study's sustainable mobility framework is inspired by terminology from business literature. These terms help articulate the complex dynamics and potential synergies between urban mobility interventions:

Table 3 Dynamic relationship classification

| <i>Theme (1)</i> | <i>Theme (2)</i> | <i>Type of Relationship</i> |
|-----------------------------------|-----------------------------------|-----------------------------|
| Infrastructure Enhancements | Technology for Seamless Commuting | Synergistic |
| Public Transport Enhancements | Behavior Change Campaigns | Catalytic |
| Technology for Seamless Commuting | Behavior Change Campaigns | Catalytic |
| Mobility Management | Public Transport Enhancements | Catalytic |
| Infrastructure Enhancements | Public Transport Enhancements | Enabling |
| Mobility Management | Technology for Seamless Commuting | Synergistic |
| Technology for Seamless Commuting | Public Transport Enhancements | Catalytic |
| Infrastructure Enhancements | Behavior Change Campaigns | Enabling |
| Mobility Management | Behavior Change Campaigns | Synergistic |
| Infrastructure Enhancements | Mobility Management | Synergistic |

The classification of the relationships between sustainable mobility themes as synergistic, catalytic, and enabling is rooted in deeper understanding of how different interventions interact within the urban mobility ecosystem. Central to the framework is the identification of key relationships between themes. By highlighting them, the model offers insights into areas where efforts can be combined or focused for maximal impact, leading to more efficient allocation of resources and efforts. For example, understanding how infrastructure enhancements can facilitate more effective behaviour change campaigns can help prioritize interventions in a way that sequences actions for greater effectiveness. This “enabling” relationship is characterized by the way infrastructure developments lay the groundwork for a shift in public behaviour.

Furthermore, the model promotes stakeholder collaboration by showcasing intersections and influences among different areas. This aspect is particularly useful in fostering partnerships among urban planners, public transport authorities, technology providers, and public. By facilitating such collaboration, the framework ensures that interventions are comprehensive, addressing the complex nature of sustainable commuting. The sustainable commuting framework's adaptability is crucial for addressing the unique needs and dynamics of different cities.

It recognizes that each city has its own strengths, challenges, and potential within various sustainable mobility themes. This flexible approach ensures the framework's relevance in the ever-evolving landscape of urban mobility, especially in smart cities where change is constant. As cities grow and new technologies emerge, the framework can be updated to reflect these developments, maintaining its utility and it can the offers a context-specific roadmap for sustainable commuting initiatives. The model's foundation in evidence-based research is another critical aspect. This approach mitigates risks associated with assumptions or inexperienced theories, fostering a more reliable pathway towards sustainable commuting. In addition to these practical benefits, the framework encourages innovative thinking.

By outlining connections and potential synergies, the framework can inspire stakeholders to adopt a creative approach, exploring innovative methods of intervention implementation that leverage multiple themes simultaneously. This aspect is pivotal in addressing the recurring gap between intention and impact in sustainable commuting interventions.

Utilizing the sustainable commuting framework as a tool offers a structured, analytical approach to guiding urban mobility transformations. Here's how this framework can be applied for effective decision-making:

The assignment of weights to these themes is a vital step. It involves a detailed analysis of each theme's ability to contribute to the overarching goal of sustainable commuting. For instance, a theme with a high potential impact and feasibility but lower urgency might be assigned a different weight compared to one with immediate urgency but lower feasibility. This weighted approach helps in prioritizing actions and interventions that are most likely to yield significant, timely benefits in improving sustainable mobility. For instance, the theme of "Public Transport Enhancements" could be weighted heavily in a city where public transport infrastructure is well-developed but underutilized. Here, a catalytic relationship can be identified with "Behaviour Change Campaigns", indicating that efforts to alter public perception and usage habits can be significantly enhanced by improving the public transport experience.

The strategic focus then shifts to identifying and prioritizing themes that hold the key to unlocking the full potential of sustainable commuting within a specific urban context. This prioritization is based on a thorough understanding of the current urban dynamics, behaviours of the public regarding commuting, and the existing and potential infrastructure

capabilities. It is about pinpointing the areas where intervention can bring about the most transformative change.

Subsequently, resource allocation becomes a pivotal aspect. This is where the strategic decisions about where to invest – both in terms of financial and human resources – come into play. Effective utilization of resources is all about directing them towards those prioritized themes. The aim is to ensure that the investments made can lead to the maximum possible return in terms of advancing the city’s sustainability goals.

With RQ2 thoroughly addressed, the study is well-positioned to delve into the practical implementation of sustainable commuting strategies. This approach is informed by a thematically structured knowledge base, exemplified in the case study of Lahti. The visual format of the framework has been presented below, offering a clear and visual representation of the key themes and dynamic relationships within the framework.

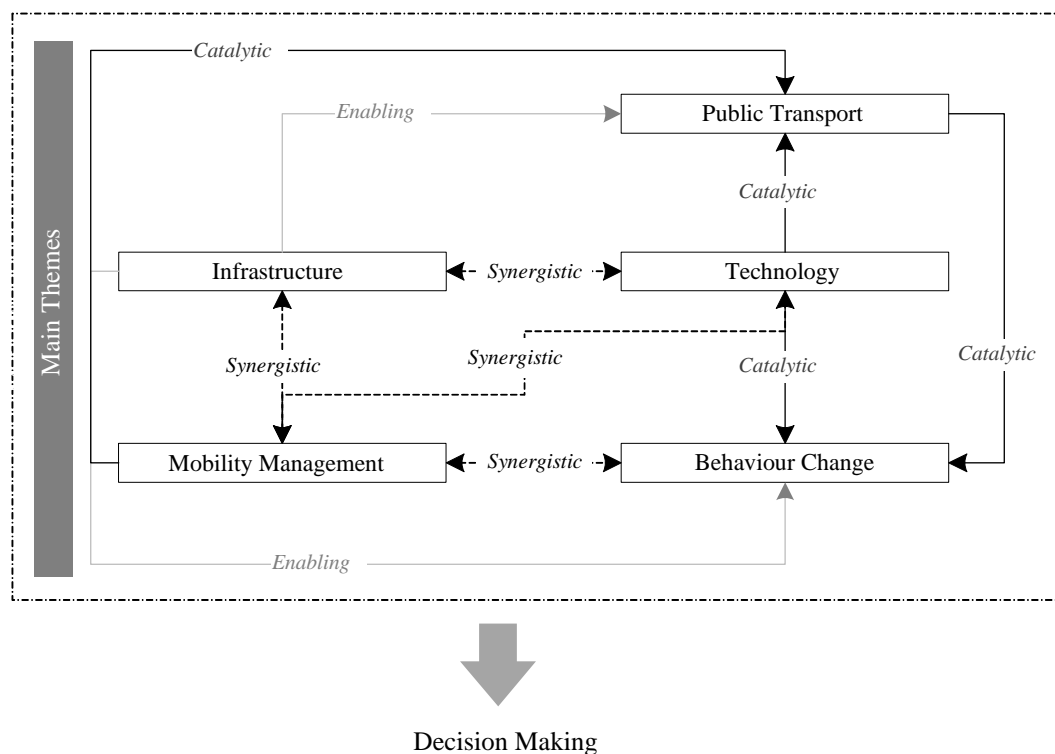


Figure 12 The framework for sustainable commuting

5.3 Sustainable Commuting Strategies and Measures for Lahti

Addressing Research Question 3 necessitates a detailed and precise approach identifying the most effective strategies for enhancing sustainable commuting in Lahti. An analysis of the city's current plans, resident behaviours, infrastructural developments, and policy support allows for the strategic alignment of literature-derived themes with Lahti's broader objectives of environmental sustainability and reduced emissions. The city faces a spectrum of barriers in its transition towards sustainable commuting, including car-centric attitudes, seasonal challenges, safety concerns, and insufficient public awareness (Heinäaro, 2023). Predominant among these is the car-centric culture that heavily favours private vehicles over alternative modes of transport, reflecting a deeply ingrained preference for driving. Compounding this issue is the underutilization of Lahti's comprehensive public transport network, which, despite its potential, remains insufficiently leveraged by the residents. This observation, derived from the city analysis presented in Chapter 3, reflects an interpretation of the underlying factors that contribute to these barriers in Lahti.

Seasonal challenges also pose significant hurdles, particularly the noticeable decline in biking and walking (as active modes of transport) during the colder months due to adverse weather conditions. This situation is exacerbated by a general lack of public awareness about the city's existing sustainable mobility options, indicating a gap in communication and outreach efforts. The objective is to introduce a set of pragmatic strategies, each precisely crafted to align with Lahti's carbon neutrality goals while addressing the city's immediate and long-term commuting needs.

Drawing from recent research Rocha et al., (2020), Lahti can leverage insights from a study focusing on thermal comfort at semi-outdoor bus stations during winter. This innovative approach involves a thorough evaluation of the station's thermal environment, blending measurements of physical parameters with passenger feedback. Research indicates that achieving thermal comfort in semi-outdoor spaces like bus stations is feasible.

The implementation of this methodology in Lahti could include an experimental campaign to assess the current thermal conditions, particularly focusing on the colder periods when discomfort is most reported. The integration of passenger perspectives through questionnaires would provide valuable insights into their experiences and preferences, informing potential retrofit solutions. By addressing these thermal comfort issues, Lahti can

enhance the appeal and usability of its public transport infrastructure, particularly in colder months.

Additional key area of focus is the adoption of new methods for winter maintenance of cycling and walking paths. This initiative is crucial in ensuring that active modes, remain a viable and appealing option throughout the year. For instance, by investing in efficient snow removal techniques and anti-ice treatments for bike lanes, Lahti can significantly improve the safety and accessibility of cycling during the colder months (Lißner et al., 2023). In tackling the seasonal challenges of winter, the city can adopt a comprehensive strategy that extends beyond infrastructure enhancements. Companies also can contribute by providing their employees with similar winter commuting gear or offering facilities such as heated locker rooms and drying areas for wet clothing. Additionally, organizations could host winter commuting workshops, educating employees about safe and comfortable winter travel practices. This combined effort from the city and its businesses would not only improve the safety and comfort of winter commuters but also reinforce a culture of sustainable commuting “year-round”.

In Lahti, to foster cycling as a preferred mode of transportation among the workforce, it is imperative for major businesses to invest in cyclist-friendly amenities. This initiative could involve setting up secure bike parking or dedicated maintenance facilities within company premises, as well as providing showers and changing rooms (Villanen et al., 2023). Such enhancements would make cycling a more feasible and attractive option for employees, particularly those who commute longer distances. (Cycling at Work, 2023).

Alongside functional improvements, Lahti has the opportunity to creatively enhance the visual appeal of its streets, making them more inviting for pedestrians and cyclists. Collaborating with local art students and independent visual artists to introduce public art installations and painting along walkways and cycling paths can transform these spaces into vibrant and engaging environments. This aesthetic enhancement could extend to bus stations, turning them into cultural showcases that offer entertainment and visual delight to those awaiting public transit (Artwork Archive, 2019). Nowadays digital street art, a fusion of AR, VR, and digital murals, is redefining the boundaries of creative expression. This innovative form, unconfined by physical spaces, allows artists to use technology to create 3D artworks, transforming the cityscape into a virtual canvas to turn urban environments into immersive, pedestrian-friendly art experiences (The Rise of Digital Street Art, 2023). The resilience of

digital art to harsh weather conditions stands out as a primary benefit. Unlike traditional street art, which can be damaged or obscured by snow and freezing temperatures, digital artworks remain vibrant and intact, irrespective of the weather. This makes digital art a reliable medium for year-round cultural expression and public engagement (Hamza, 2023).

Furthermore, implementing well-designed street sign measures is essential in creating a more cyclist-friendly city. This includes clear signage indicating bike lanes, directional signs for cyclists, and informative signs about local attractions or amenities accessible via cycling routes. Such measures not only enhance the functionality and safety of cycling infrastructure but also contribute to a more organized and user-friendly commuting experience.

In Lahti, the integration of cycling and walking paths with public transportation is progressing, with a focus on creating a seamless and secure travel experience. Key initiatives include the introduction of secure bicycle parking and locked bike carriage systems, particularly near bus stops and train stations (Heinäaro, 2023). These updates are crucial for encouraging people to combine cycling with public transport, addressing security concerns for parked bikes. Additionally, the concept of a “travel chain” is being promoted, enabling smooth transitions between different modes of transport. This approach aims to facilitate multi-modal commutes, making sustainable transportation more convenient and accessible (Heinäaro, 2023). By prioritizing innovative and cost-effective infrastructure improvements at both the city and company levels, Lahti can greatly enhance the attractiveness and feasibility of active modes of transportation.

In Lahti, addressing the challenges of car-centric attitudes, insufficient awareness of sustainable mobility options, and the management of transient traffic calls for a multifaceted approach rooted in behaviour change campaigns. The city’s strategy could begin by fostering a culture that promote active transportation. This can be achieved through organizing community events such as car-free days, walking festivals, and themed cycling events. These events not only encourage residents to explore alternative modes of transportation but also serve as platforms for raising awareness about the environmental and health benefits of sustainable commuting.

A critical component of driving sustainable commuting behaviours lies in engaging local businesses to play an active role. At the organizational level, it’s crucial to devise workplace incentives or introduce gamification elements that align with employees’ genuine interests

and values (Bartle and Chatterjee, 2019). This approach begins with conducting comprehensive surveys to understand employees' preferences and commuting challenges. Based on these insights, companies can develop tailored rewards programs that align with employees' desires (Daniel et al., 2022). Conducting regular mobility surveys is essential to understand and enhance employees' sustainable commuting practices, highlighting the significance of feedback in shaping a mobility strategy ("Pirelli," n.d.). For instance, a company might find that its employees highly value fitness and health benefits. In response, it could organize regular events like "Walk to Workdays" or "Corporate Cycling Challenges," offering incentives for participation, such as extra vacation days, gym memberships, or health insurance discounts (Hyvärinen, 2021). Another effective strategy is to introduce recognition programs that celebrate employees who consistently use eco-friendly transport modes. These programs could feature monthly spotlights in company newsletters or annual awards for "Green Commuters of the Year." Such initiatives not only motivate employees but also create role models within the organization, encouraging others to follow suit.

In Lahti, companies can introduce a sustainable commuting initiative inspired by Finland's bike benefit scheme, which has been effective since 2021. This program allows employers to offer their employees a company bike, similar in concept to a company car but focused on promoting eco-friendly transportation. The benefit is tax-free up to €1,200 per year, allowing employees to make significant savings, approximately 30 to 50%, on the bike's retail price, depending on their tax bracket (Cycle to Work Scheme, 2023). To implement this scheme in Lahti, companies first need to establish an agreement with a bike leasing service. In Finland, services such as Pelago offer a range of bikes and once this partnership is in place, employees can choose their preferred bike from the provider's selection (Pelago Bicycles 2023).

Promotion of the carpool program as an effective initiative would involve a communication campaign, coupled with incentives like preferred parking or different type of rewards to encourage participation. A key aspect would be utilizing carpooling platforms or software to facilitate the matching of carpool partners based on their routes and schedules. Safety, compliance with legal norms, and continuous evaluation would form the backbone of the program, ensuring its adaptability and sustainability over time (Lahoti, 2023). Furthermore, the development of eco-mobility reward programs can motivate workers to adopt eco-

friendly commuting modes. These programs could offer tangible incentives such as discounts at local businesses, vouchers, or even subscriptions to popular services like fitness or music streaming apps (Spotify e.g.) based on survey-based preferences and interests of workers.

In companies, workshops and training sessions focusing on sustainable commuting practices can be highly effective. These sessions should not only provide information but also inspire and engage employees to make a positive change. As a company-level intervention for sustainable commuting in Lahti, organizations can offer public transportation benefits to their employees. This could involve providing subsidized transit passes or partnering with local transportation authorities to create tailored commuting solutions for employees. For example, companies like Google have adopted similar measures by offering shuttle services to their employees, significantly impacting their commuting habits, and reducing carbon footprints (Fehrenbacher, 2021).

Local companies and organizations can also be involved, through challenges or competitions that encourage employees to commute sustainably, with the results and impacts shared widely across public media platforms. Collaborations with educational institutions in Lahti are essential for integrating sustainable mobility principles into schools shaping student's commuting habits. This approach includes developing tailored school mobility plans based on regular surveys. These surveys can assess the commuting modes used by families and students, providing vital data to update and refine each school's mobility strategy.

Simultaneously, At the city level, Lahti's public awareness campaigns should leverage various media channels to educate residents about the environmental and personal health impacts of their transport choices. The CitiCap project serves as a crucial learning point for Lahti which highlights the need for effective interaction and community engagement in the early stages of planning. Furthermore, it demonstrates that while initial resistance to change is a natural response, well-executed projects can eventually alter public perception, bridging the gap between theoretical support for sustainability and its practical, on-the-ground realization. In the context of Lahti's broader efforts towards sustainable mobility, the evolution of the CitiCap project from a point of contention to a valued asset proves the potential for successful application of eco-friendly initiatives. It also suggests the importance of patience and perseverance in the face of public resistance, and the power of tangible results in changing community attitudes.

Leveraging the insights from the study by Soe et al. (2022) on ITS and the concept of “minipilots,” Lahti has a unique opportunity to enhance its public transport utilization effectively. This approach can be particularly instrumental in understanding and addressing the reasons behind the underutilization of the city’s well-developed public transport system.

Addressing the safety concerns associated with e-scooters and other micro-mobility modes requires a holistic approach which involves creating a dedicated and protected network for micro-mobility, incorporating traffic-calmed zones and designated lanes, while regulating the use of such vehicles on sidewalks. Given that motor vehicles are involved in a significant percentage of fatal accidents with micro-vehicles, the city must prioritize establishing lower speed limits in shared spaces. Simultaneously, treating low-speed micro-vehicles like e-scooters and e-bikes in a manner similar to bicycles can encourage their use without over-regulation. For this ecosystem to function effectively, it’s vital to collect and analyze accurate data on micro-vehicle trips and crashes, which can inform future safety measures and infrastructure developments (Sabbaghian et al., 2023). The role of technology in this context is crucial. Utilizing the data from GPS and motion sensors on shared micro-vehicles can aid in identifying road condition issues and potential hazards, leading to proactive maintenance and safety enhancements. Moreover, integrating micro-mobility considerations into road user training, especially for motor vehicle drivers, will raise awareness and improve safety practices (Itf & Oecd, 2020).

Application of Sustainable Commuting Framework on Lahti City

Extending the analysis presented in this part, which focuses on research question 3, the implementation of the sustainable commuting framework within Lahti’s distinct context demonstrates its utility as a strategic guide for city planners and policymakers.

Each theme carries its own weight and holds unique potential to addressing distinct challenges of Lahti’s transition towards sustainable commuting. This application provides depth and practicality, transforming abstract concepts into actionable strategies tailored to meet Lahti’s unique challenges and opportunities. In Lahti, “Behavior Change Campaigns” emerge as a crucial theme, imposing higher priority due to the city’s persistent car-centric attitudes. This theme’s greater weight in the decision-making framework underscores the

urgent need to reshape commuter habits and encourage a transition towards more sustainable transport modes.

Concurrently, despite having a well-developed public transportation system, Lahti faces the challenge of its underutilization. This scenario further reinforces the importance of the “Behavior Change Campaigns” theme, highlighting that enhancing the public transportation infrastructure alone may not suffice. The emphasis, therefore, shifts to intensifying efforts in behavior change strategies, aiming to increase public transport use and reduce reliance on private vehicles.

Lahti’s decision-makers should prioritize themes that align with the city’s immediate needs and long-term goals. For instance, the “Infrastructure Enhancements” theme could be a focus area, particularly in maintaining cycling and walking infrastructures to overcome seasonal challenges. The prioritization of “Technology for Seamless Commuting” could also be strategic for Lahti, considering the potential to improve integration between different modes of transport.

Resource allocation in Lahti should focus on optimizing the prioritized themes, particularly regarding the enhancement of cycling and walking infrastructure for winter usage. This aligns with the identified theme of “Infrastructure Enhancements.” Given the city’s seasonal challenges, allocating resources towards developing and maintaining comprehensive cycling networks for winter is essential. Allocating resources to develop innovative public awareness campaigns and incentives for using public transportation addresses the “Behavior Change Campaigns” theme, ensuring efforts are concentrated where they can yield the most significant impact.

6 Discussion

6.1 Mapping and Consolidating Literature for Effective Interventions

This thesis has embarked on an exploratory journey to address three critical research questions, each contributing to the overarching aim of enhancing sustainable commuting. The results chapter laid a comprehensive foundation by precisely mapping existing literature to identify effective interventions, elucidating a holistic framework for sustainable commuting, and delving into tailored strategies for Lahti's unique urban mobility challenges.

In addressing RQ₁, this study acknowledges a critical gap in existing literature on sustainable mobility and commuting. While numerous scholarly articles have explored sustainable commuting, they often do so through a narrow lens, focusing on specific sustainability aspects or interventions. This segmented approach, while valuable, tends to overlook the interconnected nature of urban mobility and the multifaceted challenges it presents. Many existing studies, though rich in detail, offer limited insight into the broader, systemic impact of these interventions, often lacking a holistic perspective that integrates various aspects of urban mobility. This study addresses the gap in sustainable commuting literature by employing a thematic approach to map and consolidate diverse interventions. This method offers a panoramic and structured overview, explaining how individual interventions interact within the broader context of sustainable urban mobility. Moreover, this approach ensures a balanced consideration of urban mobility, reflecting on economic viability, environmental impact reduction, social inclusivity, and cultural integration within commuting practices.

The study "Sustainable Mobility: A Review of Possible Actions" by Gallo & Marinelli, (2020) provides an extensive exploration of environmental, socio-economic, and technological aspects, categorizing various actions and policies. This approach, while encompassing various facets of sustainability, contrasts with the focused analysis of urban commuting in the current research. The thematic mapping of interventions in this research, concentrating on specific urban commuting aspects like Public Transport and Infrastructure Enhancements, offers a more direct application to city-specific challenges. While both studies employ comprehensive literature reviews, the present research's thematic framework brings a more structured approach, especially tailored to urban commuting contexts.

In another scholarly discourse on sustainable commuting, the paper “Commuting and Wellbeing” adopts a focused lens, primarily examining the social dimensions and well-being implications of commuting. This concentrated approach delves deeply into the subjective experiences of individuals, analysing how various commuting modes and their associated stressors impact psychological health and life satisfaction. The study provides an in-depth understanding of the personal and societal repercussions of commuting choices, emphasizing the importance of considering the human element in urban mobility planning.

In contrast, the current research broadens the scope by adopting a more encompassing perspective on sustainable commuting. It does not concentrate on a single aspect of sustainability but rather integrates various dimensions, including social, economic, environmental, and cultural factors in a holistic manner. The distinction between the two studies lies in their scope and focus. While the “Commuting and Wellbeing” paper provides valuable insights into the personal well-being impacts of commuting, highlighting the need for supportive policies that consider commuters’ psychological health, the current research extends the dialogue to encompass a broader range of sustainability concerns. It acknowledges that effective sustainable commuting strategies must address not only the social and psychological aspects but also the economic efficiency, environmental impact, and cultural context of commuting practices.

6.2 Holistic Framework Utilizing Dynamic Relationships

By developing a holistic framework that categorizes sustainable commuting interventions into thematic areas and identifies dynamic relationships between them, the research enhances the understanding and implementation of urban mobility strategies. It cultivates a new perspective of urban commuting intricacies, enabling tailored solutions that resonate with the unique characteristics of different cities. One of the key contributions of this study is the recognition that cities are dynamic entities, constantly evolving with societal and urban shifts, where implementation of interventions can have ripple effects across various aspects of urban life. By identifying and analyzing the dynamic relationships between different themes, the study shifts the focus from isolated interventions to a more integrated view, where the interdependencies and interactions between various elements are acknowledged and leveraged for more effective policy-making and urban design. Moreover, this research

acknowledges that each city has its unique characteristics, strengths, and challenges, which influence the effectiveness of different themes. It provides a method for tailoring sustainable commuting strategies to fit the specific context of a city, considering its historical background, cultural aspects, and existing infrastructure, thus ensuring that the interventions are not only theoretically sound but also practically viable. This approach promotes advanced thinking and adaptability within the evolving landscape of urban mobility. Lastly, it extends the dialogue from static, one-dimensional strategies to a more complex, connected web of actions and reactions, paving the way for more resilient, responsive, and sustainable urban mobility solutions.

In comparing the sustainable transport pathway framework by Loo & Tsoi, (2018) with the thematic approach of this study on sustainable commuting, both studies prioritize comprehensive and multifaceted strategies to promote sustainable mobility, albeit through different methods and focuses. Loo & Tsoi's framework is expansive, addressing sustainable transport from national to individual scales and incorporating a wide array of transformations including city development, economic shifts, vehicle technology, modal-split changes, and lifestyle alterations. Notably, their emphasis on "Lifestyle Transformation" aligns with the "behavioural change" theme in this study, reflecting a shared understanding of the importance of shifting individual and collective behaviours towards more sustainable commuting practices. While Loo & Tsoi advocate for broad policy instruments and strategies across multiple societal layers, this research narrows its focus specifically to sustainable commuting within urban contexts. The methodology of Loo & Tsoi is broad and integrative, aiming to initiate transformative changes in multiple areas to address sustainable transport challenges. In contrast, this study adopts a mainly qualitative approach, focusing on the thematic organization and interpretation of interventions. The framework developed here is context-oriented, acknowledging that the efficacy of interventions depends on the specific urban landscape. For instance, in cities with well-established infrastructure, efforts might shift towards promoting lifestyle changes to leverage existing assets.

Another study by Kukely et al. (2017) focuses on developing a comprehensive set of indicators for monitoring urban mobility. It emphasizes the importance of an integrated approach that aligns with the SUMP process, considering various aspects such as environmental quality, social equity, economic viability, and public health. The paper argues for a top-down approach where general objectives guide the selection of specific urban

mobility objectives and corresponding indicators. This method is crucial for benchmarking and comparing urban areas across the EU while paying attention to an integrated approach in defining the methodology. It recognizes urban mobility as part of the broader sustainable city concept, stressing the importance of sectorial, territorial, and modal integration along with citizen and stakeholder engagement.

Both frameworks seek to enhance the understanding and implementation of sustainable urban mobility strategies. However, while Kukely György et al. (2017) aim to provide a standardized set of indicators for monitoring and benchmarking purposes, the framework which is developed in this research emphasizes the dynamic relationships between various interventions and the need for adaptable, city-specific solutions. It is mainly about offering a decision-making tool that considers the distinctive characteristics and needs based on the urban context.

6.3 Strategies and Measures for Lahti

The exploration of sustainable commuting strategies and measures for Lahti in this study represents a different perspective in the field of urban mobility and sustainable commuting. Through meticulous analysis of Lahti's commuting landscape, this research identifies and articulates strategies and interventions that are both tailored and grounded in the city's current infrastructure, societal norms, and environmental objectives. These strategies are not merely theoretical propositions but are informed by an in-depth understanding of Lahti's unique urban context, ensuring their relevance and applicability.

One of the pivotal contributions of this study is its dual-layered approach, addressing both city-wide and company-level strategies for sustainable commuting. By extending the focus beyond the public sphere, this research broadens the scope of potential interventions and recognizes the critical role of workplaces in shaping daily commuting patterns. The solutions proposed in this research are carefully chosen to align with Lahti's existing SUMP. They are envisioned as enhancements and extensions to the current plan, reflecting a forward-thinking approach that seeks to build upon and augment the city's existing efforts towards sustainability. This alignment ensures that the strategies are not only innovative but also integrative, weaving seamlessly into the fabric of Lahti's established plans and ambitions.

Furthermore, the strategies suggested are characterized by their potential for practical application in Lahti. They are selected based on their feasibility and the anticipated positive impact on the city's commuting landscape. This focus on actionable insights demonstrates the study's commitment to delivering real-world benefits and advancing the city's transition towards sustainable mobility.

The selection of Copenhagen as a comparative case study for Lahti is underpinned by its reputation as a leading city in sustainable mobility and its ambitious goal to become carbon neutral by 2025. Copenhagen's strategies, as detailed in the report, reflect a commitment to extensive infrastructure investments and a deep-rooted biking culture. These elements make Copenhagen an instructive benchmark for Lahti, given its aspirations to enhance sustainable commuting practices and its need to address specific urban challenges (Walthers et al., 2016).

Both Copenhagen and Lahti understand the significance of shifting commuting behaviors to meet their sustainability objectives. The report on Copenhagen particularly underscores the vital role of user involvement in progressing toward sustainable mobility. It suggests that despite its well-established infrastructure and prevalent biking culture, a deeper, more sustainable transition necessitates direct citizen engagement and active participation in mobility initiatives. This notion has a future potential for Lahti, which, based on the suggestions of this research, could also focus on behavior change campaigns alongside infrastructural improvements to influence residents' commuting choices (Walthers et al., 2016).

While the strategies proposed in this research for Lahti are tailored to its specific context, they share an underlying principle with Copenhagen's approach: the need to alter commuting behaviors and ensure user involvement. However, the recommendations for Lahti are uniquely inclusive, advocating for innovative solutions that address both city and company levels. These suggestions extend beyond just constructing physical infrastructure; they aim to cultivate a culture supportive of sustainable commuting practices in different layers. This involves a profound understanding of the local context, a factor that Copenhagen's experiences also highlight as critical for successful transition (Freudental-Pedersen et al., 2020).

6.4 Limitation and Future Research

This research, while providing a holistic thematic approach to sustainable commuting, recognizes certain limitations but it opens several avenues for further investigation. Each theme identified in this research presents a fertile ground for in-depth investigation, offering future researchers the opportunity to delve deeper into specific areas such as public behaviour change or technology integration. These focused studies can provide a more detailed understanding of individual elements within the broader context of sustainable commuting. Time constraints also posed a limitation, potentially restricting the depth and breadth of the analysis. Given more time, a more detailed exploration of each theme could be conducted, perhaps unveiling more intricate relationships and subtleties within the urban commuting landscape.

The predominantly qualitative methodology, though rich in detail and depth, might benefit from a complementary quantitative analysis. Incorporating quantitative data into future research could significantly enhance the depth and precision of the study. This approach provides a granular lens through which commuting patterns can be dissected and understood, offering vital insights into the statistical significance and scale of various interventions' impacts. It brings to light the varied dimensions of urban commuting behaviors, uncovering patterns and trends that may not be immediately apparent through qualitative analysis alone. By quantifying the effects of different strategies, researchers can gain a more detailed and layered understanding of their efficacy, adaptability, and potential for success in diverse urban settings and conditions. This level of detail is crucial for formulating targeted, effective interventions and for making informed policy decisions that resonate with the complex reality of urban mobility. The approach taken in the initial coding phase to categorize interventions into subthemes presents a methodological choice that frames the analysis within specific conceptual boundaries. This segmentation, while effective for the purposes of this study, suggests the existence of alternative methodologies that could offer different insights into the classification and prioritization of sustainable mobility interventions. The delineation of interventions into subthemes during the first-order coding process is inherently influenced by the researcher's perspective and the theoretical lens applied to the data. This subjectivity underscores the potential for future research to explore other categorization methods, potentially uncovering new patterns or thematic relationships

not identified in this study. By adopting different analytical frameworks or employing mixed methods approaches, subsequent studies could further enrich the understanding of sustainable commuting interventions, offering a broader or perhaps contrasting set of categorizations that reflect varying priorities or theoretical underpinnings in the field of urban mobility.

Regarding the city analysis of Lahti, while the qualitative insights could also offer valuable understanding and tailored interventions, future studies could employ a more detailed quantitative approach. This would provide a clearer picture of the city's commuting patterns and a more accurate assessment of different strategies' potential impacts. Quantitative data could support more precise recommendations for intervention implementation and resource allocation. Moreover, while this research provides a robust foundation (relying on existing interventions in literature), the dynamic and rapidly evolving nature of urban mobility means that constant updates and revisions are necessary to stay relevant. Future research could benefit from integrating cutting-edge trends, technologies, and innovative solutions that are continuously reshaping the urban mobility landscape. Incorporating stakeholder engagement more deeply into the framework could significantly enhance its effectiveness and applicability. Forthcoming studies should focus on the mechanisms of effective stakeholder engagement, exploring case studies where active involvement led to the successful implementation of sustainable commuting strategies. This could provide practical insights into how various actors, including citizens, policymakers, and private entities, can collaboratively contribute to the development and execution of sustainable mobility initiatives. Additionally, applying theories of sustainable transition could offer a theoretical lens through which to examine the shifts towards sustainable commuting practices more comprehensively. This approach would provide a more structured understanding of the systemic changes needed and the multi-level interactions that facilitate these transitions, thereby enriching the framework with a robust theoretical foundation and a clearer pathway for practical implementation and adaptation in different urban contexts. Lastly, future research should consider more participatory methods, engaging directly with stakeholders such as city planners, residents, and businesses. This approach could enrich the understanding of practical challenges, user preferences, and acceptance levels of various interventions. Stakeholder feedback is invaluable in designing effective, accepted, and sustainable commuting strategies that resonate with the community's needs and preferences.

7 Conclusion

Overall, it is evident that the quest for sustainable commuting is a multifaceted endeavour, essential for fostering healthier, more liveable urban environments. The research was structured to address three distinct but interrelated research questions, guiding the investigation through a qualitative process that encompassed an extensive literature review. Additionally, it introduced a framework built upon the foundation of existing literature. Furthermore, the study concludes by highlighting specific, city-tailored strategies and interventions based on a thorough analysis of Lahti's commuting landscape, aligning with its existing infrastructure, and carbon neutrality goals for 2025.

This study concludes that achieving sustainable commuting involves more than just adopting new solutions; it requires a strategic approach to applying proven interventions that are specifically adapted to the unique characteristics and requirements of cities such as Lahti. This realization points to a broader implication is that the path to sustainability in urban commuting is paved through the dynamic interplay of various thematic areas, each contributing to a cohesive strategy that addresses the specific challenges and leverages the unique opportunities within a city's commuting landscape.

The analysis of Lahti's urban commuting landscape acts as a critical filter, narrowing down the broad spectrum of potential sustainable mobility solutions to those most suited to the city's specific infrastructural capabilities and dynamic needs. This targeted approach ensures that the selected strategies are practically viable within Lahti's unique urban context. This precision in matching interventions with local conditions and challenges underscores the importance of a nuanced, city-specific application of the framework, highlighting its adaptability and relevance to Lahti's journey towards enhanced sustainable commuting practices.

To encapsulate, the journey towards sustainable commuting in urban environments is complex and layered, demanding a concerted effort that is both strategic in its reliance on proven interventions and adaptive in its application to meet specific urban challenges.

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Appendix 1. Grouping Table

| <i>Theme</i> | <i>subtheme</i> | <i>Interventions</i> | <i>Sources</i> | |
|-----------------------------------------------|----------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>Public Transport Enhancements</i> | Green Transportation Policies and Regulations | Develop policies to incentivize the use of low-emission public transit Setting emission standards for public transport vehicles Improving environmental credentials of imported cars | (ECMC, n.d.) (Gonzalez et al., 2022) (Hulkonen et al., 2020) (Emma Mulholland, 2023) (Stephenson et al., 2018) | |
| | Renewable Energy Integration in public Transportation Systems | Conduct research on biofuels' feasibility and benefits in the transport sector Bus transit systems with electric traction and establish partnerships with renewable energy providers | (Björpsson et al., 2014) (Kühne, 2010) (Vehviläinen et al., 2022) (Stephenson et al., 2019) | |
| | Accessible and Inclusive Public Transport Services | Intermodal Urban Mobility | Multi-Modal Hubs Optimization of Bus Route | (Gebhardt et al., 2016) (Stift et al., 2019) (Yuan and Yu, 2018) |
| | | | Conduct user surveys to identify gaps in intermodal connectivity Implementing real-time public transport information systems | (Chien et al., 2003) (Morozov et al., 2023) (MacEdo et al., 2021) (Lu et al., 2018) |
| | | | Targeted design of transport for the needs of different segments of the population Development of park-and-ride | (Stephenson et al., 2018) (Parkhurst, 2000) |
| | | Bicycle and Pedestrian Infrastructure Development | Building dedicated bike lanes and pedestrian walkways Creating bike-sharing programs in urban areas Studying ridership patterns in winter Development of the winter maintenance of pedestrian and cycling paths Street design measures including sidewalks, bicycle lanes, and share-the-road signs Provide streetscape amenities (benches, landscaping, lighting, public art and first aid) Enhancing Bus Infrastructure (bus station) | (Todd Litman et al., 2006) (Cervero et al., 2009) (Zhang et al., 2015) (Macioszek et al., 2020) (del'Olivo et al., 2015) (Tunnen, 2023) (Aasvik and Björnskau, 2021) (Singhal et al., 2014) (CDC, 2011) (CDC, 2011) (Rochu et al., 2020) |
| | <i>Infrastructure Enhancements</i> | Sustainable Urban Planning | Optimizing the location of stations in bike-sharing programs Implementing mixed-use zoning to reduce travel distances development of street-level shopping and restaurants along pedestrian and bicycle route | (García-Palomares et al., 2012) (Caiiskan, 2021) (Kusumastuti and Nicholson, 2016) (Yoshimura et al., 2022) |
| | | Electric Vehicle Charging Infrastructure | Installing EV charging stations in public places, companies, and buildings Providing incentives for businesses to install charging points | (Luo and Qiu, 2020) (Sierzchala et al., 2014) |
| | <i>Behavior Change Campaigns</i> | Transit-Oriented Development (TOD) and Mixed-Use Land Use Planning | Encouraging mixed-use development around transit hubs Mobility-Oriented Development (MOD) practices | (Shamskooski, H., 2012.) (RTA Michigan, 2019.) |
| | | Promoting Active Modes of Transportation | Organizing walking and cycling events and campaigns Implement workplace incentives for employees who use bicycle for work trip Cyclist-friendly amenities in company's premises Leveraging health benefits to encourage people to walk Eco-Mobility Rewards Program in companies | (Scheepers et al., 2014) (Rénat, 2019) (Wardman et al., 2007) (Baltatz, 2017) (Sallis et al., 2004.) (European Commission, 2019) |
| Carpooling and Ridesharing Initiatives | | | Facilitating carpool matching services for commuters Carpooling and Ridesharing Initiative Offering preferential parking for carpool vehicles | (Xia et al., 2015) (Molina et al., 2020) (Ferrero et al., 2018) (Penczanovic et al., 2017.) (Kelly, 2007) |
| Mobility-as-a-Service (MaaS) Platforms | | | Invest in the development of user-friendly MaaS platforms that integrate various transport modes Ticket and payment integration A gamification platform to analyze and influence citizens' daily transportation choices Create a city-wide gamification app that rewards residents for choosing eco-friendly commuting options Personalized commuter plan (PCP) tailored journey information and information about discounted | (Butler et al., 2021) (Musolino et al., 2022) (Kamargianni et al., 2016) (Kazhamiakin et al., 2021) (Manca et al., 2022) (Behavioural Insights Team, 2017) |
| <i>Technology for Seamless Commuting</i> | | Shared Mobility Solutions | Shared e-micro mobility, (shared e-bikes and shared e-scooters) | (Mountidis, 2022) (Ignaciolo et al., 2022) (Lin and Wells, 2023) (Hoseinzadeh et al., 2021) |
| | | Intelligent Transportation Systems (ITS) for Traffic Management | Installing smart traffic signals and congestion management systems Using data analytics and big data to optimize traffic flow Implementation of the road safety plan (using Augmented Reality for Cyclists) Holistic urban mobility planning using (ITS) mini pilots (with experimental approach) | (Zhu et al., 2023) (Mandhare et al., 2018) (Zhu et al., 2019) (Bowman and Müller, 2016) (Belin et al., 2012) (Matvienko et al., 2022) (Soe et al., 2022) |
| <i>Mobility Management</i> | | Multi-Stakeholder Collaboration and Engagement | Forming partnerships between public and private sectors (Foster collaboration between governments, private businesses operators, experts and retailer) Engage local communities and citizens in the decision-making process for transportation initiatives (Such as, tax reduction and funding) | (Le Pfa et al., 2016) (Cascetta and Pagliara, 2013) (Evans-Cowley and Griffin, 2012) (Potter et al., 1999) |
| | | Carbon Footprint Reduction Strategies | Encouraging the use of fuel-efficient vehicles Personal carbon trading Encourage businesses to invest in local eco-friendly transportation projects as a carbon offset, compensating for emissions | (Liman, 2013) (Usitalo et al., 2022) (Kuokkamen et al., 2020) (Floranta, 2021) |
| | | Travel Demand Reduction | Promoting flexible work hours Supporting telecommuting programs for employees and technological support | (Chakrabarti, 2018 (Wöhner, 2022) (Ye, 2012) |
| | | Land Use Management | Parking Management and Policies Implementing Pricing Mechanisms Smart Parking System | (Liman, 2006) (Mingardo et al., 2022) (Mangiaracina et al., 2017) (Ramaswamy, 2016) |