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Micro Mobility and Smart Cities

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Abstract

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This study addresses the increasing need for efficient and sustainable last-mile delivery solutions in smart cities, which is being driven by rising e-commerce and urbanisation. Traditional distribution methods have obstacles such as high costs, traffic congestion, and environmental effects, hence there is an urgent need to investigate alternate techniques to address these issues. The study's goal is to examine the possibilities of micro mobility as a last-mile delivery solution in urban areas, as well as to analyse the implications of its implementation. It aims to identify and assess existing issues in traditional last-mile delivery techniques, as well as to investigate the benefits and opportunities provided by micro mobility solutions. The research uses content analysis as a primary methodology to analyse relevant literature and get information on last mile delivery challenges, micro mobility solutions, benefits, and opportunities. The findings show that micro mobility modes including e-scooters, e-bikes, and small electric cars provide promising answers to last-mile delivery difficulties. These solutions include higher accessibility, lower environmental impact, greater flexibility, and better operational efficiency. Furthermore, the study identifies prospects for using micro mobility to optimise urban logistics and improve overall delivery performance.

Keywords: Micro mobility, smart cities, last mile, delivery, transport.

Table of Contents

List of Figures and Tables

1 Introduction

Smart cities are confronted with the challenge of efficient delivery of goods and services to urban centres. The use of traditional delivery methods like trucks and vans further increases this challenge as they create congestion and pollution, making the city less livable as these transport systems are not sustainable environmentally, socially, or economically (Comi & Polimeni, 2024). However, the existence and subsequent introduction of micro mobility may be able to solve the issue of “last mile delivery” in smart cities. Micro mobility makes use of transport systems such as electric scooters, bicycles, and electric vehicles. Although public transportation has the ability to reach larger geographical areas within short periods, micro mobility can provide more flexibility and carry out door-to-door services (Pazzini et al. 2022). The combination of public transportation's rapid speed and reach and micro mobility's door-to-door accessibility creates a degree of access, speed, and comfort comparable to that of a private motorised vehicle. Based on this information, this thesis investigates the potential of micro mobility as a suitable solution for last mile delivery in smart cities.

1.1 Problem Statement

The existence of smart cities makes the efficiency of goods and services delivery to urban areas important, in order to keep economic activities going for the benefit of residents and businesses. Transportation represents a crucial element of smart cities and ultimately people’s lives. Fast and efficient delivery has become a major contributor to economic growth, enhancing connectivity between people and goods. This proved even more crucial as was witnessed during the Covid-19 pandemic of 2020 onwards. In context, over 2 billion people purchased goods and services online in 2020 (Coppola, 2021, October 27). According to a study by McKinsey and Company, a quarter of consumers are willing to pay a premium for same-day delivery (Joerss, Neuhaus, & Schröder, 2016). This is a trend we can expect to grow. Maintaining smart cities with this growth can be a difficult task; however, micro mobility could provide possible solutions to efficient handling and delivery of these goods within the smart city concept. Last mile delivery refers to all logistics tasks linked to the delivery of shipments to private customer houses in metropolitan areas (Boysen et al. 2020). Last mile delivery bridges the gap between typical transportation hubs (train stations, bus stops, parking spots at modal interchanges, etc.) and the final destinations, particularly in instances where the infrastructure is very congested (Oeschger, 2020). In an effort to better address the issues related to mobility difficulties, many cities have begun to establish urban goods mobility concepts and also plans for transportation of goods (Comi & Savchenko, 2021). However, the methods in existence are mostly insufficient for inner-area last mile delivery of goods and services.

Transportation systems in cities significantly affect other systems, as well as the lives of citizens more generally. As technology is capable of improving connections between people and things, a quick and effective distribution system has grown to be very important in facilitating economic growth. The current delivery methods in use, including the use of trucks and vans, make last mile delivery in smart cities difficult. The increase in the number of cars, vans, and trucks make delivery slower, increases emissions, make neighbourhoods noisier, create congested roads, and increase traffic and traffic related injuries (Doddle, 2019). These methods cause traffic congestion, intensify urban congestion, and reduce overall transportation efficiency. Furthermore, the emissions produced by these cars contribute to air pollution and environmental deterioration, therefore destroying natural environments.

These issues make it necessary to research better and efficient methods of distribution in order to make last mile delivery more efficient in smart cities. One of these solutions that can be explored is the use of micro mobility. Micro mobility has several advantages, like flexibility, sustainability, cost-effectiveness, and is an on-demand transport option. Since micro mobility transport is smaller in size and more agile, it is capable of navigating congested cities, making it much more possible to reach destinations that cannot be accessed by bigger vehicles during unavoidable issues like traffic. Micro mobility transport can also reduce emissions and improve environmental safety. Also, through the use of GPS tracking, micro mobility transport can be visible and delivery fleets can be tracked easily, improving delivery. Micro mobility also has its challenges. They include safety, liability, compatibility of infrastructure, equity concerns, accessibility, and integration with existing transportation networks.

A particularly valid question that arises concerns the possibility of general acceptance of slower delivery not only by the consumers but also logistics companies in their goal towards decreased environmental impact, away from the present trend of fast efficient delivery. ’Why should Amazon, for example, deliver 3 items from the same order separately whereas, waiting until all items are available would reduce cost and decrease environmental impact? Some possible reasons might be deduced from McKinsey and Company's study which highlighted that a quarter of consumers are willing to pay a premium for same-day delivery (Joerss, Neuhaus, & Schröder, 2016). This creates a struggle to balance revenue generation with environmental sustainability goals. A possible loss of market share could also be a challenge if competitors do not adopt the same approach or do so in an unfair manner. The projected increase in urban deliveries attributed to changes in consumer demand, new or better services offered by companies and growing Urban population does indicate a continued increase in urban deliveries (Maxner, Dalla Chiara and Goodchild 2005). Ecommerce has further influenced the ways customers interact with companies by offering platforms outside traditional shopping channels. Such services include same-day delivery, prepared food delivery applications and grocery delivery services which have all resulted in the growth of e-commerce related urban freight trips reemphasizing the need for quick delivery. In the study of the trend of global grocery delivery, Albeit smaller in market size in comparison with parcel deliveries, grocery delivery projects a very strong growth with the online market estimated at $199 billion already in 2020 (Business Wire, 2020), and projected to reach $550 billion by 2027. This trend has not gone unnoticed, with venture capital firms having invested USD $14 billion in grocery delivery services globally since the beginning of the pandemic translating to more funding in the first quarter of 2021 compared to the whole of 2020. A similar trend can also be noticed in food deliveries over the last five years accelerated by lockdowns during the Covid-19 pandemic (Singh, 2019). In the US alone online food delivery market revenue increased by 204% between 2015 and 2020 (Curry, 2021). The global online food delivery market was worth USD $115 billion in 2020 and is expected to grow to USD $192 billion by 2025. It can be seen that the type of products, in this case perishable, might play a significant part with decision makers and stakeholders in their belief in the growth of faster and efficient deliveries, even when environmental impact is considered. as delivery companies also aim to grow their market shares. This is not to say there is not a tangible percentage of slower deliveries mitigating this present trend in the near future, as parcel deliveries still represent a major contributor of deliveries in general, exceeding a whopping $500 billion in 2020 (Apex insight. 2021).

Based on the potential of micro mobility, this thesis aims to investigate the potential of the adoption of micro mobility as a solution for last mile delivery within smart cities. The research aims to provide information and recommendations for cities seeking to solve the problem of last mile delivery. The research will examine opportunities, challenges, and potential impacts of the use of micro mobility in logistics and delivery.

1.2 Significance

The significance of this research lies in the fact that micro mobility as a solution for last mile delivery has the potential to address urban challenges related to delivery, hence putting the citizens, businesses, and the environment at an advantage.

Ensuring that delivery within cities is efficient is very important to the economies of cities as delivery services attend to the demands of increasing populations. Cities can be able to access goods and services on time using micro mobility. Micro mobility can also ensure faster delivery and overall productivity in cities. This is important as the demand for e-commerce and timely delivery services is necessary to ensure customer satisfaction.

The use of micro mobility for last-mile delivery can thus help to improve the day-to-day activities in cities. Using micro mobility for last-mile deliveries can help to lessen environmental impact. Replacing traditional delivery methods with electric-powered micro mobility choices can help cities significantly reduce carbon emissions, air pollution, and traffic congestion, hence decreasing urban transportation's detrimental impact on public health and the environment. This could also assist making urban environments cleaner, healthier, and more livable for residents.

Researching the potential of micro mobility could enable smart cities to provide more affordable and accessible delivery options, particularly in impoverished and marginalised areas. This might improve individual access to basic commodities and services, cut transportation costs, and broaden social and economic prospects for all individuals and businesses. Integrating micro mobility into last-mile delivery operations can help boost innovation and economic growth in smart cities. Cities that make use of micro mobility can harness technology development, production, and service hubs, job creation, attract investment, and stimulate entrepreneurship in emerging industries such as electric car manufacturing, battery technology, and software development. This helps cities develop sustainable urban mobility options.

1.3 Research Questions and Objectives

The goal of this study is to investigate the potential of micro mobility as a solution to last-mile delivery within smart cities. Hence, the primary research question is:

How can micro mobility be used as a solution for last mile delivery in cities and what are the consequences of this strategy?

Based on the research question, the secondary research questions are as follows:

1. What are the existing challenges in traditional last mile delivery methods in smart cities and how can micro mobility solve these challenges?
2. What are the benefits of the use of micro mobility for last mile delivery?
3. What are the opportunities (potential) in the adoption of micro mobility for last mile delivery?
4. What are the safety problems and risks posed in adopting micro mobility in smart cities? How can these be curbed? Are there tangible solutions?

1.4 Summary of Thesis Structure

Beginning with a detailed evaluation of the literature review, the subsequent sections of this study have been carefully organised to follow an orderly, logical pattern. The research methods section that follows this thorough assessment will go into great detail about the research design, data collection strategies, sample strategies, and ethical problems that influenced the study. The subsequent phases proceed freely, and the data presentation provides a complete analysis of the study data gathered from scholarly literature. The findings are described in the following discussion, conclusion, and recommendations, which provide a thorough understanding of their implications and contributions to the field. This structure ensures a consistent thesis by leading the reader through an exploration of the potential of micro mobility in smart cities.

2 Literature Review

2.1 Overview of Micro Mobility and its Advantages

Micro mobility is a mode of urban transport that is aimed at providing solutions for travelling short distances, both first and last kilometre trips (Abduljabbar, et al. 2021). It provides flexible, cost-effective, and sustainable travel and transport alternatives (Shaheen & Cohen, 2019). In the last few decades, several modes of micro mobility have been introduced and have been met with positive feedback (Olabi et al. 2023). Bicycle share services, for example, have increased tremendously worldwide, from 17 in 2005 to over 2900 in 2019 as hybrid bicycles combined with pedelecs (power-assisted e-bikes) become cheaper (Olabi et al. 2023). Dockless bike sharing has grown in popularity since 2010, starting in China and fast expanding around the world (Chen, 2020).

The adoption of micro mobility for travel and delivery has several advantages. Electronic micro mobilities for example are fueled by an electric battery rather than an engine that burns fuel, thus they create no greenhouse gases when in operation. They also help reduce congestion as they take up less space on the road (Bridge, 2023). Micro mobility also has various physical benefits. Fyhri and Fearnley (2015) note that electronic bikes can boost cycling engagement and encourage more frequent and longer journeys. They can cover longer distances and help to complete more tasks on the way without having to lose so much time. The use of electronic scooters also has its own benefits. Electric scooters are fun to ride, and this offers more mental health benefits when compared to riding a car or using public transport (Jones et al. 2016). As the very core of smart cities is its people, this mental health benefit is not talked about enough.

Despite these benefits, micro mobility also has its disadvantages. One of them is the possibility of injuries during use (Papoutsi et al. 2014). Another disadvantage is the problem of sufficient charge. There have been concerns about the lifespan of their batteries and the inability of these batteries to support long-distance movement (Bridge, 2023). In 2016, Harms & Heinen also found out that the parking mode of micro mobility transport was problematic, especially at major transport locations like train stations. This has considerably improved in many cities through the introduction of mandatory parking spots. Also, the reason why people originally did not usually prefer the use of micro mobility options like electric bikes was due to the stigma associated with riding them compared to other modes of transport (Popovich et al., 2014), although this appears to have declined.

The usability of micro mobility transport has been directly linked to a certain demographic. Research has shown that young adults, males in particular, are the most common users of micro mobility (Campbell et al. 2016). However, in some countries, this is not totally true. According to Li et al. (2019), some countries may have more women using bike-sharing services while in some others, this may not be the case due to religious beliefs discouraging women from using bikes.

Secondly, income and education levels affect the adoption of micro mobility. Some findings reveal that people with higher income and those that are more educated are most likely to make use of shared bicycles while some others do not believe this to be true (Campbell et al. 2016). This may be because of cultural differences or other observable factors.

The use of electric scooters has also been linked to young, educated individuals (Aguilera-García et al. 2020). This has also been observed in people who already own cars or a driver’s licence (Aguilera-García et al. 2020). In addition, people who already own electric scooters are more likely to make use of shared electric scooters (Bieliński & Ważna, 2020).

Additionally, people who are travelling short distances have also been found to prefer cycling and this makes them more likely to make use of micro mobility services (Aguilera-García et al. 2020). Environment and weather are also significant considerations in the use of micro mobility. Micro mobility is more used in environments that have cycle-friendly infrastructure (Abolhassani et al. 2019). Also, micro mobility users are more discouraged when the weather seems bad and air quality is poor (Campbell et al., 2016). Therefore, temperature, weather and air quality are also factors influencing the use of micro mobility.

Finally, safety, convenience, and privacy concerns also influence the adoption of micro mobility (Fishman et al. 2015). People only make use of micro mobility in conditions which they perceive to be safe and lack of privacy which bigger and enclosed vehicles give may also deter the use of micro mobility. Mostly observed is the use of micro mobility among individuals that are concerned with environmental sustainability (Eccarius & Lu, 2020).

Researchers have studied methods in which micro mobility options like electric scooters and bicycles can be made safer for users. This has led to the identification of the major factors that result in micro mobility accidents. One of the results is the interaction between vehicles and the environment. As noted by Prati et al. (2019) the type of road and the age of the user can affect how severe an accident turns out to be.

The state of bike paths and roads also play a role in micro mobility safety. The elements of design including accessibility and junction number can increase or decrease the possibility of accidents (Kamel & Sayed, 2020). To have a better understanding of the causes of these accidents and how they can be prevented, it is important to understand the best conditions in which micro mobility can and should be used.

The presence of intersections is unsafe for cyclists and researchers have been studying what factors contribute to accidents at intersections. It has been found that bike lanes, width of sidewalks and median width can influence safety (Cai et al. 2020). Also, the manner in which intersections are designed can affect safety of users as certain configurations increase accident risk (Deliali et al. 2020).

City officials and legislators are becoming more interested in the addition of micro mobility into urban mobility planning. Initiatives like sustainable urban mobility plans (SUMPs) and proposals for incorporating micro mobility into urban mobility planning aim to address the concerns about safety, public space utilisation, and traffic management (Comi & Polimeni, 2024).

2.2 Overview of Smart Cities

The term “smart city” is a concept that extends towards urban living incorporating IT devices, industry, governance, urban services, neighbourhoods, housing, education, buildings, lifestyle, transport, and the environment (Hollands, 2014). However, the term and the idea more generally have been criticised for ignoring the complex urban issues and processes (Hollands, 2014). In spite of this, the concept is still significant in urban development, as there are different examples of smart cities and smart city initiatives around the world.

Some examples of smart cities and smart city initiatives are Singapore's iN2015 project (Smart City Asia Congress, 2012), Songdo in South Korea, Guangzhou Knowledge City in China, Masdar City in the UAE (Smart City Asia Congress, 2012), Helsinki and Thessaloniki in Europe, Barcelona's Smart City Model and Amsterdam's Smart City initiative (Hollands, 2014). Even smaller cities like Sunderland in north east England are exploring smart city initiatives (Hollands, 2014).

The increase in smart cities has resulted in various estimations and ranking. Vienna ranks first in a list of 10 smart cities (Hollands, 2014). IBM has also claimed to be involved in building over 2000 smart city projects around the world while Pike Research has about 130 ongoing projects (Hollands, 2014).

There are certain factors driving the development of smart cities, including: population demographics, role of cities as drivers of economies, and sustainability. As 60% of the world’s population live in cities, and as cities account for a significant portion of global gross domestic product, and greenhouse gas emissions, smart cities exist to address these challenges through innovations in transport, urban mobility, and energy systems (Hollands, 2014),

IBM has contributed to the development of smart cities through its “Smarter Cities Challenge”, which was launched in 2010 and has been deployed in over 130 cities around the world (IBM, n.d.). This initiative as reported by IBM is based on its previous Smarter Planet Concept, which was targeted toward providing technology-based solutions for urban challenges (IBM, 2008). The Smarter Cities Challenge focuses on five areas including water management, public safety, traffic, buildings and energy.

IBM's approach to smart cities emphasises cross-domain integration, which connects data from several municipal domains to improve resource utilisation and decision-making (Alizadeh, 2017). This approach has been attacked for exaggerating the complexities of urban problems and overlooking smart cities' participatory and democratic potential (McNeill, 2015).

Despite these reproaches, IBM has made considerable investments in smart cities, contributing more than $66 million to the Smarter Cities Challenge effort. IBM teams have collaborated with municipal governments globally to create digitally enabled solutions in areas such as citizen engagement, public safety, transportation, sustainability, economic growth, social services, and land-use planning (IBM, n.d.).

IBM's involvement in smart cities is part of a larger trend in which multinational digital firms shape the concept of smart cities (Shelton et al., 2015). Other firms, like Siemens, Google, and Cisco, are also developing smart city technologies and processes (Wiig, 2015).

While IBM's involvement in smart cities has been criticised for potentially undermining collaborative and democratic potential, it is also recognized that the company has played an important role in shaping the concept of smart cities and providing digitally enabled solutions to urban challenges (McNeill, 2015).

Smart cities are making use of technology opportunities to promote energy conservation, waste management, and sustainable transportation systems. Micro mobility features the use of lightweight environmentally friendly vehicles for short-distance commutes. It has also gained significant attention recently as it has potential to reduce carbon emissions, alleviate traffic congestion, and enhance urban livability.

The integration of internet-of-things (IoT) technology and smart city infrastructure enables the efficient use of micro vilify systems. Smart cities with IoT sensors and data analytics can make use of route planning, reduce waiting times, and improve user experience (Nizetuc et al. 2020). Also, aligning smart city initiatives with United Nations Sustainable Development Goals can help ensure that micro mobility solutions contribute to the pursuit of sustainability (Ismagilova et al. 2020).

The use of smart logistics and industry 4.0 technologies can enhance the efficiency of micro mobility systems. Korczak & Kijewska (2020) emphasised the significance of smart logistics for coordinating transportation networks and fostering sustainable urban development. Similarly, Haarstad & Wathna (2020) stressed the importance of smart cities focusing on urban energy sustainability and implementing effective micro mobility solutions to reduce carbon emissions.

Several studies have shown the effectiveness of micro mobility solutions in smart cities. Cellina et al. (2020) studied the influence of mobile applications on low-power applications in Switzerland, whereas Battarra et al. (2020) demonstrated the advantages of smart mobility in supporting successful transportation systems. By contrast, Peprah et al. (2020) stated that developing nations such as Ghana have failed to implement micro mobility solutions, which has had a negative impact on the economy.

To address these issues, scholars have developed new strategies. Lopez-Carreiro & Monzon (2018) created the Smart Mobility Index to measure urban mobility, and Din et al. (2020) proposed a mobility management technique to improve transportation efficiency. Furthermore, Li et al. (2020) developed a lightweight, biocompatible unit known as polypropylene ferroelectric (PPFE), which can be used in micro mobility applications. Wang et al. (2020) presented a nanogenerator platform using inherently stretchy materials, as well as a strategy for energy harvesting using ferrofluid.

2.3 Overview of Last Mile Delivery

Last mile delivery is the last part of the supply chain, where goods are delivered from the last transit point to the end which the customer specifies (Jucha & Corejova, 2021). Over the years, the topic has gained attention due to the increasing demands of customers who prefer dependable delivery of their packages, notwithstanding where they order them from (Burns, 2018). These expectations are increasing, and they have influenced the emphasis on good quality of deliveries to build customer loyalty, even within competitive markets (Strenitzerova & Gaňa, 2018).

One of the challenges of deliveries is the barrier placed by the last mile issue, which is one of the major reasons why the logistics industry advances at a slow pace, worsened by the challenges of congestion in urban cities, and inadequate infrastructure in rural areas (Li et al. 2020). Providers of delivery services are faced with difficulties trying to get to the last mile including high cost, increased customer expectations, and other logistical issues (Janevic & Winkenbach, 2020).

Also, the increase in the use of e-commerce makes the need for last mile delivery on the high side and magnifies the urgency for implementation of solutions to solve challenges encountered in last mile logistics (Simonia et al. 2020). This makes the appraisal and use of technologies like unmanned aerial vehicles and intelligent logistics services very important, creating efficiency and efficacy in last mile delivery operations (She & Ouyang, 2021).

However, even as reviews should be made to delivery services to make last mile delivery easier, it is important to encourage sustainability among urban logistics. The use of vehicles that emit little or no CO_2 would be very beneficial in fighting against environmental pollution.

In parallel, there is attention on the importance of addressing environmental concerns and fostering sustainability within urban logistics ecosystems. Embracing clean vehicles and integrating management techniques like environmental degradation, curtailing greenhouse gas emissions, and reducing dependence on fossil fuels could help contribute to a greener future (Li et al. 2021; Patella et al. 2021).

The introduction of last mile delivery offers different solutions to address last mile issues. Reception boxes are used as an approach to solving delivery that goes unattended, ensuring that customers can use facilities like shared reception boxes and own reception boxes (Wang et al. 2014). Shared reception nodes are positioned in central locations like bus stations and shopping centres where they can be easily accessed, allowing customers to use the same box to receive their packages, and consequently make delivery more efficient (Tiwapat et al. 2018). Also, own reception boxes can be installed at the residences of customers for convenience and in order to enable them to receive parcels at any time without having to wait for a prefigured time (Wang et al. 2014). However, the disadvantage of this is that customers may have locations that are very far from each other, making it difficult for the dispatcher to carry out deliveries on time.

Another popular delivery method is the collecting point, which includes both locker points and service locations, each with its own set of benefits (Collins, 2015). Locker points, also known as unattended points, are characterised by unattended shared reception boxes situated in public spaces. While they provide a handy alternative for parcel pickup, they also represent security hazards and lack payment options. In contrast, service points or attended points integrated within established retail shops or service hubs provide a personalised, face-to-face service experience, although with limited office hours (Collins, 2015). Despite their differences, lockers and service points have considerably improved last mile delivery operations by reducing first-time delivery failures and responding to a wide range of consumer demands.

Traditional channels, such as post offices, continue to play an important part in the last mile delivery ecosystem, serving as dependable pickup places for undeliverable items. Post offices, like collection sites in terms of efficiency and face-to-face service, allow customers to pick up parcels when it is convenient for them, reducing the distance travelled for parcel retrieval. In contrast, attended home delivery (AHD) (Wang et al. 2014) is a popular but inefficient technique that requires recipients to be present to sign for and collect items at their door. The strict time limitations associated with AHD frequently result in low first-time delivery success rates and high operational expenses, necessitating efficiency-enhancing optimization strategies (Tiwapath et al. 2018).

Unattended home delivery appears as a possible option, addressing the difficulties of missed deliveries and limited time windows. UAHD simplifies delivery operations by using open time windows and optimising truck routes, resulting in fewer unsuccessful first-time deliveries and increased efficiency.

2.4 Challenges in Last Mile Delivery

Last mile delivery in urban areas is faced with different obstacles that have serious environmental and societal consequences. One of these issues is congestion that has impacts on travel times, consumption of fuel, and reduces the efficiency of public transport (Ranieri et al. 2018). Congestion does not just cause physical issues, but it also has a negative impact on the quality of air and the health of the public. The longer the congestion time takes, the more likely that negative consequences will result from it. The presence of more vehicles on the road leads to an increased fragmentation of last mile deliveries (Browne et al. 2017). This in turn results in traffic, air pollution, wastage of resources, and difficulty in delivering parcels efficiently (Weekes, 2020).

To solve this problem, scholars have come up with solutions like the use of micro mobility like cargo bicycles and autonomous delivery. Cargo bicycles are versatile, and they provide efficient delivery of goods in populated areas with no emissions (Pan et al. 2021). Autonomous delivery also has the potential to reduce congestion. However, it has limited battery capacity and cannot deliver more than its range (She and Ouyang, 2021).

Another challenge is the increase in the consumption of energy. The transportation sector significantly contributes to global energy consumption and research has proposed the replacement of petroleum energy with electrical energy and other means such as micro mobility has been suggested in order to reduce the increase in energy consumption (Banyai, 2022). Also identified are electric vehicles which are largely viewed as promising solutions to reduce energy consumption by approximately 87% (Banyai, 2022). However, high costs, limited charging, and degradation of batteries are all issues making the use of electric vehicles inefficient (Quak et al. 2016). Additionally, the production process of electric vehicles produces emissions which are mostly ignored when sustainability practices are talked about.

The emission of greenhouse gases is another critical last mile delivery challenge. The transportation sector contributes largely to greenhouse gas emissions. As a result, decarbonisation is essential to manage the effects of greenhouse emissions on climate and environment (Mazzoncini et al. 2021). Transitioning to electric vehicles, use of autonomous delivery, and use of cargo bicycles can help in the reduction of greenhouse gas emissions (Iwan et al. 2021; Pan et al. 2021). In addition, initiatives like the goal of the European council to reduce emissions by at least 55% by 2030 and achieve climate neutrality by 2050 (OECD, 2018) are very important in solving this challenge.

High cost of traditional delivery methods is another challenge facing last mile delivery. In a case study from Finland, delivery costs were found to range from 2€ to 6€ per delivery depending on the density of the area (Mohammad, 2022). The expensive nature of last mile delivery makes up 41% of total supply chain expenditures (Mohammad, 2022). This is more than twice any other category of expenditure, placing significant pressure on firms. This, combined with the growing demand for quick and flexible delivery alternatives, puts additional pressure on delivery companies to streamline their routes and cut costs.

Another difficulty is the uncertainty and unpredictability of last-mile delivery. Delivery drivers encounter concerns about allowed parking spaces, correct client addresses, and customer availability, resulting in unsuccessful deliveries and higher prices. Studies have found that between 12% and 60% of first-time deliveries fail due to consumers being away for extended durations (Siegfried & Zhang, 2021).

The rise of e-commerce has also resulted in an increase in the volume of delivered items, with many online firms and shops providing next-day or same-day delivery. This has put tremendous time pressure on last-mile delivery activities, which must meet extremely tight schedules. The volume of online orders for deliveries varies throughout the week and year, making it difficult for delivery businesses to manage their resources efficiently.

Furthermore, the ageing urban workforce has resulted in a shortage of staff in parcel delivery, a physically demanding job (Bogue 2024). This, combined with the increased demand for quick and flexible delivery alternatives, makes it difficult for delivery companies to recruit and retain staff.

Another difficulty is the growing demand for speedier delivery, which puts pressure on logistics service providers to deliver items swiftly and reliably in small batches (Siegfried, 2014). This has led to a substantial increase in direct house delivery of smaller items, making it one of the most difficult tasks for logistics fast delivery businesses (Aranko, 2013).

Another big obstacle is the "not-at-home" problem, which occurs when many home deliveries fail because customers are not there, resulting in items being left at parcel shops or depots (Siegfried & Zhang, 2021). This leads to longer delivery times and more environmental hazards.

The lack of urban logistic infrastructure is also a big barrier, especially in high-rise buildings without lifts, making parcel delivery inefficient (Browne et al. 2017). This can result in longer delivery times, higher expenses, and physical and mental stress for parcel delivery workers (Schaer, 2018).

Parcel deliveries' workloads have increased significantly in recent years, with couriers delivering more items than ever before (FORBA, 2018). However, the cost of transporting them has not risen, putting pressure on delivery companies and package carriers (Schaer, 2018).

2.5 Integration of Micro Mobility in Urban Transportation Network and its Challenges

Even though it seems promising, micro mobility cannot be the only kind of transportation mode. Consequently, it is imperative to comprehend the potential for its integration into the entire urban transportation system. The establishment of specialised infrastructure is regarded as a critical policy to promote modes like cycling to guarantee a successful integration (Kraus and Koch, 2021). Infrastructure for micro mobility may facilitate this integration. Bicycle infrastructure comes in a variety of forms, such as cycle tracks, off-street bike paths, painted buffer lanes, contraflow cycling lanes, and conventional bicycle lanes (Zhou, 2022). Nevertheless, many cyclists are compelled to ride in the main lanes with mixed traffic since infrastructure has not kept up with user demand (Zhou, 2022). Dedicated bike lanes that link nearby towns and bus or subway stations could promote the usage of public transport and micro mobility among commuters (Cui and Zhang, 2024). By utilising integrated shared micro mobility and public transportation, it would encourage a modal shift without necessitating the large capital expenditure of a more comprehensive network of dedicated bicycle lanes. Cui and Zhang (2024) cite several examples of shared micro mobility parking at public transit hubs, protected micro mobility lanes that connect to transit hubs, and facilities such as covered parking, bicycle lockers, and e-bike charging at public transit hubs.

In the California Bay Area, Ferguson and Sanguinetti (2023) investigated how micro mobility was integrated with public transport. The authors pointed out that repurposing outdated technologies, such as bike racks and a rule requiring cars to be locked to them (or gates, lampposts, etc.), is the key to ensuring the seamless integration of micro mobility into public transport. It was reported that the Bay Area Rapid Transit (BART) has reinstalled "old wave style" bike racks outside of stations after removing them from storage since they weren't particularly effective for bikes. These are simple and quick to install. Undoubtedly, prior to the alterations in the research area, automobiles had to be locked, and many scooters were tossed into a lake (a geofencing approach was also employed to prohibit lakefront parking). A related ordinance established by Oakland is a ten-cent fee for parking a shared micro mobility car in a parking metre zone (Ferguson and Sanguinetti, 2023). This suggests that the development of infrastructure and parking restrictions, which are characteristics of public transport, can be helpful in integrating micro mobility.

The challenges that may arise in the integration of micro mobility with mass transit are of great concern. A study conducted by Milovanović et al. (2023) focused on the difficulties of incorporating micro mobility vehicles into contemporary transportation networks. The preference city authorities have for bicycles over other micro mobility modes is one of the issues noted. Although some towns have made investments in the infrastructure for bicycles, other micro-mobility vehicles, such as e-scooters and e-bikes, sometimes lack such infrastructure, which causes problems with other road users, cars, and pedestrians. Second, the use of micro-mobility vehicles has become inconsistent and confusing due to a lack of clear rules and regulations. This covers inquiries about using sidewalks, wearing helmets, and posted speed limits. The authors also mentioned the need for efficient monitoring and education programmes to guarantee user adherence to policies and guidelines.

Among all the difficulties, parking and storage-related problems as well as visual clutter in public areas are the most crucial. According to Laa and Emberger (2020), the visually arresting colourful dockless bicycles and careless parking have a detrimental effect on the cleanliness of the public area. To address the issue of incorrect parking in shared micro-mobility, various policies and management techniques are implemented. According to Shaheen and Cohen (2019), communities should implement laws that promote e-scooters being parked on private land, like the bike or automobile parking spots that residential developers supply. According to Laa and Emberger (2020), cities must remove damaged or illegally parked bicycles (for example, 129 shared bikes were removed from Vienna between September 2017 and June 2018, 134 bikes were removed from Melbourne between mid-October 2017 and the end of May 2018, and more than 10,000 bikes were removed from Xiamen in January 2018). According to Guo and He (2020), operators must frequently move dockless bikes in order to maintain a quick search time for bikes and reduce the issue of cluttering because of the temporal and spatial variance in their use. Shaheen and Cohen (2019) suggest stricter parking laws exclusively in situations when micro mobility obstructs pedestrian or disabled person access. These papers, without disagreements, suggest that clear policies must be put in place to encourage responsible storage and use of micro mobility in urban environments. This is entirely up to the cities to make provision for infrastructure that can accommodate micro mobility vehicles. Without exception, these studies recommend that explicit regulations be implemented to promote appropriate micro mobility use and storage in urban settings.

The responsibility of providing infrastructure suitable for micro mobility vehicles rests solely with the cities. Helsinki City for example has adopted some of these by introducing MPZs (mandatory parking zones) within the core city areas to tackle the challenge of visual clutter posed by free floating parking . There are also fleet caps to deal with over-clustering, introduction of slow speed zones in areas with high pedestrian presence, and a ban on e-scooter riding during the early hours of the weekend aimed at addressing the issue of intoxicated riders.

Vasara et al.'s (2022) study of characteristics and costs of electric scooter injuries in Helsinki, showed that, in total, 201 (45%) of patients were reported to be intoxicated by alcohol at the time of their injuries. The effect of intoxication was emphasized during night time as 75% of the patients injured between 00.00 and 5.00 were reported to be intoxicated.

Requiring greater focus is the question of safety. From the different modes of micro mobility, e-scooters seemed to have attracted the most concern in this respect. Shichman et al (2022) established a significant 6-fold rise of e-scooter injuries per month sustained by patients following the launch of shared e-scooter services in Israel. E-scooters revolutionised transportation patterns and gained considerable popularity following their introduction in 2018, with reportedly millions of rides in the first 2 years.

Figure 1. Flow chart of inclusion and exclusion criteria Helsinki (Vasara et al 2022).

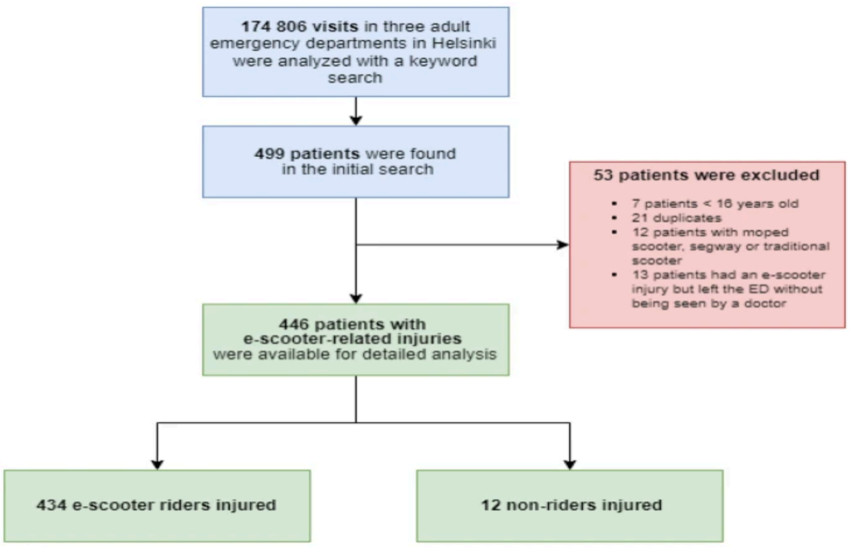
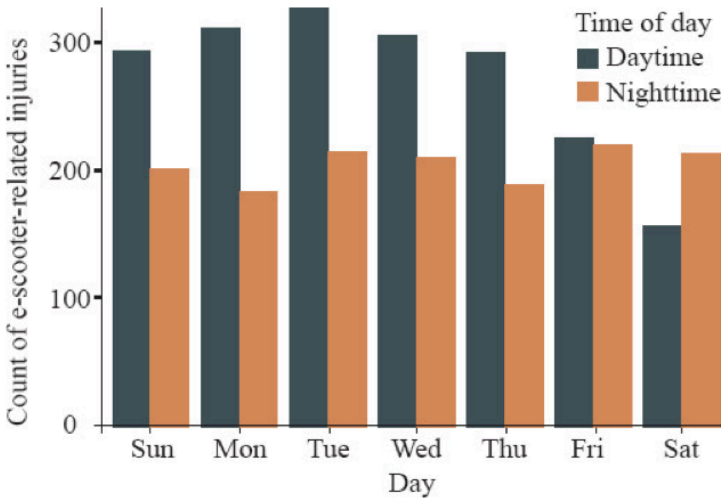


Figure 2. E-scooter related injuries in Israel by day of the week and time of the day is divided into daytime (6:00-18:00) and nighttime (18:00-6:00) and represented by colors (Shcihman et al, 2022).



Results have shown higher rates of injuries during the weekdays and during the afternoon hours when commuter traffic is usually more substantial and daylight reduced. The implication of these findings are that e-scooter use has been transformed from a recreational activity to an everyday primary commuter vehicle, making it imperative that each municipality should investigate the local characteristics of e-scooter usage in order to promote the appropriate policy for increasing safety (Shichman et al, 2022). Higher injury rates were noticed during the late-night hours during weekends which can be attributed to riders returning home after social events possibly involving alcohol consumption. Most injuries were also sustained during the summer months probably due to a high volume of usage during favorable weather conditions. In the case of Helsinki, a notable research finding established that most accidents happen during weekends and night time. Unfortunately as was the case in other publications, a greater portion of the patients were also intoxicated during these times (Vasara et al, 2022).

The total cost of hospital care (Figure 1), including ED visits, imaging, and follow-up visits, was approximately 866 889 €. A median of 1059 € (IQR 296–1966 €) was billed per patient. Based on physicians' statements, a total of 13.5 years (4928 days) of sick leave was prescribed for 178 patients. Of those affected, the median length of sick leave was 14 days (IQR 5–38 days). In total, this inflicted an estimated 284 047 € of expenses for the employers and 561 464 € for the Social Insurance Institution of

Finland. Including the cost of the hospital care and follow-up and the prescribed sick leaves, the cumulative cost of the e-scooter injuries was approximately 1.71 million euros, with a median cost of 1148 € (IQR 399–4263 €) per patient (Vasara et al, 2022). The cost analysis clearly shows that for e-micro mobility to be considered as a preferred sustainable logistic mode in a smart city, the challenge of safety must be tackled head on.

A takeaway from these publications suggests that injuries from e-scooters as a mode of micro mobility can be improved through well-defined policies and legislation as these apply to local consumer behaviours. This type of report and its findings for example have prompted the adoption of nighttime shutdown legislations during the weekend for e-scooters in Helsinki. Low speed zones have also been implemented especially in areas with heavy pedestrian presence reducing the travel speed from 20 km/hr to 12 km/hr.

Analyzing the research further, the most common type of injury was rider fall. This may be attributed to lack of proper infrastructure, lack of rider experience and optional license (Shichman et al, 2022). Nearly one-half of injuries recorded happened amongst pedestrians in the over 60 years age group. An issue that can be possibly related to e-scooter use on sidewalks for lack of separate bicycle lanes. According to Bloom et al (2021), a study from the department of surgery, division of trauma and critical care Los Angeles, CA, USA, 36% of e-scooter injuries have occurred on the street, 17% on the sidewalk as compared to a single accident requiring emergency admission happening on the bicycle lane. Policy & legislation, technological improvements on devices, collaboration with cities on educating the users and citizenry, and improved infrastructure can help in solving the major safety challenge attributed to micro mobility.

Further research and data gathering to check the adoption of these actions as possible solutions to the challenge of safety show promise. According to MMfE, Micro Mobility for Europe (2024), in 2023, the number of shared e-scooter and e-bike injuries has continued to fall. This improvement has been achieved thanks to different factors. Technological innovations enabled operators to deploy newer models while at the same time, operators and cities have invested in education campaigns while cities have taken action to improve infrastructure. In comparison with 2022, the number of all reported injuries per million trips declined by 44% for shared e-scooters. With regards to the number of incidents requiring medical treatment and fatal injuries, incidents dropped by 19%. The trend for shared e-bikes is similar, as the number of reported injuries per million trips declined by 39% while the number of incidents requiring medical treatment and fatal injuries dropped by 16% (MMfE, 2024). When comparing different transport modes, MMfE data shows that the risk of injury requiring a medical treatment while riding an e-scooter is slightly lower than with driving an e-bike, 3.3/million km and 3.9/million km for e-scooters and e-bikes respectively.

2.6 Further Review of Literature on Smart Cities

Because this thesis studies last mile mobility specifically in a smart city context, the smart city concept itself requires deeper consideration. The phrase “smart city” lacks a specific definition, but it can be defined through distinct characteristics. Giffinger et al. (2007) defines it using six characteristics, namely: smart economics, smart mobility, smart governance, smart living, smart environment, and smart people.

Vanolo (2013) in his research established that smart cities are governed by theories such as Smart Growth and Intelligent Cities. Smart growth encourages development long-term, while intelligent cities prioritise the integration of technology into urban infrastructure and administration. Corporations such as IBM and Cisco have sufficiently contributed to the development of smart cities by the integration of ICT solutions in urban initiatives (Vanolo 2013).

In Europe, the concept of smart city became popular due to EU funding projects like the European Innovation Partnership on Smart Cities and Communities. Countries like Italy have also invested in smart city projects that portray the value of technology and innovation in addressing urban issues (Vanolo, 2013).

Saunders & Baeck (2015) define a smart city as a city with efficient management, with a city-wide sensing network offering real-time and integrated data on the status of services, infrastructure, and energy flows. This data can be used by city management to improve services, monitor resource use, and predict future challenges using predictive analytics.

Smart cities promote the development of economies using infrastructure that allows local businesses to experiment and succeed in technology, making them worldwide leaders in the trade of advanced technologies to other communities. According to Saunders & Baeck (2015), smart cities are perceived as prestigious, as political leaders make efforts for their towns to be run like smart cities, making them part of the most sought-for locations for both businesses and individuals. Smart cities emphasise the importance of technology, efficient management, economic growth, and prestige as important aspects of the smart city vision, providing a background for sustainable urban development and innovation in the twenty-first century.

Colding & Barthel (2017) recognize smart cities' entrepreneurial and technological nature, which attempts to maximise the control of municipal systems while placing individuals at the centre of urban developments. Smart city technologies make use of smart technologies and the Internet of Things (IoT) to serve social and civic duties, with the goal of producing positive feedback interactions between humans and technology.

The authors note the interest of ICT industries and major vendors in capitalising on the developing Smart City market to create solutions that improve the efficiency of inhabitants and quality of life. It addresses the use of big data in urban planning and development, focusing on its ability to promote informed involvement and create more democratic forms of city governance.

However, the authors highlight the challenges and uncertainties associated with the execution of Smart City efforts in terms of developing a comprehensive IoT network and selecting best practices for urban development.

Boysen et al. (2020) emphasise the issues of last-mile distribution, particularly in cities. They highlight various creations and problems that add to the complexity of the logistics operation. Urbanisation and e-commerce have resulted in an influx of demand for last-mile delivery services. This trend is fueled by migration into megacities and the parallel increase in e-commerce that has consequently increased the number of parcels to be delivered.

The environmental impact of delivery vans moving into urban areas has increased concerns about the sustainability of last-mile delivery. As a result, there is an increase in the quest to implement sustainable and environment-friendly operations that are governed by laws that promote methods that do not cause harm to the environment. Traditional van-based delivery systems result in large expenses due to issues such as traffic congestion and delivery failures. To solve this problem, other delivery concepts such as unattended delivery or customer self-services are being analysed to determine if they are cost-effective solutions.

Furthermore, the timing constraints related to e-commerce's promise of next- or same-day deliveries provide a significant barrier for last-mile delivery operations. Scalable delivery strategies that can adapt to changing workloads are crucial for achieving customer expectations. Finally, the ageing workforce in many industrialised countries makes it harder to find candidates for physically demanding parcel delivery positions. Automation and alternative delivery concepts, such as autonomous delivery robots or drones, provide realistic solutions to labour shortages while ensuring consistent and competent delivery services.

Comi & Polimeni (2024) examine the concept of micro mobility, which refers to the use of lightweight vehicles designed primarily for human transportation on paved roads and trails. According to the authors, there is no widely accepted definition of micro mobility. Different organisations provide different definitions, mainly based on vehicle weight, design speed, and power source. Despite the lack of agreement on its definition, micro mobility has the potential to promote sustainable transportation with low environmental impact.

According to the authors, research has highlighted the potential benefits of micro mobility in encouraging sustainable forms of transportation, as well as the difficulties associated with its implementation. Cultural, legal, political, and economic impediments can all slow the transition to eco-friendly mobility. Furthermore, they claim that life cycle studies have been done to study the environmental performance of micro mobility, with mixed results in terms of emissions reduction potential.

City authorities and legislators are becoming more interested in incorporating micro mobility into urban transportation planning. Initiatives such as sustainable urban mobility plans (SUMPs) and proposals for incorporating micro mobility into urban mobility planning aim to solve operational issues like safety, public space utilisation, and traffic control.

Coli and Polimeni’s major purpose was to establish a mechanism for identifying private vehicle routes that are compatible with micro mobility and assessing the prospective demand for micro mobility as a substitute for private automobile travel. The technique tracks private car travels that could potentially be replaced by micro mobility using telematics and GPS-based applications.

Establishing this mechanism helps smart cities in promoting multimodal transportation systems where private vehicles, public transport and micro mobility options are integrated thereby allowing commuters choose the most efficient and sustainable mode for each leg of their journey. Data collected from private vehicles, micromobility modes and public transport systems provides valuable insights for urban planners to optimize infrastructure, regulate traffic flow and allocate resources effectively. In all, private vehicle routes and micro mobility are important features of smart cities, if well managed, they can work together to create a more sustainable and user friendly urban transportation system. With the aid of technology, data and integrated planning, smart cities can promote micro mobility as a viable alternative for short -distance travel and last mile delivery ultimately leading to improved urban mobility and quality of life.

I believe the definition of a smart city by Saunders & Baeck (2015) essentially captures the characteristics of a smart city as having efficient management, with a city-wide sensing network offering real-time and integrated data on the status of services, infrastructure, and energy flows. The keyword here being ‘real-time’ as this helps in analyzing present trends, managing and improving services and the ability to predict future challenges. This provides clarity not only for the moment or documenting data but for the important purpose of predicting future challenges.

2.7 Analytical Framework of the Study

The analytical framework of this study is centered on exploring the feasibility and ramifications of deploying micro mobility solutions for last mile delivery in urban environments. The framework, which is organized around research questions and objectives, guides the evaluation of critical difficulties in traditional last mile delivery techniques as well as the assessment of potential alternatives provided by micro mobility. Using content analysis as its primary methodology, the study first identifies and examines the difficulties inherent in traditional last mile delivery, such as high costs, traffic congestion, and environmental implications. As a result, several micro mobility modes, such as e-scooters, e-bikes, and small electric vehicles, are evaluated as viable solutions to these difficulties. The investigation digs into the capabilities, benefits, and constraints of each micro mobility mode within urban logistical contexts. Furthermore, the framework examines the benefits and opportunities connected with the use of micro mobility, including increased accessibility, less environmental impact, and enhanced operational efficiency.

3 Methods

3.1 Literature Review Style

A literature review summarizes and interprets literature centered around a particular subject (Baker, 2016). Literature review is carried out by determining the research questions and finding out the answers to the set questions by looking into related research. The analysis of other literature is more likely to provide new information, new focus, and new issues worthy of investigation. All this can only be possible when literature concerning an issue is collectively reviewed. This would enable the collection of bits and pieces of information from different research to form an idea or discover concepts (Aveyard, 2014).

Literature reviews are of different types like narrative review, theoretical review, systematic review, descriptive review, and qualitative review. This research utilizes descriptive literature review to determine the potential of micro mobility in smart cities. According to Paré & Kitsiou (2017) descriptive reviews are conducted in a systematic and transparent manner, including searching, filtering, and classifying studies. Descriptive literature review can also be called traditional or standard literature review. The main purpose of a descriptive literature review is to provide descriptive results through the analysis and interpretation of data to answer research questions (Coughlan & Cronin 2017).

3.2 Data Collection

The research was carried out using two scholarly databases for data search. The research only contains full-text papers in English, articles published during the last ten years (2014-2024), articles considered directly relevant to the issue, and journal articles. The literature search eliminated publications not written in English, papers that are more than ten years old, papers unrelated to the research issue, and papers that have not been peer-reviewed. The use of secondary data is a drawback of this study, but it will be offset by the use of peer-reviewed academic sources to back up the research and data collection using a qualitative technique. Based on the listed requirements, the inclusion and exclusion criteria are presented in the table below:

Table 1. Inclusion and Exclusion Criteria

Inclusion Criteria	**Exclusion Criteria**
English Language	Articles written in other languages
Available free full text	Abstract only articles with unavailable full text
Publications from 2014 - 2024	Articles published before 2014
Articles relevant to the topic	Articles irrelevant to the topic
Journal Articles	Non-journal articles

This thesis makes use of qualitative data collection methods to collect information as the research uses non-statistical sources of information like data from other published research.

A total of one hundred and twenty three articles met the inclusion criteria. Articles not relevant to the research were screened out and this produced thirty four articles. For confirmation of relevance, the abstract of these articles were carefully read through. This brought the final number of articles selected to 8. The search results are detailed in the table below:

Table 2. Summary of Search Results

Database	Keywords	Results Based on title search	Results After Screening out not-relevant Articles	Selected Articles after Screening Abstract
Science Direct	"Benefits of micro mobility"	9	2	1
Google Scholar	"Challenges in last mile delivery"	37	19	4
Google Scholar	"Benefits of micro mobility"	43	10	1
Google Scholar	"Micro mobility and last mile delivery"	34	3	2

3.3 Data Analysis

This stage gathers all the selected data for review using content analysis. Content analysis is a research technique that allows researchers to infer meaning from text and other materials based on their context. It facilitates a thorough understanding of the research data being evaluated. The content analysis process is divided into three phases: preparation, organization, and reporting. The preparation step is where the unit of analysis, which can range from words to whole articles depending on the research topic, is defined. The data is then structured and evaluated so that the information can be better understood.

The following step is the organizing phase, which includes open coding, creating coding sheets, grouping and categorizing comparable material, and abstracting results. Open coding allows researchers to locate and classify relevant information or themes within the data being analyzed. They then collect and modify the codes to establish more intelligible categories, so streamlining the process and clarifying the findings. Next, the data is abstracted to provide a clearer picture of the research findings.

The reporting phase includes data analysis and presentation. To avoid conveying incorrect findings, data must be carefully analyzed. The data is evaluated using the research questions mentioned earlier, and the observed outcomes are also explained.

Content analysis will be used in this study because it is an effective approach to synthesizing literature. The researcher will follow the processes required to conduct a thorough content analysis of the literature and use them to answer the research questions. Therefore, only research papers that can answer the research questions will be included.

The first step taken for the data analysis process was carefully reading the selected articles. Next, coding was attempted and the codes were ground. This was done repeatedly to ensure that no piece of information has been overlooked. The findings were grouped into generic categories as shown in the table below:

Table 3. Categories of information from micro mobility and smart cities research

Open Coding	Generic Categories
● Traveling distance ● Emissions ● Costs ● Traffic ● Time pressure ● Sustainability	Challenges in last mile delivery
● Accessibility ● Stimulation of physical activity ● Reduction of emissions ● Enhancement of human experiences ● Reduction of accidents ● Reduction of traffic	Benefits of micro mobility
● Perceived safety ● Traffic and congestion reduction	Potential of micro mobility in last mile delivery

● Sustainability	

Eight articles were picked to be analyzed to answer the research question. Each article had different perspectives; however, they are generally focused on micro mobility. Several results from the assessment of the potential of micro mobility in last mile delivery will be presented by three generic categories in chapter four.

4 Results and Analysis

4.1 Challenges in Last Mile Delivery

The traveling distance of customers is recognized as one of the major issues encountered in last mile delivery (Eliyan et al. 2021). Customers and retailers may need to travel long distances to be able to receive and deliver parcels respectively. This may result in the retailer consolidating parcels to the lowest number of delivery stations to reduce the distance travelled for the retailer and possibly for the customer as well (Eliyan et al. 2021).

The retailer’s transportation and the vehicles of the customers also result in carbon emissions which can damage the environment. As customers drive long distances using individual cars to pick up parcels, this increases the amount of carbon emissions they release into the air (Eliyan et al. 2021). Eliyan et al. (2021) observed that the carbon footprint per parcel delivery increased with retailer travel distance and the travel distance of the customers.

The cost of delivery is also a great challenge in last mile delivery. High cost of delivery is because of factors such as fuel consumption, traffic jams, and vehicle maintenance costs due to poor road conditions (Mogire et al. 2022). This results in high charges by transport service providers, sometimes resulting in the delivery charges exceeding the product price.

Traditional delivery transport adds to the cost of delivery as delivery vans are priced at 2 – 6 €, depending on the density of the area (Boysen et al. 2021; Mohammad et al.

2023). Also, congestion in traffic and lack of parking on busy streets also contribute to the price of delivery cost (Boysen et al. 2021; Mohammad et al. 2023). Delivery drivers may also encounter uncertainty over allowed parking spaces, correct customer addresses, and customer availability, resulting in unsuccessful deliveries (Boysen et al. 2021; Mohammad et al. 2023). Solutions like unattended deliveries and collection of packages by customers themselves can help in the reduction of delivery costs (Boysen et al. 2021; Mohammad et al. 2023).

According to Mogire et al. (2022), traffic concerns present a significant obstacle for retailers providing last mile delivery services. The main reasons for traffic congestion include continuing road construction, rain, and afternoon rush hour, all of which cause product delivery delays. This emphasizes the importance of effective traffic management and alternative delivery alternatives in reducing the impact of traffic on last mile delivery.

The growth of e-commerce has resulted in an increase in parcel deliveries, making businesses and retailers aim to provide same or next day deliveries (Boysen et al. 2021; Mohammad et al. 2023). Due to this, last mile delivery operations now have tight deadlines that must be met, with fluctuating workloads throughout the week, and Mondays having the highest number of deliveries daily and yearly as a result of seasonal sales (Boysen et al. 2021; Mohammad et al. 2023). To address these issues, there must be flexibility in last mile delivery approaches if deadlines will be met (Boysen et al. 2021; Mohammad et al. 2023).

According to Boysen et al. (2021) the rising demand for urban parcel delivery has resulted in an increase in delivery vans entering city centers, putting additional burdens on infrastructure, congestion, causing negative impacts on health, environment, and safety. To address these issues, there is a growing need to ensure the practice of sustainable and environmentally friendly operations, motivated by increasing customer awareness and governmental legislation (Boysen et al. 2021). For demonstrative purposes, regions like British Columbia (2019), have put policies in place that allow single-person electric vehicles to use high-occupancy vehicle (HOV) lanes, which could motivate courier services to electrify their delivery transport and have access to urban areas faster through uncongested HOV lanes (Boysen et al. 2021).

4.2 Benefits of Micro Mobility

Micro mobility modes can increase accessibility through reaching destinations that are nearby which may be longer if one took a walk or even rode a car in the presence of congestion (Milakis et al. 2020). Micro mobility, for example the use of dockless bike-sharing systems, will also allow connection to and from public transport (Milakis et al. 2020). Micro mobility modes may also help to increase mobility and participation in social life for the elderly or physically disabled persons who cannot drive a vehicle (Milakis et al. 2020).

Micro mobility modes can stimulate physical activity for the passenger, impacting their mood and allowing them to enjoy the environment and have fun riding the mode (Milakis et al. 2020; Olabi et al. 2023). The physical activity derived from micro mobility can contribute to elevated mood, relaxation, and reduction of anxiety. It can also encourage and increase communication with others, allow them access to meaningful activities, especially those with medical and financial restrictions that otherwise limit mobility (Milakis et al. 2020; Olabi et al. 2023). Also, micro mobility modes can enhance the sense of autonomy riders and passengers feel in traveling (Milakis et al. 2020).

Micro mobility modes may also change travel behavior if they are safe and pleasurable (Olabi et al. 2023). Micro mobility modes like e-bikes, e-bike sharing, and e-scooters are perceived as interesting modes of transportation. In addition, e-bikes are on high-demand as they are enjoyable and can assist people with physical disabilities (Olabi et al. 2023). Micro mobility modes also help users overcome obstacles, save time, avoid lengthy trips and access high quality air.

Micro mobility modes have significant environmental benefits, such as low or no direct CO_2 emissions and reduced pollutants (Milakis et al. 2020; Olabi et al. 2023). Studies have demonstrated that micro mobility modes, such as e-scooters, can reduce CO_2 emissions when compared to regular combustion-engine vehicles (Milakis et al. 2020). Furthermore, micro mobility modes can replace car trips, with an estimated 30% replacement rate (Milakis et al. 2020), resulting in lower vehicle use, kilometers traveled, and emissions. The efficiency of MM modes, which use less energy and weigh less than larger vehicles, contributes to the environmental benefits (Olabi et al. 2023). Micro mobility modes are especially suitable for short travels, with average trip distances ranging from 0.40 to 1.86 miles (Olabi et al. 2023).

The use of micro mobility can help reduce traffic, greenhouse gases, and noise pollution (Olabi et al. 2023). With the increasing number of vehicles daily, most societies are aiming at the discovery and implementation of changing the mode of transport of people to modes that do not demand a lot of energy, like walking and cycling. Electric micro mobility vehicles are seen as environmentally friendly transport alternatives for short trips within cities as this has the potential to reduce traffic (Olabi et al. 2023). E-scooters, for example, are perceived to be capable of reducing the percent of trips taken with taxis in major cities (Olabi et al. 2023). This is an indication that micro mobility modes can reduce the dependence on bigger transport alternatives for movement within cities. The only issue with electric mobility modes is that they cost higher for longer trips (Olabi et al. 2023). This means that although electronic mobility has several benefits, there is a need to come up with an alternative transport solution for public transportation. This can be resolved by using short roads to nearby bus stops (Olabi et al. 2023). This will enable the reduction in the use of transport modes that contribute to emissions.

4.3 Potential of Micro Mobility in Last Mile Delivery

Safety is critical in urban transportation, and perceived safety has a substantial impact on route selection for micro-mobility modes such as e-scooters. The lack of dedicated infrastructure for active modes in cities such as Athens, Greece, causes substantial safety issues, resulting in low e-scooter and bicycle utilization rates (less than 2%). Perceived safety evaluations suggest that linkages with bike lanes and good pavement conditions receive high safety scores, which is consistent with literature findings (Tzouras et al. 2023). However, for each study scenario, perceived safety models should be re-calibrated to appropriately represent citizens' safety perceptions (Tzouras et al. 2023).

Transport planners can utilize the established perceived safety models as a decision-making tool to identify geographical discontinuities in the road network and evaluate the success of sustainable mobility interventions. These methods aim to balance perceived safety levels while prioritizing active modes and micro-mobility, resulting in a more equitable distribution of urban space. Implementing measures such as cycling lanes, shared spaces, and traffic calming areas can increase felt safety for e-scooter users and pedestrians while decreasing perceived safety for automobile drivers (Tzouras et al. 2023).

Perceived safety influences route selection for urban transportation modes, having important implications for micro-mobility modes such as e-scooters. In contrast, car drivers have higher perceived safety levels and are less inclined to detour (de Olivera et al. 2017). In contrast, e-scooter riders experience considerable safety discontinuities and are more likely to prioritize perceived safety while selecting routes. This is especially relevant in diverse road conditions, where micro-mobility modes are challenged (de Olivera et al. 2017). Previous research has demonstrated that disregarding the road environment in utility functions can result in differences between real trajectories and model outputs (de Olivera et al. 2017). The created approach addresses this issue by reducing diversions and offering safe alternate paths with minimal overlap. However, for walking, the model is only effective in establishing pedestrian-safe pathways in specific scenarios, indicating the need for additional development to balance perceived safety levels and avoid harmful walking discontinuities (de Olivera et al. 2017).

According to scientific literature, employing smaller vehicles for last-mile deliveries in cities, such as bicycles, tricycles, motorcycles, and light commercial vehicles, is a more sustainable and efficient option. This is owing to the obstacles provided by traditional truck deliveries, including traffic demands, land use restrictions, and geographical/historical considerations (Tzouras et al., 2023).

4.4 Discussion

This research reveals that micro mobility modes, like e-scooters and bicycles, can be very beneficial for last mile delivery in cities. Traditional delivery methods are often challenged by traffic, congestion resulting in struggles to find parking spaces, and harming the environment through emission of greenhouse gases. However, micro mobility offers a faster, greener, and more flexible solution.

The use of micro mobility for last mile delivery has many benefits, including reducing traffic congestion, cutting down on emissions, and speeding up delivery times. Also, these vehicles are small enough to navigate through narrow city streets and alleys with ease. The application of micro mobility is wide, from parcel delivery to food delivery and logistics.

However, there must also be consideration of the challenges and consequences of adopting micro mobility for last mile delivery. For example, there is a need to ensure the safety of riders and pedestrians, adapt infrastructure to support these new vehicles, and ensure that delivery operations are fast, convenient and effective.

Content analysis was used to analyse the eight articles chosen. The results were found to answer the general research question of the thesis which is “How can micro mobility be used as a solution for last mile delivery in cities and what are the consequences of this strategy?”

Three generic categories were discovered from the papers and used to describe micro mobility and last mile delivery. It is evident that micro mobility has the potential to solve last mile delivery issues and also provide benefits to the environment and society. It is safe, sustainable, and helps in the reduction of congestion and emission which are all very important to urban and smart cities. However, it is very important for their disadvantages to be addressed through scientific research.

4.5 Ethical Considerations

The author understood and applied all necessary ethical considerations to this research. The research is guided by the ethical principles of the Finnish Advisory Board on Research Integrity and Helsinki Declaration. According to TENK, (2019) the ethical principles of research, particularly in humanities and social and behavioral sciences are divided into three areas, namely: respect for autonomy, avoidance of harm, privacy and protection of data.

This thesis is beneficial as it provides beneficial information to solve delivery problems in cities. It also provides recommendations for the implementation of this information in real-life scenarios. This thesis does not pose harm to society or the community. It has reviewed information based on relevant scientific publications that have been properly cited and referenced. All published books and articles used in this thesis have been quoted according to the guidelines of Metropolia University of Applied Sciences.

5 Conclusion and Recommendations

5.1 Conclusion

The purpose of this research was to find out the potential of integrating micro mobility into smart cities to solve the problem of last mile delivery. The research sought to find out the methods through which micro mobility can be used to overcome the barriers involved in last mile delivery, investigating the consequences of this strategy. The research made use of content analysis applied to scientific literature to analyze carefully selected sources addressing the challenges, benefits, and potentials in the use of micro mobility for last mile delivery.

The research found out that the problems of traditional last mile delivery methods include but are not limited to long distances, high cost of delivery, traffic congestion and emissions, among others. These challenges hinder the efficiency of last mile delivery and contribute to environmental damage which harms cities and their inhabitants. Micro mobility offers a lot of advantages such as accessibility, reduced emissions, and increased mobility.

Also, the research explains how the use of micro mobility modes, ranging from electric scooters to bicycles, can be used for last-mile delivery operations through the provision of alternatives for traditional delivery methods. It is also important to acknowledge that although promising, micro mobility has some concerns including safety concerns and operational limitations which must be addressed in order to make it fully effective.

5.2 Recommendations

Based on the results of this research, the following recommendations can be considered by authorities of smart cities in order to ensure the effective solution of last mile delivery through micro mobility.

- Replace all possible delivery trips with micro mobility:

Research indicates that replacing car trips with bikes can help save energy of about 90.3 million joules per capita (Fan & Harper, 2022). Kou et al. (2020) quantified the environmental benefits of bike share trips and compared the level of reduction of emissions. The results reveal that the emissions reduced by 41 tons to 5,417 tons and 283 to 58g per trip. Therefore, if all delivery trips are replaced with options like bikes and other micro mobility modes, energy could be saved, and emissions could be reduced. Smart cities should consider the use of micro mobility as an alternative.

- Creation of Micro Depots

The use of micro depots for delivery could be implemented to improve the efficiency of micro mobility and the accessibility of goods for delivery. This can involve creating predefined routes for the micro mobility (Veličković et al. 2023). Since traffic and free parking spaces cannot be predicted, it would be difficult to estimate the delivery time (Veličković et al. 2023). The presence of micro depots would serve as local depots and they should preferably be set up in areas where delivery is high. Micro mobile vehicles would be able to utilize this delivery innovation for the delivery and dispatch of goods.

- Investment in Infrastructures

Smart cities must consider investing in infrastructure that can support the implementation of micro mobility for deliveries. Creating lanes dedicated for bikes alongside safe lanes for pedestrians, and designated parking areas for micro mobility vehicles can be considered as well. The creation of infrastructure will improve the safety of pedestrians as well as micro mobile vehicles and the delivery providers.

- Use of incentives

In order to encourage the adoption of micro mobility, cities should offer incentives for delivery businesses to make use of micro mobility for delivery due to its promising potential of supporting a green earth. This will encourage businesses to prioritize sustainable mobility, hence solving the problem of emissions caused by traditional methods of delivery.

- Legislation

Adoption of tailored policies and legislation. Awareness raising and education campaigns.

5.3 Limitations

This research is limited by a few factors. First, it was very difficult to find specific studies that conducted research on “micro mobility and smart cities.” A better approach to this study would be a quantitative or qualitative study to help researchers better comprehend the potential micro mobility in smart cities. Therefore, future studies could research this topic focusing on primary research.

The findings of the study show that reduction of traffic congestion, cutting down on emissions, and speeding up delivery times are the advantages of micro mobility. It was discovered that the application of micro mobility is wide, from parcel delivery to food delivery and logistics. However, future research could consider how much the negative consequences of micro mobility could restrict its success in smart cities. For example, they could find out if rider and pedestrian safety considerations would deter people from using micro mobile vehicles.

The study also explains how micro mobile vehicles can be used for last mile delivery operations. However, since micro mobile vehicles are small, future studies could investigate if they can be used for freight delivery. All these must be addressed in order to establish the viability of micro mobility in smart cities.

Additionally, the concept of smart cities extends to the use of technology. Therefore, future research can investigate how smart cities can make use of technology to make micro mobility work. For example, they could investigate if the issue of short-life span of batteries in electronic micro vehicles could be solved through the introduction of charging stations and how these vehicles can still be on time even with the time spent during charging.

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Appendices

Summary of Research Used

Name of Researcher(s) and Date	Title of Research	Objectives	Findings
Boysen et al. (2021)	Last-mile delivery concepts: a survey from an operational research perspective	The research's aim is to analyze both current and novel last-mile concepts, focusing on the choice difficulties that must be handled when establishing and operating each concept.	The concepts require a lot of extra R&D effort to technically bring them to a market-ready level, as well as a lot of research on operations research approaches to support an efficient use of these delivery concepts.

de Olivera et al. (2017).	Sustainable Vehicles-Based Alternatives in Last Mile Distribution of Urban Freight Transport: A Systematic Literature Review	The purpose of the research is to identify, through a systematic literature review, the primary types of vehicles that could be utilized in the last mile of urban freight delivery in order to improve the environmental sustainability of this sort of operation.	The results reveal that reducing the size (and capacity) of vehicles used for last mile delivery in urban areas is a more sustainable and efficient choice for urban freight transport.
Eliyan et al. (2021).	The last-mile delivery challenge: evaluating the efficiency of smart parcel stations.	The research analyzed the development of smart parcel stations as a solution to last mile delivery challenge.	The findings suggest that smart parcel stations could be a viable alternative for delivering items in metropolitan regions.
Milakis et al. (2020).	Is micro-mobility sustainable? An overview of	The research provides an overview of	According to the results, deployment of

	implications for accessibility, air pollution, safety, physical activity and subjective wellbeing.	implications for accessibility, air pollution, safety, physical activity and subjective wellbeing.	micro mobility may have a detrimental effect on public transportation utilization, at least for short distances. Furthermore, linked expenditures, physical capabilities, and technical skills may preclude some social groups from employing micro mobility mode.
Mogire et al. (2022).	The Last Mile Delivery Problem: A Kenyan Retail Perspective.	The aim of the research is to find out the problems online retailers face in last mile delivery.	The findings reveal that the problems include The lack of a suitable national addressing

			system, traffic issues, security concerns, high delivery costs, postal service instability, and unfriendly county government bylaws.
Mohammad et al. (2023).	Innovative solutions in last mile delivery: concepts, practices, challenges, and future directions	The aim of the research is to review the latest trends in last mile delivery solutions.	According to the findings, incorporating fresh forms of delivery inside existing distribution systems necessitates significant adjustments. These may involve the relocation of specific facilities or depots, installation of

			recharging stations or robot hubs, adjustments to the infrastructure for the new vehicles, automation in storage, and the necessary adaptations to new requirements for navigation systems.
Olabi et al. (2023).	Micromobility: Progress, benefits, challenges, policy and regulations, energy sources and storage, and its role in achieving sustainable development goals.	The aim of the research is to totally assess micro mobility based on its title under SDG, regulations, policies, and so on.	The results reveal that micro mobility might play a significant role in attaining the SDGs, particularly SDG 3 (Good Health and Well-being), by cutting toxic gas

			emissions and reducing expected traffic accidents.
Tzouras et al. (2022).	Describing Micro-Mobility First/Last-Mile Routing Behavior in Urban Road Networks through a Novel Modeling Approach	The aim of the study is to model e-scooter riding behavior, comparing it to traditional transport modes like using a car and walking.	E-scooter was found to be the least safe option compared to the use of cars and walking.

Appendix 2