Enhancing Last-Mile Delivery Efficiency: A Lean-Based Framework for Sustainable Logistics in the Helsinki Metropolitan Area

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Abstract

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Lean principles' applicability to the increased efficiency and sustainability of Helsinki Metropolitan Area's last-mile delivery networks was explored in this research-based thesis. The study was undertaken to mitigate increasing urban deliverability issues associated with increasing proportions of e-commerce traffic, traffic congestion, and the city's ambitious targets of decarbonization. Particular emphasis was laid on route inefficiencies, coordination problems, physical network utilization, and emissions in vehicle operations that together play a pivotal role in urban liveability and logistic performance. This research tested whether Lean methods, and in particular Just-In-Time (JIT), Kaizen, and Value Stream Mapping (VSM), can overcome such challenges and be implemented in the direction of cleaner and more responsive delivery networks.

The theoretical underpinnings of the study merged Lean thinking in logistics with concepts in sustainable urban freight and theory on innovation and adapted them to the Finnish context. Methodologically speaking, the study was qualitative and grounded on ten semi-structured expert interviews that were analysed thematically during January and March 2025. Lean consultant participants, logistic operators, and representatives of startups were also involved. The study was exploratory and employed a case study methodology to elicit insights situated in actual operational environments. The research was conducted in three phases, namely theoretical basis, empirical data gathering and model development.

The findings revealed that Lean methods can reduce delivery-related emissions, increase operational flexibility, and improve continuous improvement of the services if implemented in parallel with sustainability goals. The outcomes include identification of ongoing inefficiencies in Helsinki delivery networks and demonstration of Lean methods' applicability to urban environments. A five-step Lean-based model was established and recommended to steer pipeline innovation in the future. Outcomes supported the development of a model that can help improve the performance of and meet the goals of both logistic firms and urban development authorities and be added to the general discourse in city logistics sustainability.

Key words
Lean logistics, last-mile delivery, sustainability, urban freight, Helsinki, continuous improvement

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1 Introduction

The city's landscape has drastically changed due to rapid development influenced by urbanization, expansion of consumer goods retailing through the spread of e-commerce, and increased demands towards sustainability. Due to these changes, the last-mile delivery—the terminal segment of the logistics chain from nodes of distribution to end consumers—is among the most critical, expensive, and environmentally demanding aspects of contemporary supply chains (Savelsbergh & Van Woensel, 2016). Streamlining last-mile operations and ensuring delivery operations are lean and environmentally friendly has become a rising necessity for logistics providers across the board.

Principles of lean manufacturing started within production industry contexts have increasingly been adopted with the goal of cutting unnecessary costs and enhancing the effectiveness and efficacy of delivery mechanisms within city logistics networks (Slack, Brandon-Jones & Burgess, 2022, p. 552). Lean philosophy comprises the integration of the elements of: Kaizen (continuous improvement), Value Stream Mapping (VSM), and Just-in-Time (JIT) as a systematic way of looking for and eliminating inefficiencies within the operation of the last-mile deliveries (Protzman, Whiton & Kerpchar, 2018). Application of the Lean principles towards solving the intricate city logistics problems means that the cities can cope with the most significant issues such as congestion, delivery disruptions as well as operational inefficiency through the creation of more sustainable city freight networks.

Last-mile delivery represents a timely environmental challenge, transforming a business logistics problem into a central sustainability agenda. The problem exists at the nexus of multiple global policy platforms: the Sustainable Development Goals (SDGs) of the United Nations (United Nations, n.d.), SDG 11 (Sustainable Cities and Communities), and SDG 12 (Responsible Consumption and Production), each of which enjoin decarbonization and rationalization of city-centered freight networks. Solving inefficiencies of the logistics' last mile has transcended being a question of purely economic solutions towards a social and environmental imperative for integrated, holistic strategies. Lean philosophy and the green mobility strategies of the city offer enhanced operational effectiveness and climate benefits at a world level.

This research-based thesis responds to the intersection of sustainable delivery strategies and the Lean philosophy within the context of the city of Helsinki. Helsinki city's regional infrastructural, legislative, and spatial setting provides a suitable background for unfolding the evolution of new sustainable delivery models. This work aims to develop a replicable and scalable Lean-based

model of last-mile delivery designed according to Helsinki's infrastructural and policy environment. The proposed concept should contribute both at the level of local planning practice and to the European climate-optimized logistics discussion with a special focus on economic sustainability, environmental stewardship, and social inclusion.

1.1 Background

Urbanization and the spread of globalization and e-commerce are transforming world supply and logistics. Urban areas are most susceptible because changing consumer demands as well as physical constraints are increasingly subjecting available infrastructure to mounting pressure. Comprising as much as 75 % of logistics expenses, the terminal section of the last mile of delivery between the point of distribution and the end-user remains the most expensive and emission-heavy part of the supply chain, producing significant levels of smog and congestion (Silva, Alho & Fer-nandes 2023). The study analyzes the way cities can effectively manage such changing logistic challenges.

The use of Lean thinking and green logistic methods, which include shared networks of micro-depots, has been observed to increase delivery efficiency, reduce operating costs, and reduce green-house gas emissions in tightly populated urban areas like Helsinki (Rosenberg et al., 2021).These conditions of such a logistics sector include decentralization, high frequency of delivery and space inefficiency, mostly in densely populated urban inner city areas like Helsinki, whose costs of logistics are influenced by constricted alley paths of delivery, zoning irregularities of regulation, weather conditions, and traffic conditions (Rosenberg et al., 2021).

Of Finland's overall CO_2 emissions according to the City of Helsinki (2024a), transport accounts for around 21 %, and of that transport emissions parcel vans that are heavy transport vehicles account for around 20 %. Estimated to be the last-mile parcel vans account for around 4% of the city's overall emissions in the interest of the environment and the financial need of cleaner and more efficient urban logistics. Aside from the part of CO_2 emissions, one of the factors of the health of individuals and air in cities is the emission of nitrogen oxides (NOx) and particulate matter (PM) from city transport with a harmful effect and which is increasing in visibility (European Environment Agency, 2022). In such a state of the city's operation, the planning and management of the last-mile delivery networks need to satisfy the systematic requirements of the three priorities of efficiency, circularity, and sustainability.

Helsinki set itself as a lab city that sirises for carbon neutrality by 2030 through a set of ambitious initiatives such as sustainable mobility plans for the city and smart logistics innovation initiatives

(City of Helsinki, 2024b). By stressing the critical roles of regulation, public-private collaboration, and technological innovation backed by the six scenario-based futures produced by the Dis-aggregative Policy Delphi method, Plazier et al. (2024) insist on action among the actors towards sustainable last-mile log-gistics. These trends illustrate a pan-European tendency in which cities are being used increasingly as proof-of-concepts of scalable and sustain-able transport innovation applicable to medium-sized Nordic smart cities (Müller Eie & Kosmidis, 2023, p. 6).

Table 1 List of smart mobility initiatives in mid-sized Nordic smart cities (X = present, (x) = considered, Grey = assessed in-depth in Sect. 4.1)

	DK		SE	N					IS	FI				
Smart mobility measure/initiative	Aarhus	Vejle	Malmø	Bergen	Kristiansand	Stavanger	Trondheim	Tromsø	Reykjavik	Espoo	Oulu	Tampere	Turku	Vantaa
Autonomous vehicles (incl. ferries)		X					X			X		X		X
Bicycle infrastructure/parking/prioritising (e.g., super-highway, winter route, RADICAL)	X	X	X										X	
Bicycle-sharing/rental system		X	X						X	X			X	
Car-sharing / Car-pooling	X			X					X	X			X	
Digital/intelligent/cooperative car parking system		X				X		X						
E-bike trial / car-replacement trial (e.g., 365 days)	X													
Electric vehicles (e.g., buses, waste collection) & charging infrastructure		X	X			X						X	X	
Intelligent prioritising of emergency vehicles											X			
Intelligent transport management / traffic control	X	(x)								X	X	X		
Mobility hubs / MaaS (multi-modal travel, integrated ticketing, last m	X			X		X				X			X	X
Public transport app									X		X			
Voluntary travel behaviour change program (campaigns, trial periods, personal travel planning) (e.g., super commuters)	X		X											
Travel information app (e.g., drive now)	X								X					
Travel/trip data collection		X	X											X

Figure 1. Smart mobility initiatives in mid-sized Nordic smart cities (Müller Eie & Kosmidis 2023, 7)

Especially focusing on the Finnish cities of Espoo, Tampere, Turku, and Vantaa, Figure 1 provides a comparative summary of smart mobility initiatives across mid-sized Nordic cities. The diversity of initiatives such as smart transport management, cycling networks, and electric vehicle take-up

reflect the commitment of the cities towards supporting environmentally sustainable mobility. Regional context also places Helsinki in a profitable setting of analysis for the exploration of Lean-based models of the sustainable delivery of the last mile of logistics with special focus on the synergy between smart mobility initiatives in Finland and the overall Nordic context.

Against this background, this thesis investigates the intersection of Lean philosophy and sustainable delivery logistics of the last mile in Helsinki. The aim of this thesis is to come up with a reproducible and expandable sustainable delivery solution by applying the Lean philosophy while considering the politics of Helsinki city, the city's infrastructure limitations, and the logistics innovations. The aim of the study is to inform the city's planning as well as contribute to the broader European debate on climate-smart logistics on the grounds of economic sustainability, environment management, and social integration.

In conclusion, this work contributes to theoretical as well as practical discussions of optimizing urban logistics by creating a Lean-sustainability hybrid model particularly designed for the city of Helsinki. With this perspective, the study aims to advance not only operational efficiency and emissions reduction objectives but also green innovation and resilient city logistics leadership in Helsinki.

1.2 Industry Context: Last-Mile Delivery in the Helsinki Metropolitan Area

The Helsinki Metropolitan Region comprising the cities of Helsinki, Espoo, Vantaa, and the municipality of Kauniainen provides a unique example of the challenges of delivering the final mile of logistics within the context of a connected city economy. With a population of over 1.5 million people, the region has experienced a tremendous shift in consumer behavior fueled by the expansion of the e-commerce market. As the Universal Postal Union (2022) describes, parcel numbers have increased 33.6 % between 2019 and 2021, ahead of declines for letters-post for the first time over a period of 147 years and suggesting a structural evolution of the postal market. The trends follow the same direction at the national level: Posti E-Commerce Index (2023) indicates a seasonally peak upswing of up to 35 % in parcel volume during the peak season of the holidays November and December, while mean online retailing continues to go upwards, driven by such product groups as pharmacy and cosmetics. As volume in the e-commerce market increases and the expectations for the speed of deliveries grow, the pressure mounts for the last-mile infrastructure. There is a need for scalable, sustainable solutions that weigh operational efficiency against carbon-savvy logistics design—giving the Helsinki region a special role as an urban testbed for next-generation last-mile systems.

Apart from generic problems, the city's dense spatial structure and fragmented regimes of planning also limit the logistics of the last mile within the Helsinki Metropolitan Region. Transport-oriented planning cultures as compounded by the narrow integration of transport and city planning have created infrastructure imbalances that negatively affect the operational and delivery effectiveness of high-density cities (Duman et al., 2022, pp. 3-6). Such disadvantages of effectiveness are even augmented under the conditions of winter as the conditions of ice, snow, and slush are known to decrease the functionality of low-emission last-mile transportation modes like cargo bikes. Empirical studies of respective Nordic city landscapes show that conditions of winter decrease the speed of deliveries through cargo bikes by more than 25 % and decrease the battery life, security of the riders, as well as the over-all reliability of the routes (Dybdalen & Ryeng, 2021).

The environmental effects of a disorganized last-mile delivery logistics are growing increasingly pronounced. Transport accounted for about 21 % of the city of Helsinki's CO_2 emissions in 2023, of which light-duty delivery vans and commercial vehicles accounted for almost 20% of the transport-based CO_2 emissions for roughly 4.2 % of the city's total emissions (City of Helsinki 2024a). Transport emissions need to decrease by 69 % by the year 2030 according to the city's climate targets as formulated by the city's plan on reaching neutrality (AEI, 2023). Redirection of the logistics of the last mile is not just preferable, thus, but imperative. For the sake of further enhancing its attainment, the proportion of the country's vehicle fleet that is electric will experience a sharp upward turn, increasingly replacing higher-emitting internal combustion engines (AEI, 2023). Inefficiencies such as low load factors for automobiles as well as damaged deliveries all add up to unnecessary vehicle kilometers traveled, cumulatively building emissions, citywide noise pollution, as well as dangers compromising traffic safe-ty within metro cities.

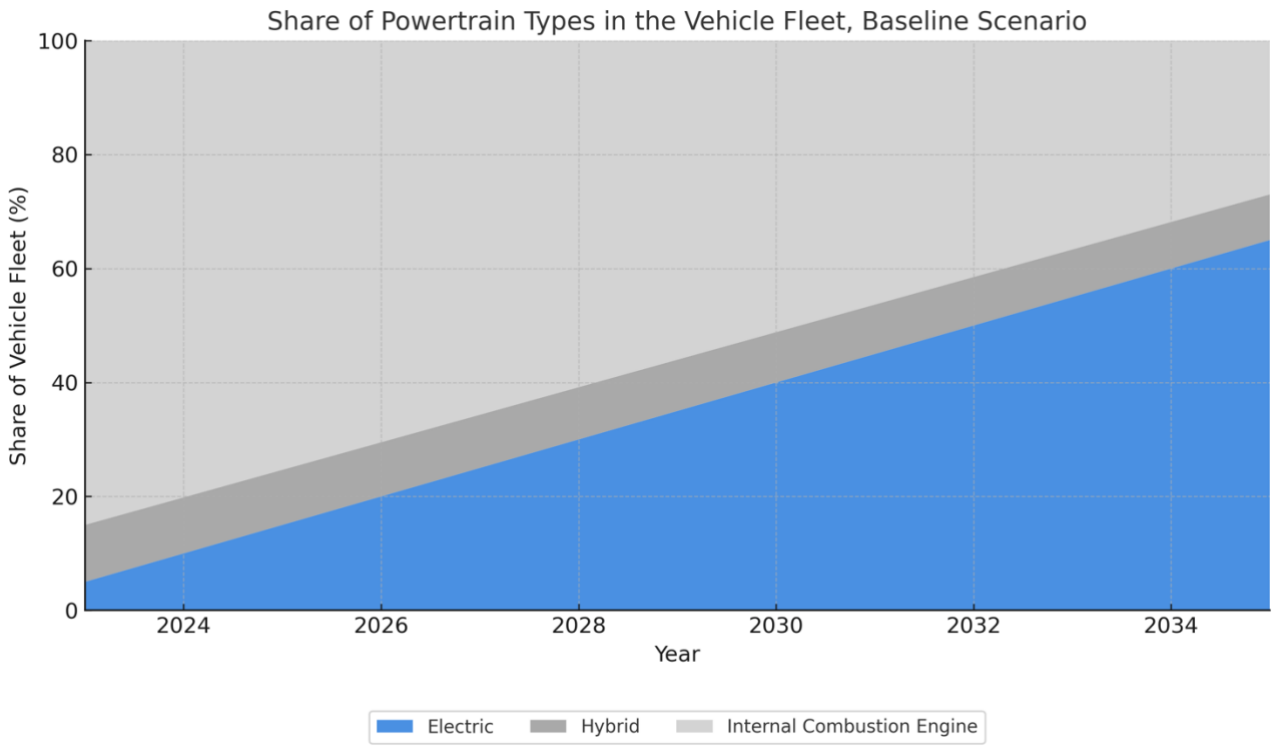

Figure 2. Projected Distribution of Finland's Vehicle Fleet by Powertrain Type, 2023–2035 (adapted)

To achieve its ambitious climate goals, Finland is significantly transforming its vehicle fleet toward electrification. The success of reducing last-mile delivery emissions and other city-level transport emissions (AEI, 2023) will largely hinge on this transition. As illustrated in Figure 2, electric vehicles are expected to make up most of the national fleet by 2035, while the number of internal combustion engine vehicles will drop sharply. Hybrid vehicles are anticipated to form only a small portion of the fleet, highlighting the crucial role that full electrification will play in meeting sustainability targets.

Helsinki, therefore, has started to pilot numerous logistics innovations. Through programs Smart Mobility and Forum Virium Helsinki, several pilot initiatives have been tested, including shared micro depot networks, electric bicycle cargo delivery fleets, and autonomous robot couriers (Forum Virium Helsinki 2023; Rosenberg et al. 2021). These initiatives share the common goal of decentralizing delivery systems, reducing emissions, and optimizing the use of urban space. For example, the Ruoholahti area now has a micro depot system that allows multiple operators to consolidate de-liveries, minimizing the number of trips to high-traffic areas.

1.3 Research Problem

Increased urban logistics complexity for the last-mile segment of transportation has introduced crucial challenges towards environmental sustainability and service quality. With the advancement of technology and environmental-friendly modes of delivery, logistics operators within the Helsinki Metropolitan Area are faced with the problem of inefficient capacity, a significant failure ratio, and the lack of a consistent planning process among stakeholders. Although there are calls for the compensation of carbon emissions and city atmospheric pollution, freight networks have the added necessity of changing and adapting. Lean methods that have shown great effectiveness for optimizing manufacturing and first-mile logistics have not yet universally been implemented for the last-mile delivery in cities like Helsinki. There are also efficiency and sustainability optimisation measures currently working disjointedly without a city level model for following lean means of approaching last-mile logistics. While par-cel numbers expand and environmental regulations strengthen, lacking a model for implementing lean methods in last-mile logistics at the city level arrests Helsinki's development towards a climate-resilient and efficient transportation system.

The aim of the study is to explore how lean philosophy can improve last mile delivery systems and make them sustainable for the Helsinki Metropolitan Region.

Research Question: How can Lean philosophy improve last-mile delivery systems for the metropolitan area of Helsinki to make them efficient and sustainable?

IQ 1. What inefficiencies exist in last-mile delivery systems in the Helsinki Metropolitan Area?

IQ 2. How can Lean principles—specifically Just-In-Time (JIT), Kaizen, and Value Stream Mapping (VSM)—address these inefficiencies?

IQ 3. What benefits can be achieved by integrating sustainability goals with Lean practices in urban last-mile logistics?

1.4 Research Objectives and Scope

This dissertation tries to research how principles related to Lean can make last-mile delivery systems within the Helsinki Metropolitan Area operationally efficient and environmentally sustainable. Investigating how Lean philosophy can align economic performance with environmental responsibility for last-mile logistics with increasing delivery volumes, intensifying environmental pressures, and persistent logistical inefficiencies assists with matching economic performance and environ-mental responsibility.

The main intent of the present work is to evaluate how Lean principles systematically can be implemented for the purposes of addressing issues of non-efficiency and sustainability within Helsinki's last-mile delivery system. For this aim, the work shall scrutinize prevailing constraints of city logistics for the region, determine Lean practices suitable for dense Nordic cityscapes, and discuss how Lean principles could be combined with sustainability goals. Logistics startups and pilot initiatives are particularly highlighted as the point of emphasis on how and to what capacity they support the application of innovative principles towards these purposes.

Aside from theory, the work aims at producing evidence-based practical advice for public authorities, logistics businesses, and entrepreneurial firms emanating from Helsinki. Based upon an analysis of the urban goods situation, sustainability agenda, and entrepreneurial environment of Helsinki, these recommendations will reflect.

The geographical scope for the study is restricted to the Helsinki Metropolitan Area, which includes Vantaa, Kauniainen, Helsinki, and Espoo. The empirical scope is restricted to last-mile logistics for small commodities and parcels for metropolitan and semi-urban environments. To ensure specificity and consistency, rural delivery networks, bulk goods haulage, and intercity logistics operations are specifically excluded from study.

Lean management and sustainable logistics intersect to form the framework theoretically. Viewing lean thinking through the lens of, for example, the Toyota Production System and relevant models, lean thinking is viewed with consideration for process tool examples like Just-in-Time (JIT), Value Stream Mapping (VSM), and Kaizen. With specific reference to SDG 11 and SDG 12, sustainability is considered with consideration for Finland's national abatement targets together with the UN Sustainable Development Goals (United Nations, n.d.; Ministry of the Environment of Finland, 2024).

Methodologically, this research employs a qualitative, exploratory approach. It employs policy documents, available case studies, scholarly literature, and semi-structured interviews with public and private sector professionals. It attempts to generate academically informed, regionally specific prac-tical insights through which research is guided.

1.5 Relevance and Benefits

At the junction of urban logistics, Lean management, and sustainable studies, this work is both contemporary and practically relevant. Through scattered, reactive policies, the urban constraints currently confronting cities like Helsinki—spanning e-commerce expansion at an accelerated rate to climate considerations—threatens to overwhelm available resources. One particularly important

pressure point where operational inefficacy meets environmental damage is last-mile delivery. Therefore, improving last-mile performance by means of adaptive Lean principles presents excellent chances for fulfilling environmental responsibility as well as financial efficiency.

Academically, the study confirms understudied fields of knowledge for how challenges of sustainability can be implemented together with Lean management within the transportation systems of cities. Reduced cost and efficiency, promoted by Lean philosophy, have long addressed its applications within warehouses and manufacturing, not its implementation within the logistics last mile within cities, particularly Nordic cities. By putting together principles from Lean operations, sustainable urban development, and intelligent city solutions within a structured framework for research, the research addresses such a gap. It builds on existing research by authors such as Bicheno and Holweg (2021) and extends further on developing new frameworks by synthesizing tools such as Kaizen, Just-in-Time, and Value Stream Mapping within the distinct climatic, infrastructure, as well as regulation, environments of Helsinki.

Research can engage with multiple stakeholder groups. For logistics firms, it provides means of delivery cost-cutting, reduction of waste and surplus and ensuring reliability in dynamic and space-constrained city environments. It provides insight to city officials and planners on how Lean-related logistics may enhance urban livability and assist in reducing climatic emissions. By exemplifying scalable patterns of data-driven and sustainable delivery systems, the results are equally intended to promote agencies of innovation, entrepreneurs, and stakeholders within an ecosystem. These results are particularly crucial considering the country's e-commerce growth rate and the city's goal of reaching a state of carbon neutrality by 2030 (City of Helsinki, 2024b).

The present research also aligns with Finland's national goal of being carbon-neutral as well as broader international targets such as the United Nations Sustainable Development Goals - SDG 11 (Sustainable Cities and Communities) and SDG 12 (Responsible Consumption and Production) - United Nations, n.d. Therefore, this thesis not merely resolves a domestic city logistics challenge but equally fosters a global discussion of how cities could be made resilient, inclusive, and environmentally sustainable through the use of system innovation.

Ultimately, the relevance of this work resides in its capacity to provide both useful and conceptual advances. Framing Lean philosophy as an enabler for sustainability rather than a driver of efficiency promotes rethinking urban delivery models—centered on cooperation, experimentation, and continuous progress. Though they are centered on Helsinki's metropolitan scene, these

lessons probably have resonance in other European cities dealing with similar environmental challenges and logistics.

1.6 Key concepts

This research is based on an inter-disciplinary framework enriched with lean management, the science of sustainability, and urban logistics. The concepts below demarcate and frame themselves for purposes of this research to promote terminological coherence and conceptual clarity:

Last-Mile Delivery

Last mile urban logistics is the ultimate phase of the value chain, moving products from the ultimate transit point to the ultimate delivery location. This is generally the most expensive as well as environmentally suboptimal part of the logistical process, causing urban traffic, pollution, as well as high delivery expenses, particularly in urban areas where e-commerce is on the rise (Kiba-Janiak, Marcinkowski, Jagoda, & Skowrońska, 2021).

Lean Management

Lean production, based on Toyota Production System principles, is a systematic philosophy that seeks to generate the greatest value while reducing waste by continuous improvement, client value focus, as well as removing inefficiencies (Hüsselmann, 2023). Lean is a methodology as well as a mindset that can be utilized across all sectors, such as service and logistics industries.

Lean Logistics

Lean logistics is a philosophy of managing the flow of goods within the supply chain by finding and removing waste. It seeks to maximize the efficiency of the logistics function by minimizing unnecessary inventory, transportation, and processing steps, to enhance overall efficiency. The main principle of lean logistics is that goods are produced, transported, and delivered in the correct quantity, time, and location, with the lowest costs possible, while customer service is kept as high as possible. The approach stresses the need for being customer-demand oriented, having timely and accurate information, and minimizing the length of time between starting a production order and its delivery (lead time). In contrast with the traditional systems, depending on massive inventory, lean logistics works with low stocks, with higher flexibility, and higher capacity for responding to customers (Alvim & Oliveira, 2020; Womack & Jones, 2003; Zylstra, 2005).

Sustainable Urban Logistics

Sustainable urban logistics is the practices and strategies employed to make urban freight transportation systems as environmentally friendly as possible, with minimal loss of efficiency and service quality. It involves minimizing CO2 emissions, and infrastructure usage, as well as encouraging the deployment of low-emission vehicles for last-mile delivery within urban centers (Cano, Londoño-Pineda, & Rodas, 2022). Implementation of such strategies is integral to promoting sustainability within urban logistic systems, including minimizing traffic congestion, enhancing delivery efficiency, and reducing any negative effects on the environment.

Kaizen

Kaizen is the Japanese philosophy of promoting efficiency and productivity by continuous, incremental improvements. Kaizen emerged post-World War II, within the Toyota Production System (Liker, 2004) and is nowadays a fundamental building block of lean management practices, including lean logistics. Kaizen is an integrated concept for constantly enhancing processes and systems through incremental, small improvements. Kaizen is employee-centered at all levels, developing a continuous improvement culture within all organizational sections, aimed at enhancing efficiency, productivity, as well as competitiveness. Kaizen integrates operations, human, as well as strategic ideas into an adaptable method of supporting long-term achievement (Berhe, Hailu, & Beyene, 2023).

Just-in-Time (JIT)

Inventory cost reduction is the goal of the inventory control methodology known as Just-in-Time (JIT) which addresses the need for inventory only as it is required within the production process. JIT minimizes waste through the elimination of inefficiency, aligns production with customer demand, and highlights issues where the material is not received as anticipated. By eliminating waste and delays, JIT enhances throughput, reduces variability, and creates a competitive advantage within the production systems (Heizer & Render, 2017).

Value Stream Mapping (VSM)

Value Stream Mapping (VSM) is an approach invented by engineer Taiichi Ohno at Toyota for proactively detecting and removing sources of waste. VSM is one of the flowcharts employed for modeling, analyzing, and recommending improvements of the processes that lead up to the delivery of a product or service. VSM is a main component of the Lean approach for detecting and

removing waste. By clustering all the processes that constitute the value chain, the VSM tool seeks out non-value-adding processes that are deemed wasteful. Improvement solutions are then created following such collaborations, aimed at fixing such bottlenecks to streamline the production flow. The VSM tool considers physical flows, but notably information flows (Kihel, Y. El, Kihel, A. El, & Embarki, S., 2022, p. 5).

Lean Startup

A Lean Startup is a framework that encourages speedy, incremental product development for the purpose of experimenting with business ideas as well as hypotheses rapidly. It is geared toward developing minimum viable products (MVPs) for getting back input from early adopters, aimed at identifying a viable and replicable business model. Lean Startup applies agile engineering, customer development, as well as the business model canvas for driving innovation as well as responsiveness based on customer input, as opposed to customary business planning processes (Blank & Euchner, 2021).

These definitions, collectively, provide the philosophical and practical basis for this thesis. They guide the analytical framework by which Lean principals of operation could make last-mile delivery more sustainable and efficient.

2 Lean and Sustainable Last-Mile Delivery Practices

This chapter develops theoretical grounds underpinning analysis of how lean philosophy and sustainable practice might be coexisting to improve last-mile distribution in Helsinki's Metropolitan Area. Based on existing research and actual data, it explores the central principles of lean logistics, social and ecological elements of sustainability, as well as possibilities for conjunction of the two. To ensure applicability to practice and to fit with actual environments, throughout this chapter, such theoretical considerations are placed in Helsinki's urban transport environment.

Often accounting for over 50 % of total delivery costs and disproportionately contributing to urban pollution and congestion, the last-mile is clearly the most inefficient and cost-intensive element of the supply chain (Abad, Parsaee, & Afshari, 2022). Cities like Helsinki are under pressure simultaneously to lower emissions, eliminate traffic externalities, and promote livable urban environments (**Ministry of the Environment Finland**, 2024). These twin problems—environmental unsustainability and logistical inefficiency—demand solutions with both operationally lean and ecologically benign character.

Lean thinking provides a workable framework for minimising waste, achieving flow, and optimising system performance. Lean is used extensively in transportation, especially in areas where visibility, dependability of service, and punctuality are most sorely lacking (Slack, Brandon-Jones & Johnston, 2022; Womack & Jones, 2003). Lean principles such as JIT, Kaizen, and Value Stream Mapping are applied more in transportation as well as in urban logistics in order to prevent delays, restrict empty mileage, as well as remove non-value-added activities (Protzman, Whiton & Kerpchar, 2018).

On the contrary, in logistics, sustainability means those tactics which minimize carbon footprints, utilize resources responsibly, and promote social equitable working conditions. Green last-mile initiatives proven to reduce carbon emissions as well as enhance efficiency with widespread scaling include electric vehicles, freight bicycles, urban consolidation facilities (CCs), as well as parcel lockers (Buldeo Rai, Verlinde & Macharis, 2018; Mangiaracina et al., 2019).

Green Logistics (GL) practices not only generate economic and environmental value, but they have social benefits as well. GL practices have a positive effect on enhancing the well-being of employees as well as other stakeholders, such as customers, suppliers, and society (Makov & Newman, 2016). Researchers highlighted the social dimensions of Circular Economy (CE) by listing alternative social practices (Padilla-Rivera et al., 2020). Health and safety, employee training

and development, diversity, working conditions, and supporting community initiatives are some of the practices that add up to social performance (Kumar & Anbanandam, 2020; Piecyk & Björklund, 2015). By building human and social capital, such practices generate social value for CE (Jayarathna et al., 2022, p. 7). The lean and green processes not only reduce unnecessary waste as well as improve efficiency of resources, but they help achieve greater environmental as well as economic performance by aligning organisational processes with sustainability goals (Singh, Kumar Mangla, Bhatia, & Luthra, 2022). Green operations, environmentally responsible production, cleaner production, sustainable consumption and production, green logistics, green purchasing, green supply chain management, closed-loop supply chains, and numerous other phrases became increasingly used terms within corporate environmental sustainability language (Sarkis, 2019). However, integration also produces conflicts. For instance, JIT deliveries would add to transport frequency unless supplemented by route consolidation software or electric vehicles to minimize emissions. This chapter also critically assesses where lean and sustainability objectives intersect, where they conflict, and how they can be reconciled in an integrated framework for developing urban transport.

Beginning with an analysis of lean thinking foundations in logistics, their main ideas along with their applicability to last-mile problems in urban space, so framing this theory in coherent, practice-focusing terms. It then looks at sustainable logistics solutions, balancing social and technical interventions with the aim of lower emission levels and best urban goods movement optimisation. Theoretically, then, the frameworks are examined in relation to the overall last-mile issues in the Helsinki Metropolitan Region: congestion, regulatory framework, seasonal climate, consumer expectations, and infrastructure constraints. Based on this contextual study, the chapter then combines lean and sustainability viewpoints, analysing synergies and conflicts using such frameworks as the Green Lean. At last, the role of startups as innovators is investigated to take into account how creative business models help to develop to create last-mile systems with low emissions. The chapter ends with showing how lean, sustainability, and innovation interact to help to address the research questions and create practical solutions in next chapters.

By including these aspects, the theoretical framework provides a strong basis for evaluating current inefficiencies of last-mile delivery and suggesting context-specific solutions lean from an operational perspective, ecologically friendly, and socially inclusive in Helsinki's urban environment.

2.1 Lean Principles in Urban Logistics

In recent times, lean philosophy has increasingly been adopted in urban logistics environments as an alternative to factory floors. It represents a sound methodology for enhancing last-mile carrying system robustness as well as performance. Lean thinking, which was developed by the Toyota Production System, emphasizes elimination of waste (muda), inconsistency (mura), and overburden (muri) as well as creation of value in optimized processes (McGovern, 2019, pp. xv–xvi). When applied to urban logistics, lean presents organizational direction for pinpointing inefficiencies as well as aligning operations with customer aspirations, particularly in last-mile delivery, which is generally recognized to be the costliest as well as emission-intensive segment of supply chains (Mangiaracina et al., 2022).

In last-mile settings, waste occurs as failed deliveries, detours, idling time, inefficient operations, and low-capacity utilization of vehicles. Since lean settings direct a great deal of focus toward value creation as well as flow optimization, they provide an organized way of working through such issues. Corporate Social Responsibility (CSR) and traditional concerns of operations management align. For instance, such initiatives could involve minimizing waste or emissions (which can also lower costs). Indeed, much of operations management's environmental considerations focus on waste.

Decisions in operations management related to product and service design affect how materials are used and their potential for recycling in the long term. Additionally, process design affects the amount of energy, materials, and labor that is wasted (Slack, Brandon-Jones, & Johnston, 2022, p. 27). In relatively dense cities such as Helsinki, with high levels of digitalization, and increasing customer demands for real-time delivery information, Just-In-Time (JIT) is particularly suited to reducing waste associated with overstocking, providing faster service, and minimizing overstocking.

In a bid to alleviate the load of excessive delivery traffic within urban centers, several communities are experimenting with two-echelon schemes based on decentralized micro-depots as well as cargo bikes, particularly within inner-city locations. Besides easing traffic congestion, it further provides relief for the emission of CO2, improves operational efficiency, as well as supplies alternative modes of delivery, including cargo bikes and drones. Nevertheless, such systems are not free from challenges, including volatile traffic, climatic changes, and varied customer demands. For such, optimized planning as well as real-time tracking of data is the key for efficiency, as presented by the research by Boysen et al (2020).

In the same way, as observed by Choi et al. (2023), JIT is not easy to adopt where such volatile environments, such as external disturbances including disruption from the value chain, volatile demands, as well as fluctuations of lead time of supplies, are encountered. According to their suggestion, JIT has to be tailored for turbulent environments, including the advent of advanced technologies to provide visibility as well as predictability, so as to ensure that the operations do not affect their efficiency even during disturbances (Choi et al., 2023, p. 118). For such, the inclusion of JIT with real-time tracking as well as analysis of the data is necessary for the success of last-mile delivery systems, as such systems have to be flexible enough for unexpected delays while minimizing emissions as well as operational costs.

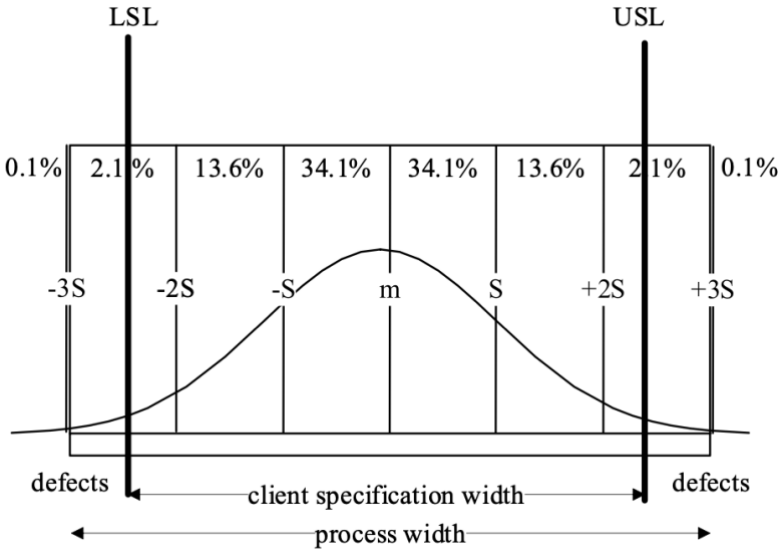

Figure 3. Six Sigma process distribution with specification limits (Lemke et al. 2021, 7)

The process distribution chart presented in Figure 3 (Lemke et al., 2021) clearly demonstrates how Six Sigma strategies can assess the efficiency of last-mile delivery systems by identifying defects and refining processes. This quality control approach is grounded in Lean principles, such as Kaizen, which emphasizes ongoing improvement and waste reduction. By evaluating process performance and understanding deviations from specifications, companies can optimize their operations, boost efficiency, and reduce errors in logistics management.

Kaizen, continuous improvement, is another essential element of lean urban logistics. Differently from disruptive redesigns, Kaizen is all about frontline worker-led, continuous incremental improvements through cross-functional teams. In delivery situations, this can include iterative improvements to courier routing, parcel handling procedures, or communication with customers.

Protzman, Whiton and Kerpchar (2018) demonstrate that those logistics companies which use Kaizen not only minimize delivery mistakes and delay but also improve staff morale and engagement. In Finnish culture where team working organizational cultures are highly prevalent and employees are generally autonomously empowered, Kaizen represents an organizational practice which supports bottom-up-led innovation.

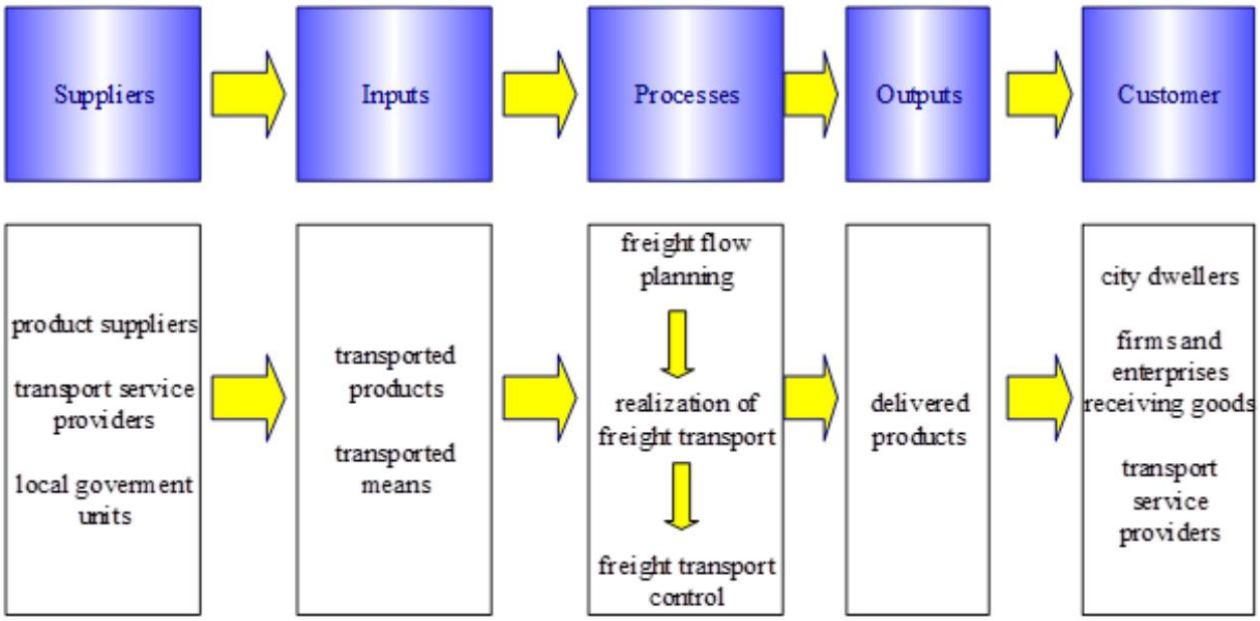

Figure 4. SIPOC diagram for a last-mile logistics process (Lemke et al. 2021, 10)

The SIPOC diagram provides a clear snapshot of the key elements in last-mile logistics, including suppliers, inputs, processes, outputs, and customers. By mapping out these components, businesses can pinpoint important touchpoints and find ways to improve overall efficiency (Lemke et al., 2021).

Identifying waste within the total last-mile delivery process—from customer doorstep through warehouses—value stream mapping (VSM) is an ideal fit. By breaking down each step of value-added activities and non-value-added activities, organizations are able to identify waste, delays, and bottlenecks, with the goal of refining their processes and increasing productivity. In city logistics, where time is of the value and delivery density can vary from neighborhood to neighborhood, this is of particular value. VSM can, for the purposes of operational improvement, highlight traffic congestion and areas within the inner districts of overcrowded Helsinki where capacity is not entirely utilised in small roads as well as restricted loading zones (Heizer, Render, & Munson, 2017).

In urban transport, where local time is of paramount importance and density of deliveries can vary by neighborhood, VSM is particularly useful in optimizing lean solutions to hyper-local operational facts. For instance, mapping out routes through Helsinki's inner districts with congested one-way layouts and tight loading capacity can identify essential chokepoints and capacity under-use—an evidence bases to build upon in designing process improvements (Oakland, Oakland & Turner, 2021).

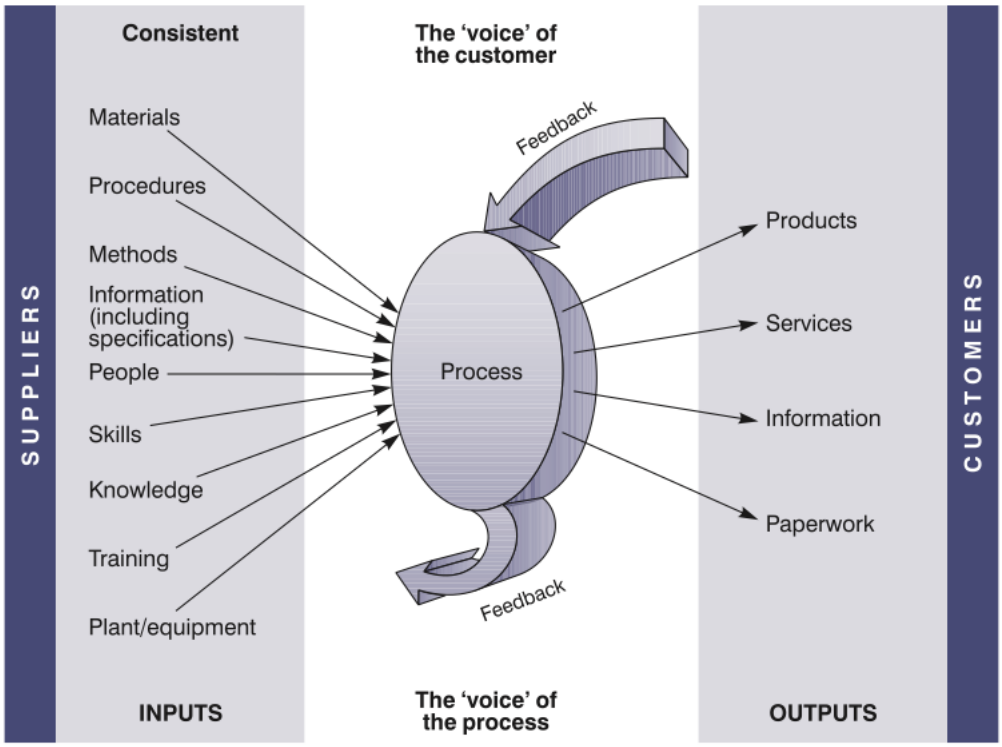

Figure 5. SIPOC framework illustrating process flow and feedback integration (Oakland et al. 2021, 12)

By means of interlinking main elements of last-mile logistical systems, Figure 5 shows the SIPOC model, so linking Suppliers, Inputs, Processes, Outputs, and Customers. It shows how applying customer input through repeat improvement loops turns steady inputs—that is, materials, techniques, and competencies—into outputs—that is, products, services, and information. By using the SIPOC model in metropolitan logistical settings like Helsinki, process management is improved, systems are optimised, and customer needs are more responsively (Oakland et al., 2021, page 12).

Additional vital tools for lean logistics are standardised work processes, visual controls, and the application of the 5S methodology (Sort, Set in Order, Shine, Standardise, Sustain). The methods help distribution centers and urban micro-depots remain orderly and cut the time spent loading, searching for, and shipping packages. 5S methodology, which is typically applied to manufacturing shopfloors, is also used in parcel sortation facilities and cellular depots in urban logistics to improve efficiency as well as safety (Bicheno & Holweg, 2023). For Helsinki operators, such standards are particularly important during colder months when exposure to outdoor environments must be kept to an absolute minimum, and operational safety is of most importance.

Empirical evidence exists of the capability of lean practices of enhancing efficiency. In specific, lean thinking implementation within urban logistics is able to translate into cost reduction as well as higher levels of work efficiency. Grandval, Nimtrakool, and Grant (2019) outline how lean-centered systems can maximize efficiency by reducing waste as well as redundancies along the value chain. Urban freight transportation is aided by practices such as routing maximization as well as pooling of logistics facilities that not only benefits economic purposes but also contributes toward sustainable objectives by minimizing environmentally damaging effects. These lean strategies, together with novel digital technologies, generate insightful recommendations for optimizing deliveries, reducing consumption of fossil fuels, as well as improving the reliability of service within urban settings.

Considering the physical, legal, and demographic complexities of cities, lean logistics must be implemented with additional vigilance, especially within urban settings. In Helsinki, issues such as rush hour traffic, differing municipal delivery policies, and the city’s dispersed development all factor into how lean logistics models are implemented. According to Duman et al. (2022), lean models that disregard local policies as well as the physical layout of the city can cause additional inefficiencies, fixing one issue, only to create another. The European Commission (2023) highlights the need for regulation, such as the 2010/40/EU directive, that oversees the implementation of intelligent transport systems (ITS) within Finland, impacting urban logistics processes. This highlights the necessity of a place-sensitive approach in implementing lean logistics models, most notably within cities such as Helsinki, where the surrounding environment as well as the regulation of the place are the most essential determinants of logistics strategies (Duman et al., 2022; European Commission, 2023).

Whereas lean logistics is based on efficiency by reducing processes to eliminate waste, critics contend that it is inflexible unless there is appropriate contingency planning or buffer systems. Its minimized redundancy makes last-mile delivery systems susceptible, especially for instances of

snowstorms, labor disputes, or IT outages—the usual perturbations common with Nordic climates. Duman et al. (2022) suggest that lean logistics for Helsinki would require contingency programs, as well as dynamic scheduling, for improving resilience while not compromising on efficiency. The European Commission (2023) highlights the need for adaptive systems that can adjust for disruption, further supporting the idea that lean models must be flexible enough to handle unexpected events in real-world environments (Duman et al., 2022; European Commission, 2023).

One of the strongest theoretical contributions of lean thinking is its demand for systemic optimisation rather than localised improvement. Logistically, this translates into considering last-mile delivery as part of the overall supply chain complex rather than as an independent service node. From this systemic viewpoint, inefficiencies in last-mile delivery—in this case, failed delivery attempts—are likely to be symptoms of upstream inefficiencies in inventory, forecasting, or communication with customers. Through root cause analysis and VSM, organisations can map these problems back through their cause chain and solve them in context. In Helsinki Metropolitan Area, where there are various actors (private postal companies, municipal authorities, consumers) who are interacting in one and the same logistical space, systemic lean thinking is needed to align goals as well as to avoid duplication of effort.

Finally, lean practices also offer performance measures for evaluating performance in urban logistics. Indicators used include lead time, first-time delivery success rate, value-added time ratio, and load utilization, and are commonly utilized in lean audits and quality improvement programs (Slack et al., 2022). In scholarly literature, such metrics are more commonly used as baseline measures for measuring last-mile performance. Using these measures in Helsinki will be an important component in the empirical section of this study to work out baseline levels to improve.

In brief, lean thinking presents an highly organized but flexible system of diagnosis and solution for optimizing last-mile delivery inefficiencies. In Helsinki, the urgency is heightened by the compounded intensity of the city's logistical sophistication, digitalization, and policy objective to have smarter, more ecological transport. Operational efficiency through lean logistics is necessary, but being coupled with sustainability and innovation in subsequent sections is what will ultimately facilitate revolutionary change toward greener, more efficient, and equitable urban delivery systems.

2.2 Sustainable Practices for Last-Mile Delivery

The last mile of delivery is of particular significance in city logistics, being most often the costliest as well as environmentally degrading component of the distribution chain. With further urbanization

as well as e-commerce, cities such as Helsinki are experiencing increasingly mounting congestion, emissions, as well as last-mile delivery systems inefficiency. The environmental effects of such operations have been demonstrated by studies, where last-mile delivery vans have been noted as being one of the prime sources of CO_2 emissions as well as city traffic congestion (Bates et al., 2018, p. 2). These inefficiencies call for environmentally friendly solutions that can meet the need for increasingly affordable as well as prompt delivery service while reducing environmental as well as social issues (Silva et al., 2023, p. 11).

Sustainable city logistics operations, notably last-mile delivery, target minimizing the degradation of the natural environment, cost savings, as well as the maximization of delivery systems efficiency. A key determinant for the realization of such realities constitutes the use of electric vehicles (EVs) as well as cargo bikes, whose low-carbon emission as well as cost benefits render them appropriate alternatives for reducing environmental impacts. Electric vehicles, according to Silva et al. (2023), present a low-emission option, notably for short-delivery trips typical of urban communities, by which logistics firms can introduce environment-related effect mitigation (Silva et al., 2023, p. 11).

Cargo bikes, by contrast, have worked well in the urban environment. Leveraging available infrastructure, such as bike roads, for instance, cargo bikes can beat traffic, conserve transportation time, as well as avoid the need to reserve parking space, such as that seen to be difficult in an urban estate like Helsinki (Silva et al., 2023, p. 10). Supporting its drive towards sustainability, Finland's postal organization, Posti, introduced delivering by means of electric vans into towns, an initiative that contributed to lowering emissions of CO_2 by it (Bates et al., 2018, p. 3). Further, Helsinki's cargo bikes have helped make short-distance deliveries, thus avoiding the deployment of normal vans, saving emissions cumulatively (AEI, 2023).

Together with such vehicles, route planning, as well as sophisticated logistics technologies, have a key role to play in improving last-mile delivery efficiency. In accordance with Silva et al. (2023), artificial intelligence-powered systems as well as machine learning algorithms adapting delivery routes dynamically, with consideration of traffic, weather, as well as delivery time slots, are necessary (Sil-va et al., 2023, p. 23). These technologies have the ability to reduce fuel use, emissions, as well as overall delivery efficiency. GPS-supported route planning as well as software optimization aid drivers in following shortest routes, eliminating unnecessary detouring as well as idle times, significantly as major reasons for excess emissions as well as operational inefficiencies (Bates et al., 2018, p. 4).

Moreover, urban consolidation centers (UCCs) and smart lockers are a more efficient way of minimizing carbon footprints when making last-mile delivery. Urban consolidation centers are strategically positioned smart lockers placed in public spots like transportation hubs or malls where consumers can receive parcels at a convenient point, minimizing delivery frequency along with re-delivery emissions (Silva et al., 2023, p. 6).Smart lockers have the added benefit of enabling logistics companies to aggregate delivery to central points before final delivery, thereby reducing the number of vehicles required during last-mile delivery along with urban congestion (Silva et al., 2023, p. 6).UCCs operate by bundling packages from various suppliers into a single destination before being delivered finally using cleaner, more environmentally friendly modes of transport like e-vans or freight bicycles. It saves vehicle kilometers traveled, emissions, as well as increases delivery efficiency (Bates et al., 2018, p. 5).

The collaborative economy together with joint infrastructure also provide alternative sustainable solutions to last-mile logistics. Collaborative networks of lockers, also known as micro-depots, enable a number of logistics firms to share operations, avoiding duplicate trips along with idle capacity. Crowdsourced delivery concepts coupled with joint infrastructure has been successful in making product flow more efficient in urbanized areas, coupled with lower carbon emissions as well as transport expenses (Silva et al., 2023, p. 17). Mutual access of the micro-depots, in turn, is enhancing efficiency by reducing deliveries and cutting access of vehicles into congested areas, as in Helsinki city (AEI, 2023).

In their pursuit of sustainability, cities are increasingly implementing policies that support the uptake of low-emissions vehicles as well as shared infrastructure. The Smart Mobility Programme within the city of Helsinki, for example, encouraged public-private partnership for pilot implementation of concepts like electrical cargo bikes and shared micro-depots, helping the city attain its aspiration of being carbon neutral (Bates et al., 2018, p. 6). The city is topping up its initiatives with investments in electric vehicle charging infrastructure and the enforcement of urban logistics policies that enhance green action (AEI, 2023).

In summary, adopting sustainable last-mile logistics solutions like the deployment of electric vehi-cles, cargo bikes, route optimisation software, smart lockers, as well as collaborative infrastructure, together with compliance with urban sustainability norms, minimizes emissions while improving effi-ciency of delivery. Cities such as Helsinki, through pilot schemes as well as policy, set an excellent example of how such practices can be adopted for urban logistic systems to be made sustainable. These practices not only ensure environmental sustainability as well as economic benefits through cost reduction in operations and enhanced service levels for customers. The

subsequent chapters will examine considerations of how such sustainable practices can be scaled up, as well as their inclusion within the larger logistics framework.

2.3 Integration of Lean and Sustainability in Logistics

Lean philosophy and sustainability methods in the context of logistic operations are gradually emerging as a necessity to achieve operational efficiency to the maximum extent with environmental implications. Lean logistic is aimed towards the removal of wastage, efficiency in the process, and value delivery improvement, whereas sustainability aims at minimizing resource utilization, emissions, and improving society (Tripathi et al., 2024). In more and more complicated logistic systems, particularly in cities, implementing both is required to achieve operational efficiency and long-term environmental sustainability.

The deployment of Lean philosophies such as JIT, Kaizen, and VSM in conjunction with sustainability has been credited to improve performance in a number of dimensions. These programs help ensure each stage of the process is maximized, eliminating wastage, determining inefficiency, and streamlining operations, all of which ensure cost-saving on consumption of resources as well as reduce the environmental footprint (Tripathi et al., 2024, p. 215). By implementing Lean, logistics operations can notably conserve energy, reduce emissions, as well as eliminate material waste—vital elements of any sustainable logistics network.

Besides, sustainability innovation through Lean logistics also enables organizations to adopt green-er technology as well as practices. For instance, adopting electric vehicles as well as bicycles as means of carrying freight during the last-mile delivery operations not only lowers emissions, but also aligns to Lean philosophy since it minimizes environmental footprints at no expense to efficiency (Erdal, 2024). The innovations have twofold advantages: enhanced efficiency through lean applications as well as lower environmental footprints through green practice.

The conceptual model of Figure 3 represents how the linkage of Lean principals with sustainability-driven innovation for logistics is established. It reflects the factors—infrastructure, lean viewpoint, waste handling practices, and environmental systems—that affect the successful adoption of both lean practices as well as sustainability objectives. The framework also depicts how the practices affect economic, operational, environmental, and social dimensions of performance. The approach of interlinking leads to the development of turnover, business development, customer relationships, environment, as well as business performance as a whole (Tripathi et al., 2024, p. 215).

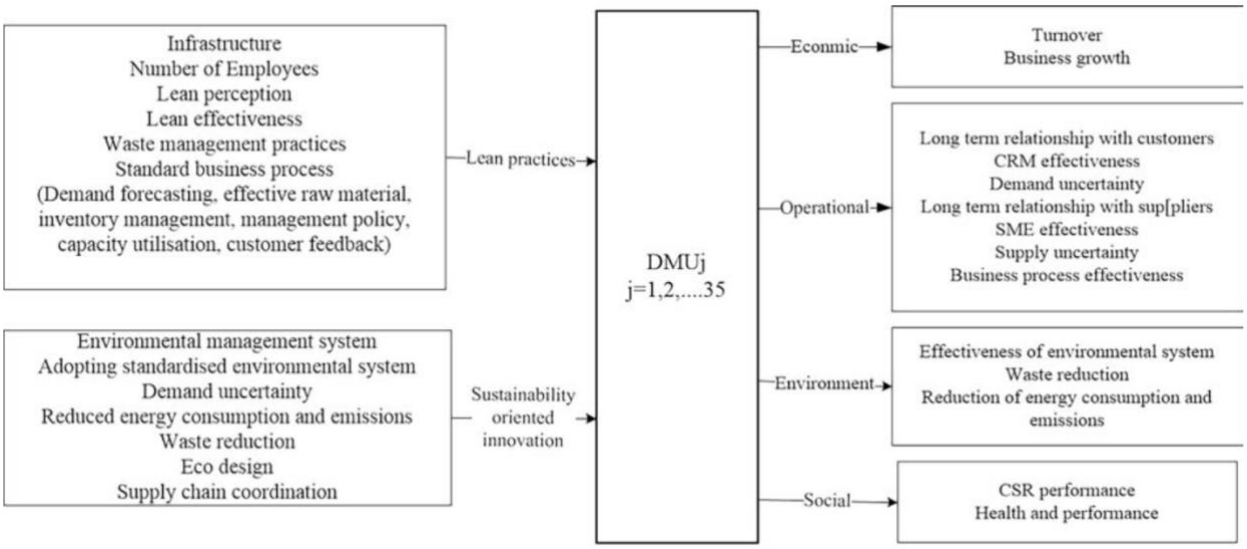

Figure 6: Conceptual model demonstrating the integration of lean practices with sustainability-oriented innovation.

The model shown in Figure 6 delineates the relationships between several factors, including lean practices, environmental systems, as well as sustainability objectives, affecting the economic, operational, environmental, as well as social performance of logistics activities.

The alignment of Lean with sustainability has quantifiable impacts on business performance. Companies adopting green logistics techniques such as lessening wastage and reducing energy use not only save costs but also enhance their corporate image with increased customer loyalty and stakeholder relationships. For example, those companies that utilize eco-friendly technologies in transportation and align their value chain to be more sustainable typically experience increased customer satisfaction and consequently improved financial outcomes (Tripathi et al., 2024, p. 215).

Operationally, lean and sustainability methods enhance several critical metrics, including reducing waste, coordinating the value chain, as well as promoting energy efficiency. They are of specific priority for optimizing last-mile delivery systems, where route optimisation, waste reduction, as well as energy-saving technology, can have great environmental as well as operational advantage (Erdal, 2024).

The alignment of such sustainability practices with Lean principles is a strategic framework for operational enhancements as well as for environmental stewardship. Businesses can significantly enhance the last-mile delivery mechanisms by adapting Lean tools and sustainability-led innovations. Businesses can reduce waste, emissions, and enhance business efficiency

dramatically by doing so. Companies embracing such practices will be well-prepared to cater to the need for sustainable logistics, advance market competitiveness, as well as ensure a sustainable world as demand for sustainable logistics continues to grow.

2.4 Startups as Drivers of Lean and Sustainable

Startups, especially those that are active within emerging economies, play central roles both in promoting innovation as well as the uptake of sustainable practices. The young, agile companies tend to be at the forefront of frugal innovation, exploring cost-effective solutions for resource-constrained environments. Abbas and Liu (2022) emphasize the typical challenges confronted by emerging economy startups, paying special consideration to lean and frugal eco-innovation. In this report, they address the vital role played by lean startups to orchestrate eco-innovative practices employing limited resources to provide scalable, sustainable solutions (Abbas & Liu, 2022, p. 340).

The concept of frugal innovation has become highly popular given that start-ups are able to innovate without significant investments made in infrastructure or capital costs. As argued by Abbas and Liu (2022), start-ups in developing nations have been using this kind of strategy to meet both the needs of affordability and sustainability. The start-ups generally have diagnostic issues in relation to the dynamics of the marketplace, regulatory requirements, as well as access to resources required to conduct sustainable innovation. The above notwithstanding, the frugal innovation competency that they have given them an edge over other companies by allowing them to make significant contributions to both economic as well as environmental sustainability (Abbas & Liu, 2022, p. 345).

Knowledge sharing is a critical success factor among these innovative start-ups. Efficient, systematic knowledge sharing is necessary as start-ups evolve. Tacit knowledge, based upon experiential knowledge, proves significant to the rapid innovation of such start-ups, as explained by de Andrade et al. (2023). Informal sharing of knowledge during routine interactions amongst workers speeds up innovation, as well as assists companies in adapting fast to changing markets. Formalization of practice in knowledge sharing becomes a necessity when start-ups are growing to upscale activities, as well as to ensure competitive edge (de Andrade et al., 2023, p. 10338).

Parallel to that, dynamic capabilities are also in the lead of facilitating innovation of startup business models towards sustainability. Oliveira-Dias et al. (2022) present that business model innovation are core since business model innovation calls upon startups to adopt emergent technology, as well as include sustainability in business operations. Dynamic capabilities facilitate startups to continue evolving indefinitely, as they adapt to environmental regulation changes, as

well as changing marketplace expectations. Dynamic capabilities incorporate sustainability practices in business model designs, from carbon footprint reductions to circular business designs (Oliveira-Dias et al., 2022, p. 108).

This is an argument shared by Abbas & Liu (2022) who argue that the application of lean practices to eco-innovation at the early start-up level can be long-term sustainable. Such start-ups make it possible to offer competitive pricing without compromising eco-sustainable solutions by giving due importance to lean manufacturing practices to reduce waste and maximize utilization of resources. These writers set a mandate to adopt agile practices to respond swiftly to evolving environmental needs as well as opportunities in the environment (Abbas & Liu, 2022, p. 350). Such agility coupled with committed sustainability enables such start-ups to contribute significantly to increased green innovation needs in the emerging economies.

Finally, the intersection of knowledge sharing, lean practices, and dynamic capabilities empowers startups to maximize the few resources at their disposal using sustainable innovation. The success of such startups in promoting sustainability, as observed by de Andrade et al. (2023), lies in the management and sharing of knowledge along with agility to deal with arising challenges and market prospects (de Andrade et al., 2023, p. 10338). By adopting these practices, emerging economy startup firms promote not only business development but also environmental sustainability at large.

2.5 Visual Concept Map: Integrating Lean, Sustainability, and Innovation

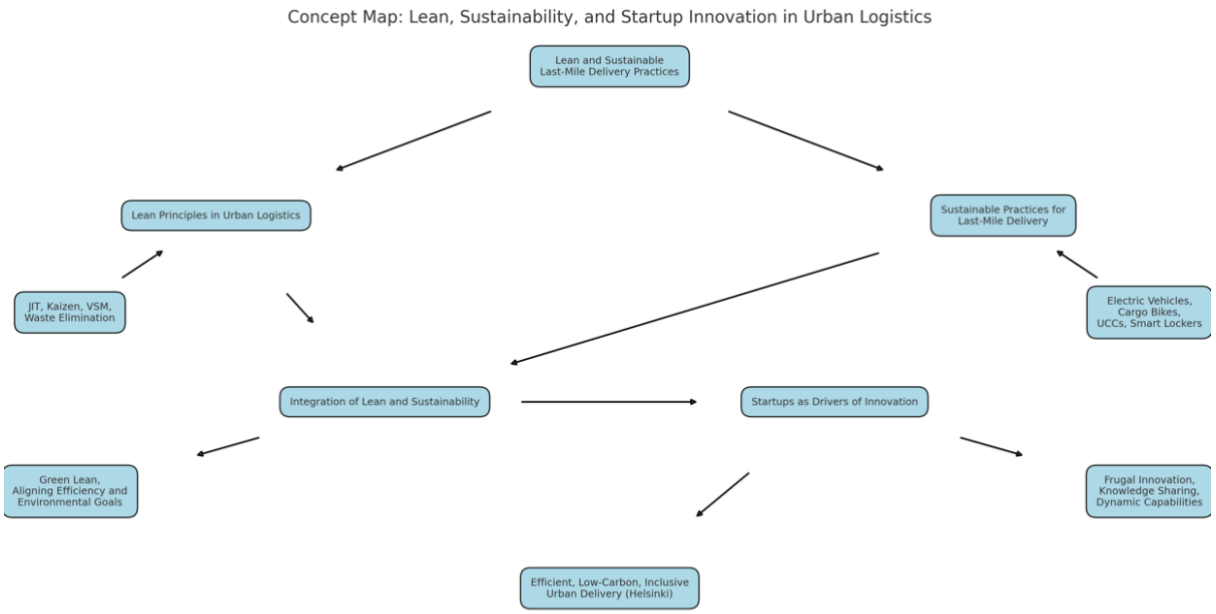

Figure 7: Visual Concept Map: Integrating Lean, Sustainability, and Innovation

A conceptual map combining the most important components of Lean principles, green last-mile logistics activities, as well as startup-generated innovation has been created to close the theoretical framework developed in this chapter (Figure 7).

The framework above shows the direction of this research guided by Lean philosophy which provides a basis of operational excellence using Kaizen, Value Stream Mapping (VSM), and Just-in- Time (JIT) techniques. Particularly in last-mile delivery, they focus on eradicating wastage, optimizing assets and enhancing responses in urban networks of logistics.

Together with Lean, sustainability also aims at addressing the core challenge of reducing the effects on the environment via green initiatives in the form of electric vehicles, urban consolidation points, smart lockers, and freight bicycles intended to curb carbon emissions, decongest traffic, and assist in eliminating inefficiency in urban freight transport.

Lean and green integration, also referred to as "Green Lean," unites operation optimization goals and environmental stewardship goals. However, this unification poses a conflict: Lean emphasis on

efficiency sometimes stands in contradiction to green needs (e.g., increased transport emissions from more-frequent JIT deliveries), requiring smart adaptation, along with system thinking to address these paradoxes.

Startups become an instrumental force enabling such integration. Startups combine frugal innovation, dynamic capabilities, and agile business designs to apply Lean-styled methods while, at the same time, integrating sustainability into urban logistics services. They design scalable, adaptable models that combine operational efficiency with societal as well as environmental goals.

These dimensions, when combined, move towards the common objective of this research: effective, low-carbon, and socially inclusive Helsinki Metropolitan Area last-mile delivery networks design. The abovementioned conceptual structure hence unites the most significant theory pillars, presenting a clear concept map that directs the empiric analysis as well as proposals presented in next chapters.

3 Research Design and Methods

The qualitative approach has been utilised throughout research in order to gain a deeper insight into inefficiencies and sustainability problems that plague last-mile delivery operations in the Helsinki Metropolitan Area. Qualitative research is especially suited where complex and context-dependent phenomenon is being researched since it provides rich insight into operational and environmental factors that may be problematic to measure (Silverman, 2021).

As per Saunders, Lewis, and Thornhill (2019), qualitative methods will be most effective where study aims to answer "how" and "why" questions on both societal and organizational dynamics and hence fit logistics systems where diverse actors interact in dynamic fashion together with changing contingencies. Lincoln (2021) also highlights why qualitative methods allow re-searchers to examine systems as experience, thus revealing how things really do work in real-world settings, structurally, through inefficiencies, as well as human dimensions of sustainability innovation.

Employing Lean principles in urban logistic contexts, the current thesis relies upon a qualitative exploratory design to determine operational limitations, sustainability gaps, and prospects of improvement space. Qualitative research never pursues statistical generalizability and rather aims at depth of context and theoretical richness (Lincoln, 2021; Saunders et al., 2019). This research also gives importance to methodological consistency in turn, which is a principle of twenty-first-century qualitative research. By methodological consistency we refer to the fact that research philosophy should accompany approach and methods in order to complement them and to guarantee internal consistency and evidence authenticity (Poucher et al., 2020). Building blocks of the research — problem identification, method selection, data gathering and also data analysis — have been designed to be in tune with the exploratory nature and a constructivist perspective to study lean-sustain-ability combinations in urban logistic circumstances.

The qualitative perspective also allows research to be conducted on a multilevel level that combines macro-level structure dilemmas (infrastructure and regulation and climatic targets) with day-to-day action on a micro-level (warehouse tasks, delivery routines, and innovation in start-up firms) (Köhler, 2024). Qualitative research on a multi-level level is capable of enabling researchers to analyze dynamic interaction among systemic determinants and actor behaviors in a way that identifies the processes through which last-mile logistics sustainable innovation emerges and diffuses in cities.

Briefly stated, a qualitative method has been chosen to provide rich, descriptive and practically informed opinions of what Lean thinking can be used in order to make the last-mile logistics of Helsinki more sustainable. The research method in this chapter ensures that the subsequent empirical investigation is firmly context bound in addition to being rigorous in relation to its purpose.

Table 1. Overlay Matrix

Investigative Question (IQ)	**Theoretical Framework**	**Research Methods**	**Interviewees**	**Results/Outcomes**
IQ 1. What inefficiencies exist in last-mile delivery systems in the Helsinki Metropolitan Area?	Lean logistics practices include JIT, VSM, Kaizen	Semi-structured interviews; Qualitative thematic analysis	Interviews 1-5 (2 Lean Experts, 3 Last-Mile Operators)	Identification of Priorities: congestion, missed deliveries, lack of communication with customers, utilization of vehicles, fragmented business processes
IQ 2. How can Lean principles—specifically Just-In-Time (JIT), Kaizen, and Value Stream Mapping (VSM)—address these inefficiencies?	Lean logistics adaptation in urban regions; Process flow optimization	Semi-structured interviews; Theoretical framework analysis	Interviewees 1-2 (Lean Experts)	Lean concepts improve operations through increased delivery accuracy (JIT), waste minimization (VSM), as well as incremental improvement in processes (Kaizen)

Investigative Question (IQ)	Theoretical Framework	Research Methods	Interviewees	Results/Outcomes
IQ 3. What benefits can be achieved by integrating sustainability goals with Lean practices in urban last-mile logistics?	Green Lean integration, or Lean sustainability: The innovation contribution of start-ups	Semi-structured interviews; Startup case analysis	Interviewees 3-10 (Startups, Innovation Organizations)	Lean combined with sustainability brings emissions reductions, added resource optimization, besides higher levels of consumer satisfaction. Start-ups introduce agility, together with frugal innovation, to sustainable logistics platforms.

Table 1 illustrates the overlay matrix that has been used in the conduct of research here to link research queries with theory, methodology and participants, and expected end products. By linking empirics and theory in a harmonious context, methodology consistency is ensured in such a way that qualitative exploration of the possibility of merging Lean thinking and sustainability goals is enabled to achieve improved Helsinki Metropolitan Area last-mile delivery performance.

3.1 Research Design

A qualitative case study methodology applies to examining how Lean concepts are paired with sustainability goals in last-mile logistics networks in the Helsinki Metropolitan Region. Case study enables a phenomenon to be examined in its real-world context, particularly where boundaries are not clear between phenomenon and context (Saunders, Lewis & Thornhill, 2019; Lincoln, 2021). Investigating operational practices, stakeholder relations, and innovation contexts, attention shifted to knowledge of systemic inefficiencies as well as sustainability-related urban logistics issues.

The case-study approach was adopted as it was able to break open challenging, context-related issues like those facing last-mile delivery mechanisms. It provides a space for in-depth inquiry—through field interview, literature, and thematic synthesis—to facilitate development-oriented recommendations on urban logistics. Great emphasis is put on maintaining methodology consistency, i.e., ensuring consistency across analysis strategy, design, and research philosophy (Poucher et al., 2020).

It allows empirically grounded field studies to be coupled more easily with theory-guided insight into Lean and sustainability-focused paradigms in logistics. Non-representative, in-depth analysis of ten semi-structured field interviews of logistics operators, Lean experts, and startup innovators, but not statistical representativeness, is what we pursue here. Instead, we seek to yield meaningful insight into Lean applicability to real urban sustainability change.

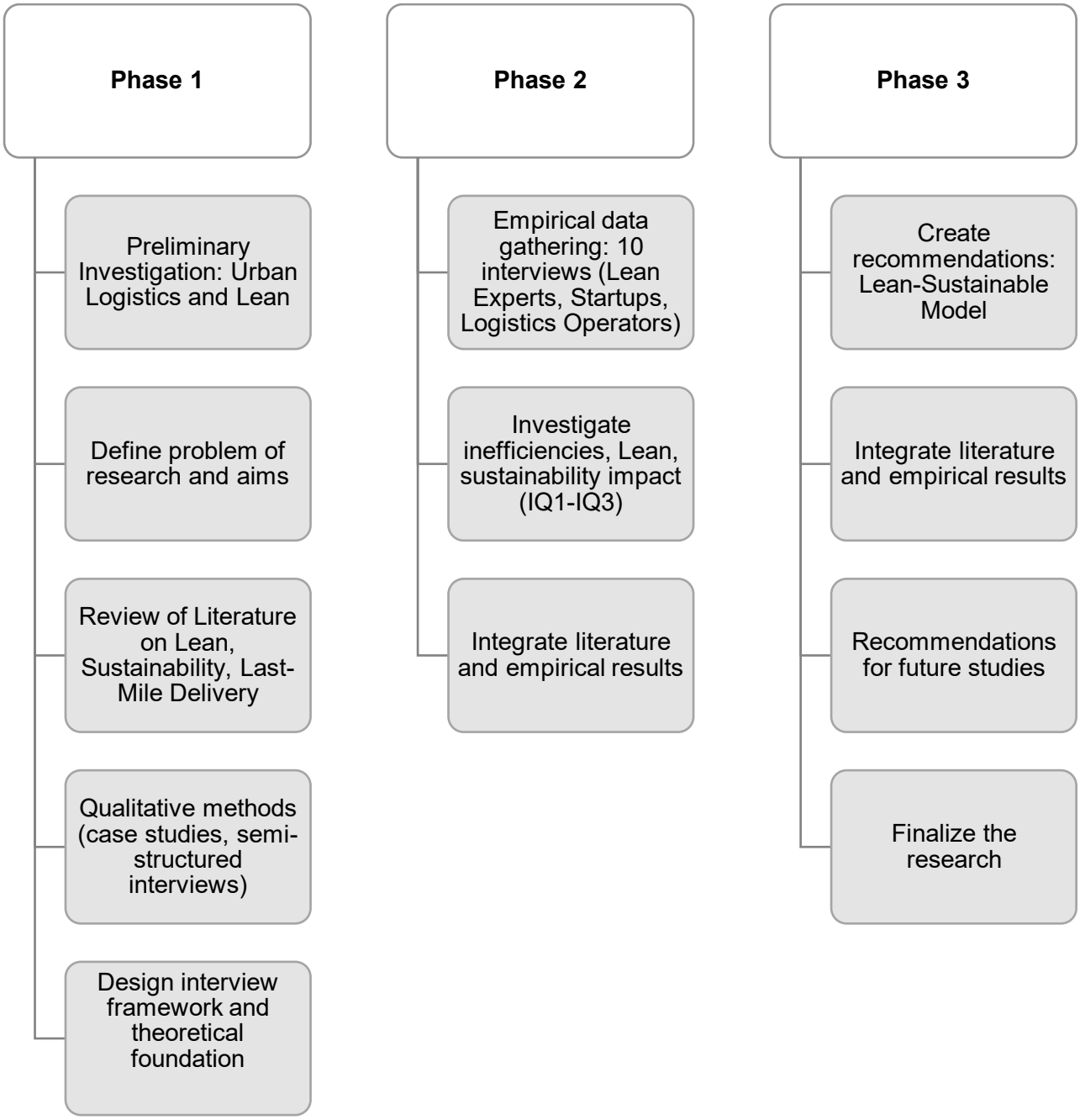

Figure 8. Research design model outlining the three phases of this study

The design model used throughout this work has been depicted in Figure 6, outlining tri-phased characteristics of approach to the research: theory foundation and planning; data gathering; synthesis of evidence and writing up. The graphic design allows for transparency and replicability, so that each phase from problem establishment through generation of recommendations follows a clear, step-by-step set of steps.

3.2 Data Collection: Expert Interviews

To analyze the research questions and establish context-specific knowledge, in this study, qualitative data were collected using semi-structured expert interviews as its main data gathering technique. Expert interviewing has been widely considered a robust means of collecting rich, practice-sensitive views from individuals possessing domain-specific knowledge (Flick, 2018). In this research, professionals from Lean consultancy, logistics operations, urban transport, and startup innovation were interviewed. They were chosen based on direct implementation involvement in practices of last-mile delivery in Finland or Lean and sustainability integration knowledge.

The interviews were carried out from January to March 2025, largely through Google Meet. Each interview was 40-55 minutes in length. Consistent with qualitative inquiry's requirement of methodological coherence, interview design aimed to ensure congruence between the data gathering approach, theoretical foundation, and the goals of the analysis (Poucher et al., 2020). Questions were derived from the theoretical pillars of Chapter 2, framing around this research's three inquiry questions. Although all interviews were centered around central themes of Lean fundamentals, inefficiencies in last-mile delivery, integrating sustainability, and startup innovation, interview-specific questioning was designed to align with each respondent's background. Lean experts were queried more in-depth about operation optimization, applications of Lean tools relative to urban logistical networks (IQ1, IQ2), whereas startup innovators, as well as operators in logistics, were queried on pragmatic sustainability issues, real-world installation examples (IQ2, IQ3).

This flexible approach facilitated deep insight while maintaining consistency and theoretical coherence. Semi-structured guides were employed to conduct interviews, allowing room for open-ended discussion and clarification without compromising on the thesis' fundamental goals (Silverman, 2021; Saunders, Lewis & Thornhill, 2019). Through making possible adaptability, interviews revealed unforeseen pitfalls and observations a single-question approach might have missed, hence enabling a richer, more empirically informed, understanding of Helsinki's last-mile logistics environment.

All interviews were anonymized and transcribed to ensure ethical consideration during analysis. No interviewees have been identified by organization or by name in this thesis, adhering to data protection laws and standards of research ethics. An outline of interview questions and respondent types can be found in the Appendix 1.

3.3 Data Analysis Techniques

Thematic analysis was employed in this thesis as the primary method of data analysis. In accordance with the way that Braun and Clarke (2006) have defined them, thematic analysis is a qualitative method of analysis that is used to discover, examine and interpret patterns—'themes'—in qualitative data. It has been stated to be a highly flexible and user-friendly method of research in applied qualitative research in particular. In the current study, thematic analysis was chosen because of its use in handling complicated operational and societal problems, e.g., urban delivery system inefficiencies, challenges to integrate sustainability and implementation realities of Lean in city logistics.

The interviews were taped and transcribed verbatim and coded with a coding scheme that captured latent and semantic patterns in the data set. Individual transcripts were cod-ed carefully and cross-compared to allow recurring concepts relating to the research themes of operational pinch points, environmental trade-offs, and strategic responses of startup and logistics professionals to be surfaced. Inductive themes were constructed, i.e., those developed from data and not forced by a priori coding scheme so that context-laden insight was allowed to surface and allow subjective expert opinions to be captured in Helsinki’s last-mile delivery context.

The methodological underpinning of this research was also descriptive phenomenological because of the dynamic thematic model proposed by Ozuem, Willis, and Howell in 2022. Their model of five steps—scoping and excavation, data segmentation, manifestation and categorization, development and refining categories, and finally meaning-making and consolidation—proved best suited to structure the research process in this thesis. In these steps, immersion in data, conceptual link classification, and recursive interpretation are the focal points. Such a multi-layered approach in order to understand individual experiences of Lean logistics' implementation in the context of systemic urban logistic problems is critical here.

The research analytic strategy of the study was also phenomenologically attentive to permit more richly construed interpretation of stakeholder narratives. According to the argument of Ozuem et al. (2022), that is recognizing interpretative practice to be what drives themes since human action, operational routines, and innovation culture are in fact context-embedded. Thematic analysis here was not intended to be a routine exercise in codes but a sensemaking exercise in the lifeworld of logistics professionals, Lean experts, and innovators in startups.

Analytical rigor was guaranteed in this process through a triangulation of thematic patterns both with theoretical concepts and multiple types of interviewees. Such triangulation guaranteed

increased validity of resulting insight prior to final interpretation, as well as determining areas of variance across stakeholder groups. Empirically informed and practically applicable insight into the way Lean and sustainability may be combined was developed in the end through thematic analysis in relation to increasing Helsinki's last-mile delivery performance.

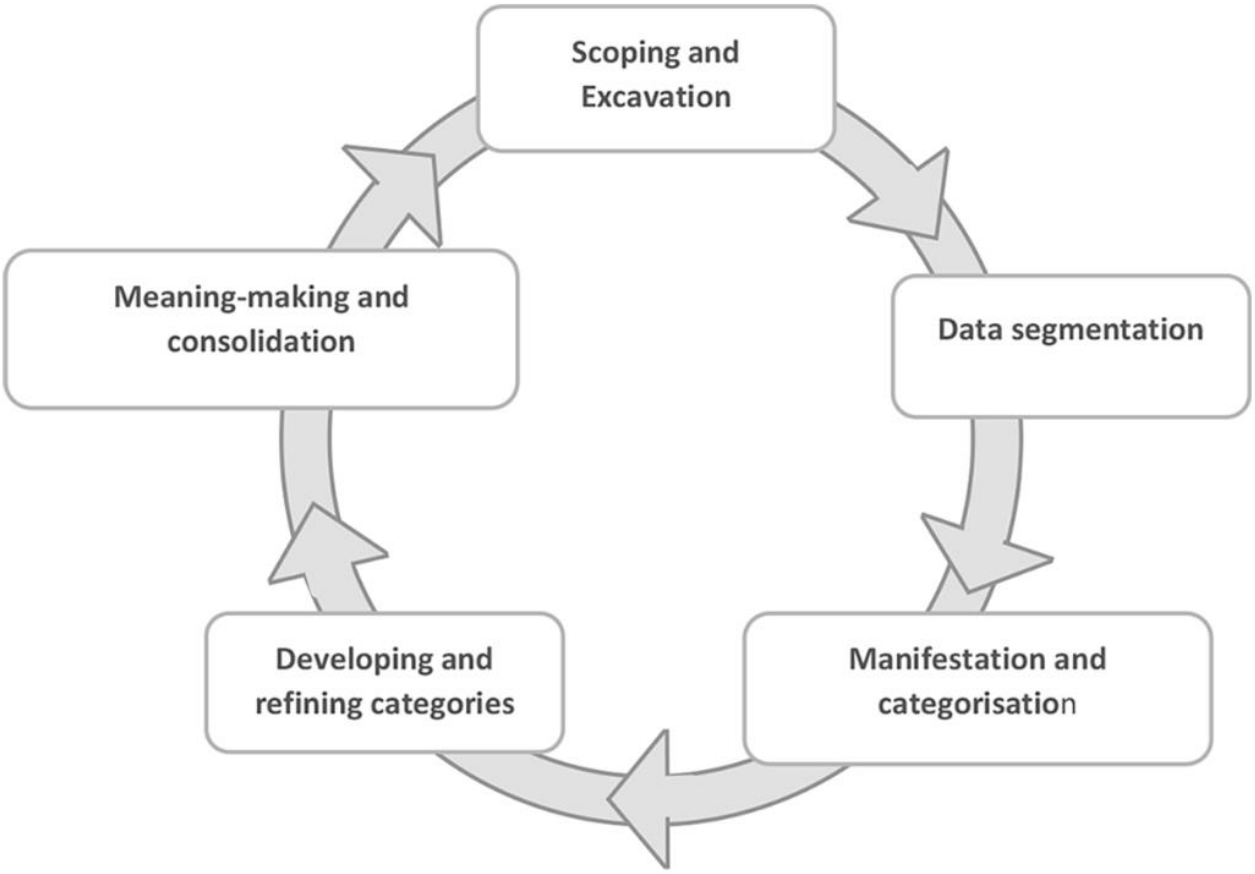

Figure 9. Dynamic Thematic Analysis Process (Ozuem et al., 2022)

The following diagram in Figure 7 shows the cyclical thematic analytic process that was employed in the current thesis. Adapted from Ozuem et al. (2022), scoping and excavation steps, segmentation of data, manifestation and categorisation, development and refinement of categories, and meaning-making informed the analytical process from data immersion through interpretation of deeper patterns of themes Back-and-forth in this continuous cycle enabled the researcher to move between raw data, emergent conceptual themes with the aim of maintaining coherence and responding to rich, layered realities in Lean and sustainable last-mile logistics in Helsinki.

3.4 Risks and Limitations

Though in itself good methodology-wise in terms of research design and suitable to this research study, there exist some inherent risks and limitations which need to be noted. Firstly, qualitative research is by its very nature susceptible to researcher bias where interpretations of interview information can be vulnerable to being tainted by a researcher's personal perceptions. In mitigating against the risk that this was achieved, the study was stringently dedicated to a systematic thematic coding and analysis process, ensuring that findings were maintained firmly in focus with raw data in mind and without contamination by prior assumptions and expectations (Flick, 2018).

A further limitation relates to the relatively modest number of expert interviews carried out. Though ten interviews yielded rich and varied views on Lean practices, sustainability issues, and last-mile logistics phenomena, the sample size necessarily limits generalizability of the results. Case study methods, nevertheless, prioritize richness over breadth, as noted by Yin (2018), in pursuit of detailed, context-specific insight as opposed to statistical generalization. The findings are hence highly applicable in the context of the Helsinki Metropolitan Area urban context and logistics environment.

Additional risks were potential inconsistency in participants' expertise and views. Interview participants were from various backgrounds in organizations—Lean consultants to logistics startup companies—which, although enriching, brought variations in areas of interest and vocabulary. Such variance was controlled through meticulous modification of interview questions to suit a participant’s field of expertise and stringent thematic synthesis in analysis.

Moreover, since the time when this study was conducted was a time of evolving technology and environments, where new innovations in green logistics and urban mobility were being made at an accelerative rate, there is a built-in potentiality that any practice covered by this assessment would change, or be replaced by newer innovations, shortly after this study concludes. The assessment addresses this limitation by framing its observations in the contemporary context of 2025, and outlining potential areas of future research to track advances made from then onwards.

Lastly, these constraints and risks are present but were rigorously addressed throughout the course of the research, in a way that maintains methodological consistency, analytic rigor, as well as applicability to the goals of this research.

4 Interview Results

The study's main empirical insights from ten semi-structured interviews with Lean specialists, logistics professionals, and start-up innovators from January to March 2025 are discussed herein. Thematic analysis was employed to organize responses in terms of the three investigative questions (IQ1–IQ3) with distinct dimensions to the Lean–sustainability nexus in the context of last-mile logistics. To maintain anonymity and to be compliant with ethical standards, all participants in the interviews remain fully anonymized and cited only by interview number. No professional, organization, or personal information is revealed. The findings below are organized in response to the research questions and thematic categories and synthesized from the anonymized transcripts.

4.1 Inefficiencies in Delivery Processes

To maintain anonymity and to be compliant with ethical standards, all participants in the interviews remain fully anonymized and cited only by interview number. No professional, organization, or personal information is revealed. The findings below are organized in response to the research questions and thematic categories and synthesized from the anonymized transcripts.

The interviews uncovered a range of inefficiencies which continue in last-mile delivery systems of the Helsinki Metropolitan Area under circumstances of growing urban density and increasing expectations of e-commerce. One of the major themes among respondents was the incomplete or ineffective implementation of Lean principles in areas of logistics beyond manufacturing. For Interviewee 1 (2025), many of the firms which had successfully instituted Lean methods on the factory floor had not been able to translate them to supporting functions like urban delivery.

Interviewee 2 (2025) reinforced that operational inefficiencies remain in the technology and people handoff. Although delivery applications and routing algorithms have been advanced, companies remain squandering time on manual customer communications, failed delivery attempts and fragmentation of coordination among delivery actors. Interviewee 2 states that incompatibility between customer expectations (specific delivery windows or customized drop-offs) and capacity results in excessive use of vehicle kilometers and redundant service.

Respondent 3 (2025) also asserted that delivery density in inner Helsinki is uneven and causes frequent under-usage of delivery vehicle capacity. Parcels often travel in half-full vans, particularly during off-peak delivery times or during poor weather conditions. This result is in-line with observed patterns in urban transport where light commercial vehicles frequently use less than optimal capacity in inner city areas.

A further matter of concern mentioned by Interviewee 4 (2025) is the lack of standardized roadside facilities for delivery. Numerous delivery drivers must double-stop or stop in the wrong places to gain entry to the building with no allocated delivery zones — a matter mentioned by several respondents as a constant source of inefficiencies and traffic congestion and of wasted time. This is compounded in dense urban areas where delivery to apartment complexes with limited access control systems takes additional time per stop.

Interviewee 5 (2025) also referred to operational inefficiencies caused by suboptimal data integration among logistics partners. In shared delivery networks where packages pass through several subcontractors, the lack of common information platform results in route duplications, dispatch of extra vehicles, and constant miscommunication. Interviewees 6 and 7 (2025) concurred that particularly during peak seasons, the lack of visibility of parcel flow in real-time decreases the capacity to re-allocate capacity in a dynamic way.

Finally, Interviewee 8 (2025) reminded that even though green delivery pilot schemes like cargo bike delivery and micro hubs were launched, their geographical cover is limited. Without strategic scaling and policy support at the municipal level, these also remain niche experiments with limited overall impact on performance of the systems.

Overall, the literature shows that last-mile logistic inefficiencies come not just from technologically driven deficiencies, but from deeper systemic misalignments between urban infrastructure, stakeholder collaboration, and inadequate unified Lean adaptation strategies. These limitations will be explored in more detail in the next section because the research continues to investigate Lean solutions tailored to Helsinki's urban setting.

4.2 Environmental Impacts of Current Practices

A general thread throughout expert interviews was the environmental effects of existing Helsinki Metropolitan Area last-mile logistic methods. Repeatedly mentioned by respondents was the contradiction in increasing consumer demand for rapid delivery and the need to constrain impact on the environment in the form of carbon emissions at the same time. This was described by various interviewees as a structural contradiction which ensures that urban sustainability is never attained.

According to the Finnish Transport and Communications Agency (Traficom, 2023), transport emissions cover some 20% of Finland's total of greenhouse gases, and 96% of them come from the road transport sector. Within urban environments like Helsinki, these emissions become even

more focused on particular areas of high density in which commercial vans run inefficiently and create much of the traffic congestion and localized air pollution. Underlying such challenges is the City of Helsinki's Carbon Neutral 2030 Roadmap in which a transport sector reduction of 69% by 2030 is proposed (City of Helsinki, 2024a). Interviewees questioned constantly the achievability of that without changing delivery operations on a systemic level, investing in infrastructure, and policy reform.

Interviewee 1 believed where cost of operations is cut down by elimination of wastage with Lean initiatives like 'first-time right' delivery and routing optimisation, customer demand is dominated by speed of delivery in most case studies. In confirmation of Interviewee 1, speed of delivery is typically inefficient and unbundled routing which maximizes the vehicle kilometers travelled (Interviewee 1, 2025). It was concurred with by the second interviewee that whereas routing optimisation is undertaken by some carriers to save cost, general efficiency is never achieved because of chaos in coordination among carriers, retailers, and consumers.

Environmental limitations were also reflected in the challenges of embracing electric delivery vehicles (EVs). Interviewee 2 noted that although EVs are considered to be low-emissions option, their operational effectiveness in Helsinki is hindered by lack of charging points and decreased efficiency when the weather is cold (sub-zero degrees). "Charging points in busy areas are few and battery efficiency plummets in sub-zero weather," they stated (Interviewee 2, 2025). These findings corroborate transport sector studies that recognize charging facility readiness and weather resilience to be significant deterrents towards electric vehicles deployment in Nordic cities (Traficom, 2023).

Both interviewees 5 and 6, being practitioners of logistic operations, commented on other inefficiencies—namely, the number of “empty returns” in vehicle routing. Vehicles oftentimes return from delivery runs with nothing in them and so without payloads, duplicating emissions per trip. This is supported by national statistics that indicate average fill levels in light commercial vehicles below 60 % in cities (Traficom, 2023). Interviewee 5 added that “We’re burning fuel and creating carbon even with vans that are empty. It’s one of the most glaring inefficiencies that we’ve yet to fix systematically.”

Challenges of sustainability are also exacerbated by capacity disparities between large and small logistics operators. Interviewee 7 emphasized that whereas larger operators are experimenting with electric vans, AI-aided route optimization, and carbon footprint tracking tools, smaller operators cannot access or finance such technology. “There’s a significant innovation gap,” they

opined, “and in the absence of public investment or shared infrastructure, we risk having a lopsided playing field” (Interviewee 7, 2025). Interviewee 8 echoed this by underlining shared micro-depots and public-private partnership importance to decentralize and decarbonize last-mile delivery.

Digital innovation was identified as a promising area of environmental improvement. Interviewee 3 mentioned pilot schemes that Forum Virium Helsinki has been funding to pilot autonomous delivery robots and shared smart locker networks. These pilot schemes show scope to eliminate unrequired journeys and emissions but, in respondents' opinions, need to be scaled with supportive policy to deliver significant change.

Overall, though Helsinki has been commendably committed to cutting transport emissions, the ecological footprint of last-mile delivery is compounded by fragmentation in logistics, lack of adequate infrastructure, and incoherence between consumer demand and sustainability imperatives. Interviews reinforce that Lean thinking has to be harmonized with ecological ambitions on the basis of a systemic approach that aligns technological innovation with municipal incentives and attitude shift in the logistics ecosystem.

4.3 Operational and Customer-Centric Challenges

A shared operational problem that was mentioned by respondents was the ongoing challenge of aligning last-mile delivery logistics with consumers' immediate wants and behaviors. Interviewee 1 (2025), being a Lean practitioner in a senior capacity, mentioned that most delivery service carriers persist in over-producing delivery services ahead of what consumers want even where Lean initiatives focus on reducing operation complexity. This causes avoidable inefficiencies in the way of duplicate vehicle dispatches and low fills. Interviewee 3 (2025), who has operational management responsibilities, also stated that demand misalignment between planned and actual demand tends to result in duplicative trips and routing capacity over-allocation.

One particular inefficiency that was named was the lack of use of delivery lockers. While companies more and more regard lockers as a remedy to last-mile inefficiencies—especially in preventing failed delivery—consumers' uptake is low. Interviewee 1 (2025) was firm that while locker networks are growing in Helsinki in general, consumers are not yet sufficiently informed about utilizing them or regard them as too much of a bother. This creates extra operational expenses to businesses in form of multiple delivery attempts to failed parcels with significant idle times waiting to be delivered. Higher public-private information campaigns and easier-to-use app interfaces were put forward by Interviewee 5 (2025) to be next measures to increase locker use and cut the cost of the last mile.

As far as customer-focused expectations of service go, delivery flexibility in terms of timing and location was considered paramount. Interview 2 (2025) is a founder of a start-up and works in the field of logistics and explained that providing real-time tracking equipment and preferable delivery times greatly enhances the customer experience. These functions remain inadequately supported by delivery platforms in Helsinki. Such unevenness causes customer expectations to be left unmet and losses in the form of missed pickups and rescheduling by hand.

These results support the general conundrum of balancing expectations of high-level servicing and slim operating margins. In Lean philosophy, operations should be engineered to remove waste and maximise customer value (Slack et al., 2022). But without the proper digital foundations so that near-simultaneous coordination with consumers is enabled—e.g., routing optimisation through machine technologies and predictive delivery windows—both efficiency and satisfaction aspirations are being compromised, argues Interviewee 4 (2025).

Operational inefficiencies also reinforce each other through incoherent regulation of shared facilities since Interviewee 6 (2025) indicates that municipal zoning regulation and ambiguous maintenance duties on shared lockers and micro-depots hinder deployment in densely populated residential areas in particular. Such regulatory resistance was identified as a non-technical and high-impact reason that discourages both operational optimisation and user access.

Finally, the section uncovers a systemic misalignment between what Lean logistics models prescribe—waste removal, demand alignment and process improvement—and what is delivered by current urban last-mile operations. To fix it, coordination has to be enhanced among city planners, logistical operators and consumers, in conjunction with investment in technologies to support more flexible and adaptable delivery operations.

5 Developing a Lean-Based Framework for Sustainable Last-Mile Delivery

The design of a Lean-based model of sustainable last-mile delivery in the Helsinki Metropolitan Area is based on empirical evidence and extant scholarly literature in the field of optimisation in logistics. The chapter synthesises interview evidence and peer-reviewed theory to create a context-sensitive and operationally realistic model of implementing Lean measures with green goals in urban delivery networks.

The design is cognizant of the design and behavioral aspects of city logistics. Underpinning is the use of Lean philosophy—Just-in-Time (JIT), Kaizen and Value Stream Mapping (VSM)—in the removal of wastage in the last-mile processes. Such measures are known to eliminate wastage, rationalize the functions and improve the accuracy of the service (Slack, Brandon-Jones & Johnston, 2022; Protzman, Whiton & Kerpchar, 2018). While carrying out logistic functions in places like Helsinki where coordination with the stakeholders and weather and city planning is what poses the challenge, such concepts may be used to guide operations in accordance with actual-time limitations

The model also draws upon Wang, Li, and Lu (2023) model design research in order to study the siting of centers' impact on sustainability metrics that consist of carbon footprint, traffic congestion, and delivery time. Their study shows that routing policy and center site in comparison to the city center affect the performance of logistics and accrual cost to the environment. Incentivizing routing that minimizes travel time has been shown to improve cost and service performance and mitigate emissions that in turn equate Lean operational targets to climatic targets (Wang et al., 2023).

Findings from interviews conducted in this study also reinforce the need for such a comprehensive model. Interview respondents all identified incoherent coordination among actors, limited use of vehicles, and reactive rather than anticipatory delivery planning as major challenges to be overcome. These examples reveal missed chances to implement Lean thinking—namely in demand planning, delivery planning and routing planning—all of which result in operational wastage and additional emissions (2025; Interviewees 1, 3, 5, 7).

Moreover, innovation is embedded in the model by startups with the application of startup-like methods. Startups in some of the interviews set forth agile method-ologies and frugal innovation and speed-testing capabilities that can prototype decentralized delivery models and green solutions more cost-efficiently than the large existing players in the logistic industry.These dy-namics align with research by Abbas and Liu (2022) that finds that lean-focused startups can be

agents of sustainable innovation through decreased input require-ments and increased social and en-vironmental impact.

As a collective, the model in this chapter is designed to be taken from theoretical and empirical strata to support sustainable urban freight transport. It provides a strategic synthesis of Lean philosophy, ecologically adaptable planning of the transport structure, and mechanisms of innovation—all to transform last-mile delivery into an efficient low-carbon and inclusive mode of delivery.

6 Proposed Framework Lean and Sustainable Last-Mile Delivery

6.1 Overview and Key Indicators

To meet Helsinki's 33.6 % parcel-volume growth during 2019–2021 and 35 % holiday-season peak and meet the city's target to cut transport carbon emissions by 69 % in 2030, this chapter suggests a shared five-step approach. It combines Lean philosophy, green KPIs and digital modules in a cycle of continuous improvement. Winter weather reduces cargo-bikes' speeds by over 25 % (Dybdalen & Ryeng 2021), transport accounts for 21 % of Helsinki's CO_2—light-commercial vans alone contributing some 4.2 % (City of Helsinki 2024)—and light-commercial vans' average fill factors remain below 60 % (Traficom 2023). Table 2 brings these statistics together that in aggregate call for a design that addresses operational efficiency and decarbonization concurrently.

Table 3. Key Performance and Environmental Indicators

Indicator	Value
Parcel-volume growth (2019–2021)	33.6 %
Holiday-season peak upswing (Nov–Dec)	35 %
Winter-time cargo-bike speed reduction	>25 %
Transport share of Helsinki's CO_2 emissions (2023)	21 %
Vans' share of transport CO_2 (2023)	4.2 %

Table 3 consolidates the metrics that underpin the framework: rapid volume growth (Posti 2023), seasonal performance degradation (Dybdalen & Ryeng 2021), environmental impact (City of Helsinki 2024, 9) and suboptimal vehicle utilization (Traficom 2023).

6.2 Framework Phases

The model is developed through five stage-based, iterative steps that cumulatively build upon each other. During the Pilot Deployment stage, a theoretical micro-depot in a representative district—Ruoholahti being a prime example—would see ICT specialists, logisticians and carriers' partners work together to design the process flow, plan consolidation bays and electric and biogas charging points and roll out a real-time order dashboard. Under rules of Just-In-Time dispatch of cargo-bikes

and electric vans, it would set baseline standards in the metrics of lead time, fill rate and first-time delivery success and thereby guide the priority of all the following steps (Slack, Brandon-Jones & Burgess 2022).

With these fundamentals in place, Value-Stream Mapping and Kaizen renders the stated process steps into a complete end-to-end Value-Stream Map—from modeled warehouse reception to micro-depot sorting and ultimate delivery to expose waste-causing activities. Weekly Kaizen sessions engage all involved parties to focus on measures to eliminate waste (such as streamlined loading patterns and grouped routing), set up rapid "one-week" improvement rushes, and verify gains in performance via ongoing metric monitoring (Wang et al. 2023).

With efficiency measures in motion, Sustainability Integration incorporates eco-friendly KPIs—quantifying CO_2, NOx and particulate emissions per delivery—into every iteration. Local renewable-electricity and biogas supply chain partners underpin zero-emissions operations and reduce life cycle footprints, and subsidized “green delivery” time slots encourage consumers to use lower-impact alternatives (Silva, Alho & Fernandes 2023).

Capitalizing on these achievements, Technology and Data Scalability utilises a modularity-enabled IT architecture—consisting of routing-optimization APIs, interoperable dashboards and a centralized telematics data lake—in order to roll out the model in two-week increments to Espoo, Vantaa and Kauniainen. This plug-and-play model minimizes integration friction and speeds up regional deployment.

Lastly, Governance and Partnerships institutes a structured oversight process. On a month-by-month basis, a Steering Committee of ICT leads, urban planners, and logistics professionals reviews KPI dashboards to improve strategic priorities. Concurrently with that, fortnightly public-private forums with Helsinki Smart Mobility coordinate on regulatory enablers of low-emission zones and siting of micro-depots (Slack, Brandon-Jones & Burgess 2022).

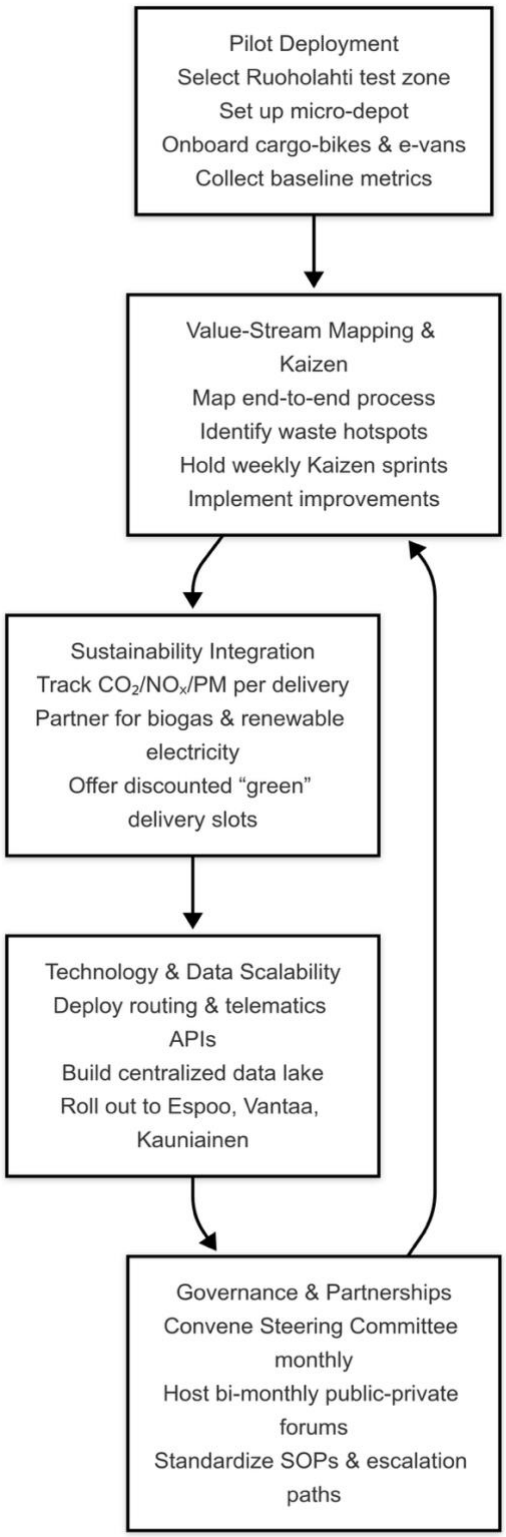

Figure 10. Process Flowchart

The five consecutive and cyclical steps in the planned framework and illustrated in Figure 10 include Pilot Deployment; Value-Stream Mapping and Kaizen; Sustainability Integration; Technology and Scalability in data; and Governance and Partnerships. Plan-Do-Check-Act is the cycle that acts as the backbone of Lean and sustainability integration and is captured in this return loop from Governance to Value-Stream Mapping (Slack, Brandon-Jones & Burgess 2022).

Table 4. SIPOC

Suppliers	Inputs	Process Steps	Outputs	Customers
Fulfillment centres	E-commerce parcels	Receive parcels	On-time deliveries	Online shoppers
Parcel carriers	Order & origin data	Sort and consolidate	Delivery confirmations	Local residents
Municipal authorities	Traffic and zoning	Dispatch to doorstep	Clustered “green” runs	Businesses and NGOs

Table 4 identifies stakeholder roles and information flow by placing Suppliers (fulfillment centers, local authorities) onto the row and column list of Inputs (parcels, traffic patterns), Process steps (receive, sort, dispatch), Outputs (timely delivery, group runs) and Customers (online consumers, local businesses). Proposed roles and flows based on expert interviews and process mapping.

Table 5. Value-Stream Map: Time, Emissions and Waste

Stage	Time	CO_2	Waste
Warehouse	45 min	2 kg	3 kg
Loading	45 min	2 kg	1 kg
Transport	1 hr	1 kg	2 kg
Sorting	35 min	1 kg	1 kg
Doorstep	20 min	3 kg	1 kg

Time estimates and estimates of waste according to framework design assumptions; CO_2 factors from Helsinki 2024 municipality (Table 5).

Table 6. Consolidated Scaling Timeline

Phase	Duration
Pilot Deployment	4 weeks
Value-Stream Mapping and Kaizen	Ongoing
Sustainability Integration	4 weeks
Technology Roll-out (per city)	2 weeks
Governance & Partnerships Setup	2 weeks
Continuous Improvement Cycles	Indefinite

Table 6 consolidates realistic phase times informed by pilot planning standards and reported city logistics roll-outs (Slack et al. 2022).

Potential challenges of public resistance to siting micro-depots, costs of ICT integration and seasonal demand fluctuations are countered by embedded stakeholder participation, phased budgeting of technology and capacity planning adaptation during the Governance phase.

By combining Lean methods with digital scalability and environmental KPIs in one iterative cycle—and explicitly handling risks—this innovative framework enhances Helsinki's efficiency and decarbonisation goals and contributes new insights to Lean-sustainability integration in city logistics.

7 Conclusion

Efficiency and environmental sustainability of Helsinki Metropolitan Area's last-mile delivery has been explored in this research by applying Lean and sustainability concepts. It has been established that urban logistics stands at a crossroads in its history from interaction with policy documents, systematic review of peer-reviewed journal literature, and qualitative data from expert interviews. This change is driven not just by Green regulation and customer demand but also by operational ineffectiveness that reduces flexibility and performance in densely populated areas. By applying Lean methods of Just-In-Time production, Kaizen and Value Stream Mapping to the context of urban freight transport, the research shows that delivery systems can be streamlined and environmentally improved. These findings add usefully to the literature on sustainable logistics and to the practice of those working in Helsinki and similar urban milieux.

7.1 Key Findings

The studies uncovered that existing last-mile logistics in the Helsinki Metropolitan Area is hindered by disjointed infrastructures, lack of cooperation between delivery networks, and inefficient use of real-time digital tools. While the city has ambitious sustainability targets, most of the logistics functions remain tied to isolated methods where data is not shared effectively, neither are the resources nor related infrastructure shared effectively. From expert interviews and document studies, the research underscored the need for cooperative planning and the use of streamlined and agile systems immediately.

Lean frameworks' analysis revealed that principles of traditional manufacturing industry can be successfully translated to the delivery context of cities. Just-In-Time methods, applied to optimizing routes and inventory distribution in the use of micro-depots, can minimize unproductive mileage and warehouse dwell times. In turn, Kaizen thought has proved beneficial in continuous process improvement in particular in coordination among public authorities and private carriers. Implementation of the Value Stream Map, a key Lean diagnostic tool, has helped map latent delivery cycle inefficiencies and support data-based decision-making.

A most relevant discovery is one concerning the overlap of operational and sustainability goals. Statistical evidence indicated that measures to limit emissions usually come in conjunction with those to enhance process efficiency. Cutting down on carbon emissions through the shift to bicycle couriers and electric cars in city centers reduces traffic congestion and increases delivery confidence in addition to cutting carbon emissions. Such double-bottom-line practice demonstrates

the synergism of Lean philosophy and sustainability towards achieving a robust and vision-oriented urban transport paradigm.

7.2 Recommendations for Logistics Stakeholders

All parties significant to Lean and sustainable last-mile delivery need to pledge long-term strategic alignment and systemic change in order to achieve maximum value from Lean and sustainable delivery in the last mile. For logistics operators, municipal planners, and technology developers, the study suggests setting up a joint network that enables the sharing of information in near-real time, joint facilities, and compatible performance measures. This involves reconfiguring the geo-graphic distribution point plan in Helsinki so that shared-use micro-depots catering to multiple carriers and cut-optimization in the last-mile zones is maximized to its full extent.

Urban authorities stand to drive such change in particular by implementing Lean-based selection standards in purchasing contracts and incentive policies to encourage innovation and recognize those that achieve concrete efficiency gains and greater sustainability. In addition, there is a pressing need to enhance capacity among public sector actors who are largely uninitiated in continuous improvement tools.

Private freight operators should invest in internalization of Lean philosophy outside the warehouse walls. This should entail extending value stream thinking to the entire delivery chain from order intake to end delivery and rewarding employee innovation at the operational level. Cross-industrial forums and public-private pilot schemes can be key venues for experimentation, discovery and scaling of best practice. Specifically, the Helsinki region can gain from having an institutionalized Lean Logistics Forum where urban planners, researchers and industry players come together to share and co-create solutions that fit the Finnish context.

7.3 Suggestions for Future Research

While this thesis provides a good foundation to understand interaction between Lean thinking and urban delivery sustainability, it also points to various research directions to be pursued in the future. Future research can examine the measures of the environment and costs saved associated with Lean-supported last-mile modes through relative case studies or pilot project implementation data. One direction is through lifecycle assessment (LCA) models that compare long-term carbon and cost savings of applying Lean logistics in various urban areas throughout Finland.

Yet another significant research thread may investigate the dynamic aspects of Lean transformation in logistics with regard to employee commitment and resistance in embracing iterative improvement frameworks. Additional research is also needed to determine consumer-level expectations and trade-offs of Lean logistics, including the perceived value of same-day delivery against its consolidated and environmentally friendly alternatives. Such patterns of consumer behavior can also offer valuable insights towards the practice of Lean and green delivery paradigms' feasibility.

Additionally, comparison of Helsinki with other urban centers in the Nordics or Europe—specifically Norway's Oslo, Netherlands' Amsterdam, and Denmark's Copenhagen—would be most beneficial in enabling studies to help determine the extent to which government structures, societal norms, and regulatory environments influence Lean logistic scaling. Such studies not only contribute to research literature but also guide urban planners and logistic companies that aim to join in on sustainability goals.

7.4 Learning Reflection

Throughout the thesis research process, the author exhibited outstanding improvement in research skills in academia, critical thinking, and analytical reasoning applied to practice. From his initial perception of Lean management being a set of methods limited to manufacturing effectiveness to his continuous improvement to recognizing its applicability to larger urban freight transport systems, the author developed a rich appreciation of Lean's methodology in addressing complex problems of sustainability in the context of urban freight transport through critical thinking and persistent interaction with scholarly research literature and expert respondents and case studies.

The iterative focus of Lean, and specifically its focus on continuous improvement and elimination of waste, influenced the analytical style of the author in determining inefficiencies in the last-mile delivery. Tracing through theoretical and empirical parts of the thesis, the author developed the skills of synthesizing significant amounts of data and applying strict evaluation measures based on academic and professional standards. This built the author's ability to critically evaluate multiple stakeholder views, reconcile contradictions in source material and uphold methodological clarity.

The academic writing skills of the author were also improved by maintaining strict adherence to paraphrasing conventions, citation norms, and referencing in accordance with Haaga-Helia guidelines of ethics. The utilization of triangulation—incorporating literature, empirical interviews, and actual development projects—allowed the author to gain higher credibility and argumentative coherence. Further, the strictness in creating logically organized formally worded paragraphs

increased the capacity of the author to convey complicated ideas in a very clear and persuasive way.

Aside from academic competence, the research experience has also aided the professional development of the author in supply chain and logistics management. Exposure to Lean in a sustainability context has enabled the author to acquire a practical and strategic outlook to approach real-world problems in urban logistics in general and in high-density settings like the Helsinki Metropolitan Area in particular. This is likely to guide the author in making contributions to multidisciplinary projects with the aim of optimizing supply chain networks in accordance with societal and environmental interests.

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Appendices

Appendix 1. Interview questions

Table 6. Interview Questions by Interviewee Type

Interviewee Type	Linked IQ	Interview Question
Lean Experts	IQ1	What are the common inefficiencies in activities of a last-mile delivery?
Lean Experts	IQ1	Why do low levels of coordination make urban delivery a challenge in highly populated areas?
Lean Experts	IQ1	Which Lean tools are most effective at diagnosing urban logistics problems?
Lean Experts	IQ2	How can JIT reduce operational delays in last-mile delivery?
Lean Experts	IQ2	What role has VSM in uncovering non-value-adding activities in urban transport?
Lean Experts	IQ2	Can Kaizen be realistically applied in real-time delivery settings?
Lean Experts	IQ2	Are you aware of successful instances of Lean in public sector logistics?
Lean Experts	IQ3	Is Lean able to address sustainability goals, or do adaptations need to be made?
Lean Experts	IQ3	What type of conflict exists where Lean intersects with environmental goals?
Lean Experts	IQ3	What are necessary conditions for successful Lean-sustainability integration?
Startups	IQ1	What operational bottlenecks have you encountered in urban delivery?
Startups	IQ1	Do city ordinances have an impact on your delivery routes and service quality?
Startups	IQ1	Where do you see inefficiencies in collaboration across logistics actors?
Startups	IQ2	Where do you practice continuous improvement (Kaizen) during your workday?
Startups	IQ2	Have you tested route optimization or streamlining of goods using Lean tools?
Startups	IQ2	What role has customer input played in shaping your improvement in processes?

Startups	IQ3	Do you include emission targets in your service, or do you have sustainability KPIs?
Startups	IQ3	Have you been obliged to implement lean adapted methods to meet your environment targets?
Startups	IQ3	How does being a startup help or hinder green logistics innovation?
Startups	IQ3	Do you collaborate with cities or NGOs on green pilot schemes?
Last-Mile Operators	IQ1	What are typical delays and disruptions to your deliveries?
Last-Mile Operators	IQ1	Do weather conditionality or infrastructure constraints make your operations difficult?
Last-Mile Operators	IQ1	What types of inefficiencies occur inside hubs or micro-depots?
Last-Mile Operators	IQ2	Do you apply any standardized tools or indicators to monitor performance?
Last-Mile Operators	IQ2	What's your process for reducing repeated deliveries or failed attempts?
Last-Mile Operators	IQ2	Are there communication tools that help improve flow across teams?
Last-Mile Operators	IQ3	Do you have electric vehicles or cargo bikes in your operational activities?
Last-Mile Operators	IQ3	What new sustainability initiatives has your organization launched recently?
Last-Mile Operators	IQ3	Where do you foresee the largest opportunity for green innovation in your operations?
Last-Mile Operators	IQ3	How do you think Lean would contribute to reducing emissions and enhancing efficiency simultaneously?