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Sustainable Last-Mile Logistics in Finland: Strategies for Reducing Emissions and Ensuring Reliability in Winter Conditions.

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ABSTRACT :
The last mile of the supply chain is particularly challenging to operate and environmentally unsustainable. In northern climates, the winter months compound this issue by introducing conflict between sustainability and service reliability due to seasonal conditions. Existing literature explores sustainable strategies and delivery reliability separately, resulting in a blind spot in empirical knowledge about the interplay between sustainability and reliability under challenging seasonal circumstances.

This research addresses which last-mile logistics strategies enable emissions reduction and reliable delivery in Finland during winter. The research is informed by contingency theory that suggests organizational efficiency is contingent on the fit between strategy bundles and the environment.

The study is interpretivist, abductive and employs a multiple-case qualitative design. Five semi-structured interviews were held with front-line employees of three Finnish last-mile logistics companies, complemented with secondary data. The analysis involved a six-phase process of thematic analysis by Braun and Clarke, with cross-case comparison of six analytical themes.

Winter was found to be a seasonal contingency, rather than an event, which limits vehicle capabilities, route options and human capacity. Reliability is achieved through a complex set of practices such as time buffering, workforce adjustment, route knowledge and task postponement. Sustainability strategies vary across types of companies - large companies focus on formal electrification despite winter constraints, while contractor operators focus on efficiency. The sustainability-reliability trade-off is not universal nor inevitable, but rather constructed within certain organizational contexts, especially where sustainability is institutionalised. This research offers an empirical contingency view of winter last-mile logistics.

KEYWORDS: last-mile logistics, sustainability, delivery reliability, winter conditions, contingency theory, Finland, qualitative case study

Contents

1 Introduction

1.1 Background and Motivation

Last-mile logistics has emerged as a key part of supply chains due to the rapid rise of e-commerce and the growing need for fast, flexible delivery options. The growth of e-commerce has led to a surge in shipments and an expectation of faster, more flexible delivery (Bosona, 2020; Gevaers et al., 2011). This has led to increased complexity for logistics companies, especially in urban areas where route efficiency and service quality are key (Comi & Savchenko, 2021).

Although the last mile is relatively short, it is well known to be the most expensive and environmentally damaging part of the supply chain (Gevaers et al., 2011; Olsson et al., 2019). Sparse drop-off points, low drop density, and many start-stop moves lead to higher vehicle kilometers traveled, fuel consumption, and subsequent greenhouse gas (GHG) emissions (Halldórsson & Wehner, 2020). As a result, enhancing sustainability in last-mile deliveries has emerged as a critical research topic.

These issues are further compounded in cold-climate regions, such as the Nordic countries, by regular winter weather. Snow, ice, cold, and shorter days' influence vehicle handling, speed, and route predictability, increasing uncertainty (Dybdalen & Ryeng, 2022). The weather has also been found to negatively affect transport efficiency and increase fuel or energy use (Sabir, 2011). With rising e-commerce, maintaining sustainable and reliable last-mile delivery in these conditions is a major challenge for logistics companies.

The research is based on the contingency theory contention that organizational performance is contingent upon the fit between strategies and environmental conditions (Donaldson, 2001). For last-mile logistics, this view implies that the success of sustainability strategies depends on the operational conditions, such as weather and infrastructure. This is especially important in winter logistics, where sustainability initiatives must be implemented without sacrificing reliability.

The literature has proposed various sustainability strategies to minimize environmental impacts in last-mile delivery, such as electric vehicles, cargo bicycles, parcel lockers, and route optimization (Browne et al., 2011; Comi & Savchenko, 2021). These strategies are designed to lower environmental impacts, but it is also essential to ensure delivery reliability, as customers expect reliable service levels, regardless of external factors (Klein & Popp, 2022). This poses an operational challenge between sustainability and reliability.

While there has been a recent surge of interest in sustainable last-mile logistics, current research often focuses on either sustainability strategies or delivery reliability in isolation (Olsson et al., 2019). There is little empirical understanding of how these goals are managed together in practice, especially under challenging weather conditions like winter. This is particularly important in countries such as Finland, where winter is certain to arrive, and operational effects are unpredictable.

This research fills this gap by exploring the coordination of sustainability strategies and delivery reliability in last-mile logistics in cold climates. Drawing on a qualitative multiple-case study of last-mile logistics organizations in Finland, the study explores wintertime operations and provides empirical evidence on how logistics providers manage operations in response to environmental constraints while achieving both sustainability and operational performance.

1.2 Research Problem and Gap

Sustainable last-mile logistics has been gaining momentum in research and practice. But the current body of research tends to focus on urban logistics in mild or temperate climates or to assess the performance of individual sustainability strategies (Gevaers et al., 2011; Olsson et al., 2019). In cold-climate countries, winter operating conditions are a regular operational challenge that impacts the efficiency of transport operations, emissions performance, and delivery reliability.

Although this is a real-world challenge, there is a lack of empirical evidence on how logistics providers implement sustainability strategies in winter operations and how these strategies perform in practice (Heikkinen, 2024; Olsson et al., 2019). Previous reviews of last-mile logistics operations confirm that sustainability and operational performance variables, such as delivery reliability, have been largely studied in isolation, with only a handful of studies considering winter operating conditions and focusing on specific vehicle technologies rather than on the strategy-performance interaction (Dybdalen & Ryeng, 2022). Specifically, there is little empirical research on the interaction between strategies for emission reduction and delivery reliability in cold-climate logistics.

This study extends the literature by empirically investigating how technological, operational, and organizational strategies are bundled and adjusted in response to recurrent winter uncertainties, and by offering empirical evidence on how the sustainability-reliability interaction is managed in practice (Sousa & Voss, 2008). The insights are relevant for logistics service providers in cold climates, as they can be used to plan fleet renewal, seasonal fleet planning, and corporate governance amid winter uncertainty (Dybdalen & Ryeng, 2022).

1.3 Research Question and Objectives

This thesis addresses the following research question:

Which last-mile logistics strategies support emissions reduction and delivery reliability during winter conditions in Finland?

To answer this question, the study pursues three primary objectives:

- To identify operational challenges related to winter conditions in last-mile logistics
- To examine sustainability strategies used in last-mile delivery operations
- To analyze how these strategies, support delivery reliability under winter conditions

1.4 Methodological Positioning and Scope

This research uses a qualitative case study approach in Finnish logistics companies. This approach is suitable for this study because it allows a deep understanding of operational practices and processes in real-world situations (Yin, 2018). This approach was chosen because the interaction between sustainability and reliability under winter conditions is context-dependent, reliant on supervisory discretion and operational adaptability, and requires interpretive rather than statistical access to real-world decision-making (Eriksson & Kovalainen, 2008). This study uses secondary document analysis and semi-structured interviews to analyze operational practices during winter.

Finland is an appropriate context for the study because of its extended winter and advanced logistics sector. The research specifically addresses last-mile parcel deliveries and environmental sustainability, particularly emissions-reduction measures. The analysis does not focus on social and economic aspects of sustainability, to keep the focus on environmental aspects. Also, the analysis is conducted under winter conditions, and seasonal effects are ignored.

1.5 Structure of the Thesis

This thesis is organized as follows. The background of the study, problem statement, and research aims are discussed in Chapter 1. The literature review on winter logistics problems, sustainability in freight transport, and last-mile logistics is in Chapter 2. In Chapter 3, the research and data collection approach is presented. The empirical findings of the case study are discussed in Chapter 4. Chapter 5 discusses the results in relation to the literature, and Chapter 6 concludes the thesis and discusses the implications for research and practice.

2 Literature Review

2.1 Context and scope: sustainable last-mile logistics in Finland under winter conditions

Last-mile logistics is generally described in the literature as the final step of parcel delivery from a distribution node (e.g., an urban depot or micro-hub) to the final consumer, typically in the urban business-to-consumer (B2C) setting. The last mile is considered operationally complex because it involves multiple stops, tight deadlines, and high exposure to variability, and it also has an environmental impact due to frequent stopping, limited consolidation potential, and failed deliveries in a B2C context (Boysen et al., 2021; Halldórsson & Wehner, 2020).

In winter in Finland, these challenges arise as a recurring operating regime, with snow cover and sub-zero temperatures persisting throughout the season rather than being occasional disruptions (Finnish Meteorological Institute, n.d.). Snow/ice, low temperatures, and fluctuating travel times affect transportation operations by influencing the feasibility of routes, the ability to operate at reasonable speeds, and the reliability of service in accordance with the promised delivery schedule (Rastani et al., 2019). This is important because sustainability practices, such as using more electric vehicles, planning routes more effectively, and combining deliveries, are integrated into the operating system, while delivery reliability remains a core performance outcome (Boysen et al., 2021). During winter, the same operational strategy can affect both emissions performance and delivery reliability.

Treating winter conditions in Finland as structured environmental contingencies, this thesis adopts contingency theory to maintain theoretical coherence and shape the effectiveness of last-mile strategies. From this angle, sustainability and delivery reliability depend on the degree of fit between operational configurations and winter-triggered uncertainty, rather than on universally optimal practices (Drazin & Van de Ven, 1985; Wong et al., 2011).

2.2 Theoretical foundation: contingency theory

This thesis is based on contingency theory; it argues that the degree of alignment between internal configuration and external environmental conditions determines the effectiveness of an organization's operations, rather than universally applicable best practices (Donaldson, 2001; Drazin & Van de Ven, 1985). Due to several uncertainties related to the environment, researchers studying operations and supply chains widely use contingency theory to explain why differences in performance result in variations in reliability and sustainability (Flynn et al., 2010; Wong et al., 2011). Recent research has also extended contingency theory to environmental management, demonstrating that the fit between organizational practices and external conditions shapes sustainability-related outcomes (Mahmud et al.,2021)

The main idea of contingency theory is fit. Fit in contingency refers to the alignment between organizational arrangements (e.g., structure, processes, and decision systems) and environmental conditions. High fit results in higher performance improvement; similarly, low alignment (fit) results in performance decline (Drazin & Van de Ven, 1985). In the area of logistics and operations, environmental uncertainty (e.g., demand volatility, operational disruptions, or variations in operating conditions) moderates the relationship between operational practices and performance outcomes (Sreedevi & Saranga, 2017; Wong et al., 2011).

Affecting the route feasibility, operating speeds, and service reliability due to snow, ice, low temperatures, and increased travel time, Finnish last-mile winter conditions are a structured environmental contingency. From this perspective, the strategies used to reduce emissions—such as using more electric vehicles, route optimization, consolidation, and buffer allocation—depend on their alignment with seasonal contingencies rather than on their theoretical efficiency under stable conditions (Flynn et al., 2010; Tenhiälä, 2011).

Contingency theory provides a logical framework for evaluating sustainable last-mile logistics in winter conditions. This helps focus on how operational configurations are modified and adjusted rather than on “optimal” strategies, to allow the smooth flow of operations and maintain performance under elevated environmental uncertainty. Delivery reliability and sustainability performance are treated as outcomes in this thesis, which are influenced by the degree of fit between strategy bundles and winter operating conditions.

2.3 Sustainability performance in last-mile logistics: emissions sources and logic of intervention

Operational design choices and conditions under which they are implemented shape sustainability performance in last-mile logistics. Emissions in the last mile are influenced not only by total distance traveled but also by speed profiles, load factors, idling, stop frequency, and failed first-attempt deliveries, which yield additional re-delivery loops (Agatz et al., 2008; Demir et al., 2014). This highlights that distance minimization alone cannot yield environmental performance—interaction among routing decisions, vehicle characteristics, service promises, and customer behavior is also involved.

Notably, operational efficiency and environmental sustainability are related but not the same. The study of green routing indicates that reducing distance or cost does not always result in reduced emissions, since fuel consumption is determined by vehicle load, driving style, congestion, and speed variability (Demir et al., 2014). In urban logistics environments characterized by uncertainty, performance results are determined by how operational practices are designed in relation to environmental conditions (Flynn et al., 2010; Wong et al., 2011). This means that the sustainability interventions cannot be presumed to have similar effects under operating regimes.

Uncertainty in the environment in winter is caused by changes in travel time, slower speed, and limited access to curbs. This variability may lengthen the route's runtime, increase idleness, and increase energy use per parcel. Empirical studies on energy consumption in transportation demonstrate that weather and temperature conditions play a vital role in determining the efficiency and viability of vehicles (Pelletier et al., 2019; Rastani et al., 2019). In such a situation, sustainability performance is determined by how routing logic, vehicle deployment, and consolidation practices are based on seasonal operating constraints rather than being optimized under consistent conditions alone.

Therefore, sustainability performance in Finnish last-mile logistics should be considered a condition-specific phenomenon, determined by the level of congruence between operational setups and the uncertainty caused by winter. This view focuses on the effects of varying the outcomes of emissions by using strategies across various environmental circumstances, rather than a universal efficiency impact.

2.4 Strategy categories for emissions reduction and their reliability implications in winter operations

Following the contingency theory, this section outlines the major types of strategies adopted to reduce emissions in last-mile delivery to ensure reliability during winter. According to contingency theory, structural practices of operational performance are contingent on how they relate to environmental uncertainty and variability, rather than universally optimal forms (Drazin & Van de Ven, 1985; Wong et al., 2011). The performance impacts of technology, operational strategy, and organizational strategy are hence conditional on their respective contextual fit in winter operating regimes characterized by ever-changing travel times, low speeds, and limited feasibility.

2.4.1 Technological strategies: electric and alternative vehicles

One of the key directions for eliminating emissions in the last-mile delivery system is electrification. Nonetheless, the operational potential of electric vehicles (EVs) and their environmental advantages depend on the context. Studies of electric freight vehicles reveal that ambient temperature is a major factor influencing energy use and route viability, as heating loads and cold-temperature efficiency losses consume more energy and reduce the range of usability (Rastani et al., 2019). Besides that, the electric vehicle routing literature recognizes weather and road conditions as significant sources of energy-consumption uncertainty that need to be included in planning decisions (Pelletier et al., 2019).

Contingently, the performance effects of technological decisions will depend on how compatible they are with environmental constraints. This is illustrated in empirical contingency studies in operations management, which show that operational effectiveness varies with technological deployment under different degrees of uncertainty (Flynn et al., 2010; Tenhiälä, 2011). Under winter conditions, EV deployment might require changes in route allocation, charging planning, and vehicle assignment to maintain the level of emissions performance as a universally promising solution, and its sustainability and reliability will depend on compliance with winter variability.

2.4.2 Operational strategies: routing, consolidation, scheduling, time windows, and buffers

Operational strategies such as routing optimization, consolidation practices, scheduling design, and delivery time-windows configuration are primary determinants of both cost and environmental performance in last-mile systems (Boysen et al., 2021). However, their sustainability effect is influenced by how they change driving patterns, speed profiles, load factors, and failed-delivery loops, rather than by distance reduction alone (Demir et al., 2014).

Tighter routing and higher consolidation can reduce vehicle kilometers and emissions under stable conditions, but they may also reduce slack and increase vulnerability to disruptions as variability increases. Evidence from operations management literature indicates that buffering, flexibility, and adaptive planning enhance performance in the case of environmental uncertainty (Helkiö & Tenhiälä, 2013; Sreedevi & Saranga, 2017). In winter regimes, high travel time variability and feasibility constraints increase the value of reliability protection practices, such as buffer time, route contingency rules, and flexible task reassignment.

Accordingly, the environmental and reliability outcomes of routing and consolidation strategies depend on the extent to which they align with winter operating conditions. Practices that are efficient in stable environments may become fragile in the face of increased uncertainty and need to adapt to maintain alignment with performance.

2.4.3 Organizational strategies: decision-making, KPIs, and seasonal planning

In addition to technology and routing design, sustainability and reliability outcomes are determined by organizational structure, performance metrics, and decision authority. Contingency research shows that organizational effectiveness depends on the fit between structural arrangements and environmental complexity (Drazin & Van de Ven, 1985). To support contextual alignment in uncertain logistics environments, governance mechanisms such as flexible decision rights, performance measurement systems, and adaptive planning processes are useful (Flynn et al., 2010; Sreedevi & Saranga, 2017).

In winter conditions, it is common for supervisors to face trade-offs between service reliability and emission goals. Organizational design elements, such as the weighing of KPIs, procedures for escalating issues and seasonality planning routines, become critical mechanisms through which firms adjust to increased uncertainty. Empirical studies of Nordic urban freight initiatives suggest that sustainability initiatives can underperform when organizational and financial conditions are not aligned with contextual constraints (Nordtømme et al., 2015).

From a contingency perspective, these findings indicate that the concept of sustainability in winter last-mile logistics cannot be assessed solely in terms of technological or operational choices. Performance outcomes depend on whether organizational governance structures facilitate adaptive responses to restore alignment between strategy bundles and environmental contingencies.

2.4.4 Out-of-scope strategy discussions

To keep up with the topic of the research question, this thesis considers the following areas as being outside the main contribution: (1) product-level impacts of the life cycle, including packaging. (2) long-term network redesign and facility location optimization, and (3) optimization model development as a thesis result. These boundaries are justified, as the empirical aim is to explain the implementable configuration and adaptation of the strategy bundle under recurring winter contingencies.

2.5 Delivery reliability: definition and determinants in last-mile operations

Delivery reliability is a fundamental performance measure in last-mile operations, especially under environmental contingencies such as winter variations. In operations and supply chain research, reliability is associated with the consistent fulfillment of delivery promises, such as time windows and service expectations (Flynn et al., 2010). In last-mile scenarios where delivery windows are tight, the number of parcels fluctuates, and it is unclear whether customers will be at the delivery location, reliability has a direct impact on customer satisfaction, operational stability, and cost efficiency (Boysen et al., 2021).

Empirical and modeling studies show that the first-attempt delivery failure can be operationally important in B2C distribution systems, leading to additional vehicle kilometers, increased emissions, and service recovery costs (Agatz et al., 2008). Studies on routing in uncertain customer presence further demonstrate that delivery reliability is structurally sensitive to the variability of travel times and recipient availability, and that adaptive planning mechanisms can have a material impact on system performance (Özarık et al., 2021).

From a contingency perspective, delivery reliability depends on the alignment between operational practices and environmental conditions (Sousa & Voss, 2008). When environmental uncertainty is high, as in winter operating regimes, the rigidity of the planning approach may lead to a decline in reliability, whereas adaptability in buffering, flexible resource allocation, and contingency routing can improve performance fit (Sreedevi & Saranga, 2017). Under conditions of high uncertainty, operational outcomes depend on the degree of match between configurations and the requirements of the context, rather than on universal scheduling rules (Wong et al., 2011).

In this thesis, delivery reliability is defined in practical terms reflecting supervisory decision-making and operational control. It covers four dimensions that are interrelated: (1) on-time delivery/time-window compliance, (2) first-attempt delivery success, (3) consistency of service during disruptions, and (4) recovery capability (how delays are managed and service is restored), which is understood as the ability of the organization to recover the performance of its services after delays or exceptions.

Winter conditions underscore the importance of these reliability dimensions. Empirical research indicates that adverse weather conditions and environmental variability increase travel time uncertainty, decrease operating speed, and increase the likelihood of delivery disruptions (Pelletier et al., 2019; Rastani et al., 2019). Under such contingencies, reliability protection mechanisms such as buffer allocation, dynamic route adjustment, and flexible driver/vehicle deployment become critical for maintaining performance alignment in uncertain logistics environments (Sousa & Voss, 2008; Sreedevi & Saranga, 2017). However, these adaptive measures may require additional slack capacity or resource deployment, potentially increasing operational effort and affecting emissions performance (Demir et al., 2014).

Accordingly, delivery reliability in winter last-mile logistics should be understood as context-dependent, an outcome of the extent of fit between operational configurations and environmental uncertainty. This view forms a basis for the analysis of how supervisors balance reliability protection and emission goals under the recurring seasonal contingencies.

2.6 Winter operating conditions in Nordic context: why transfer from general urban studies is limited

Winter in Finland is a yearly, systematic operating regime, not an occasional disruption. From a contingency perspective, this regime is a form of permanent environmental uncertainty that shapes the fit between last-mile strategies and performance (Sousa & Voss, 2008). Authoritative national statistics from the Finnish Meteorological Institute indicate that snow cover and sub-zero temperatures persist for long seasons, with large regional differences in duration and severity (Finnish Meteorological Institute, n.d.). In parallel, national road authorities set the standard for winter maintenance and snow-clearing response requirements, which influence the institutional environment for freight and parcel distribution (Finnish Transport Infrastructure Agency, n.d.).

Conceptually, winter conditions influence last-mile operations through two related mechanisms, namely feasibility and variability. Feasibility refers to whether routes can be carried out safely and within the promised time frames under conditions of snow, ice, and reduced curb accessibility (Pelletier et al., 2019; Rastani et al., 2019). Variability is the term used to describe increases in fluctuations in travel time, stop, duration, and energy consumption due to lower speeds, congestion spillover, and temperature-sensitive vehicle performance (Demir et al., 2014; Rastani et al., 2019). Empirical measurements in Finnish subfreezing conditions further confirm that cold ambient temperatures substantially affect real-world vehicle energy and emissions performance (Leinonen et al.,2024).

From a contingency-theoretic perspective, winter is a structured environmental contingency that moderates the relations between operational strategies and performance outcomes (Sousa & Voss, 2008). Strategies that may work well in stable situations (e.g., tight routing, high consolidation, and little buffer allocation) can fail under more variable environmental conditions. On the other hand, adaptive structures (such as buffer time, contingency routing rules, and flexible resource reallocation) are more valuable in conditions of higher uncertainty. Contingency research focuses on the fact that performance relationships found in one set of environmental conditions cannot be presumed to remain true in systematically different contextual regimes (Drazin & Van de Ven, 1985; Wong et al., 2011).

Winter enhances the interaction between sustainability and reliability. Reduced speeds and longer route durations may increase energy use and emissions per parcel, while stricter reliability protection mechanisms may lead to additional slack capacity. Understanding the process of adaptation of strategy bundles under these structured contingencies is central for understanding sustainable performance during the last mile in the Finnish winter situation.

2.7 Why modelling and optimization literature is not sufficient for this research question

A considerable amount of research on last-mile logistics is modeling-oriented, with a special focus on vehicle routing problems, scheduling within time windows, and cost-service optimization. Comprehensive surveys of the field of operations research confirm that routing and scheduling models dominate the research landscape of the last mile and offer more advanced formulations that include time windows, stochastic travel times, and environmental objectives (Boysen et al., 2021).

However, such a modeling approach usually abstracts from organizational and contextual realities through which decisions are enacted. While research on modeling provides rigorous analytical formulations of routing and scheduling problems, these models typically present clearly defined objectives, stable parameter structures, and centralized decision logic within formal optimization frameworks (Boysen et al., 2021). Research on operations management has found that performance results are not determined by technical sophistication but by contextual fit between operational configurations and environmental situations (Sousa & Voss, 2008; Tenhiälä, 2011). This suggests that optimization models developed on the basis of stylized or generalized assumptions may not fully capture how operational decisions are enacted across different environmental conditions.

On account of these limitations, they are especially salient in winter operating regimes. Research on electric vehicle routing under energy uncertainty highlights weather and road conditions as exogenous drivers of feasibility risk, demonstrating that neglecting these uncertainties can result in infeasible or fragile routes (Pelletier et al., 2019). But even strong optimization formulations might not be enough to describe supervisors' discretionary actions in the pursuit of contextual fit during real-time disruption (Sousa & Voss, 2008).

Moreover, implementation research in urban freight settings emphasizes that sustainability initiatives often face financial, organizational, and stakeholder barriers despite being technically feasible (Nordtømme et al., 2015). Therefore, no matter how important the conceptual foundations presented by the modeling and optimization literature are, they remain insufficient to explain how sustainability and reliability are balanced in practice under recurrent winter contingencies. A qualitative case approach is suitable for examining how supervisors interpret constraints, use buffering and contingency mechanisms, and manage trade-offs in the Finnish winter context to address a lack of contextual fit (Sousa & Voss, 2008).

2.8 Strategy implementation constraints and barrier relevant to winter sustainability transitions

Beyond technical feasibility, sustainability efforts in last-mile logistics are affected by organizational, financial, and stakeholder constraints that determine whether suggested strategies are implemented, expanded, or abandoned. Research on Nordic urban freight initiatives shows that even environmentally promising initiatives - such as urban consolidation centers or coordinated e-grocery delivery systems often fail or underachieve when financial viability is uncertain, stakeholder acceptance is lacking, or there is a lack of coordination between actors (Bjørgen et al., 2021; Nordtømme et al., 2015).

Contingency theory proposes that barriers to implementation arise when strategies are poorly suited to contextual factors such as financial viability, stakeholder acceptance, and coordination difficulties (Doetsch & Huchzermeier, 2024). In winter, increased variability may prompt supervisors to temporarily switch back to conventional vehicles, increase buffers, or ease emissions targets to maintain service continuity and restore alignment with contingencies (Doetsch & Huchzermeier, 2024; Sreedevi & Saranga, 2017).

Contingency theory also proposes that the implementation barrier would be even stronger under conditions of increased environmental uncertainty. When travel time variability increases or route feasibility is compromised, supervisors may choose to compromise sustainability goals to ensure reliability. Such adaptive responses can be considered attempts to maintain performance in the face of heightened winter uncertainty (Sousa & Voss, 2008).

Therefore, the issue of sustainability in winter last-mile logistics becomes a dynamic governance process based on contingency fit rather than static technology adoption. The value of the case study lies in analyzing how superconductors perceive the feasibility constraints and in justifying trade-offs and adjusting strategy bundles when winter contingencies increase tensions between environmental objectives and reliability.

2.9 Sustainability-reliability trade-offs: mechanisms and managerial responses

The interaction between sustainability and delivery reliability in last-mile logistics is organized around recognized operational mechanisms rather than as a generic, inevitable conflict. Sustainability-oriented strategies-any of the following: electrification, tighter routing, increased consolidation, or a narrower delivery window-alter vehicle kilometers traveled, speed profiles, load factors, and idling patterns, which have a direct impact on fuel consumption and emissions intensity (Demir et al., 2014). However, these same strategies can affect service robustness when variability increases.

An important central mechanism is variability sensitivity. When routing plans are finely tuned for efficiency, there is a higher risk of missing time windows due to uncertainty in travel times. Winter conditions further amplify this impact, compounded by low speeds, variable road conditions, and greater service-time variability. According to contingency theory, the greater the level of environmental uncertainty, the more valuable the buffering and adaptive coordination mechanisms (Sousa & Voss, 2008).

A second mechanism is a constraint of energy and feasibility, especially for electric freight vehicles. Temperature-related energy use and range inconsistency can limit route feasibility, forcing rerouting of vehicles or adding more charging buffers (Pelletier et al., 2019). These adjustments may improve reliability but negatively affect operational efficiency and emissions performance.

A third mechanism relates to failed first-attempt deliveries, exception loops, and failed first-attempt deliveries. Empirical research shows that unsuccessful deliveries can result in significantly greater distance traveled and operational costs (Agatz et al., 2008). Reliability failure thus has a direct impact on sustainability performance through triggers for re-delivery activity. In winter, when customer presence uncertainty is combined with travel time variability, the probability and costs of such loops may increase.

These mechanisms indicate that sustainability and reliability, rather than being fixed opposites, should be conceptualized as dynamic and interactive outcomes of the degree of fit between strategies and environmental contingencies. Buffer allocation, contingency rules for routing, flexible resource deployment, and seasonal adjustment of the service promises are managerial tools for handling this interaction. Sticking to such practices, from a contingency perspective, reflects adaptation practices, in which configurations are adapted, and contextualization is achieved as uncertainty rises, especially during winter conditions (Sousa & Voss, 2008; Sreedevi & Saranga, 2017).

The empirical contribution of this thesis is therefore to identify the strategy bundles employed in practice, the influence of winter conditions on the strength of these mechanisms, and how supervisors will justify trade-offs between the emissions objectives and service reliability in case of contingencies.

2.10 Research gaps and justification for an empirical case approach

Despite the extensive modeling and sustainability research in the field of last-mile logistics, there are three analytically distinct gaps for the specific research problem addressed in this thesis.

First, winter conditions in research on the last mile are often modeled as stochastic perturbations or exogenous constraints and not as conceptualized structured environmental contingencies. While routing and green logistics models are increasingly incorporating stochastic travel times and weather-sensitive parameters (Demir et al., 2014; Pelletier et al., 2019), they often lack theoretical grounding in winter as a persistent mode of operation that systematically moderates the relationship between operational strategies and performance outcomes. Contingency research has proposed that performance relations change across different environmental regimes rather than remain stable across contexts (Drazin & Van de Ven, 1985; Wong et al., 2011). Empirical insight is therefore required as to how bundles of strategies are reconfigured when winter is a structural condition that is experienced repeatedly rather than a temporary disturbance.

Second, sustainability and reliability are often considered independently as performance dimensions or abstract multi-objective optimization problems. Green routing research is usually focused on mechanisms for emissions reduction (Demir et al., 2014), while service-oriented research focuses on time-window compliance and the first-attempt success rate (Agatz et al., 2008). However, little research has examined how these objectives interact operationally under conditions of high environmental uncertainty and how managers balance them in practice. Contingency theory suggests that the magnitude and pattern of performance relations will be a function of situational variability (Sousa & Voss, 2008; Sreedevi & Saranga, 2017). Yet empirical evidence is lacking on how sustainability-reliability trade-offs are determined under sustained seasonal contingencies.

Third, even though optimization research offers sophisticated decision models, it often assumes stable conditions for implementation and the rational execution of plans. Contingency research in operations management proposes that actual performance depends on the adaptation of organizational configurations to uncertainty rather than on formal decision rules alone (Flynn et al., 2010; Tenhiälä, 2011). Evidence from Nordic freight initiatives also suggests that sustainability initiatives may be constrained by organizational and contextual factors despite being technically feasible (Nordtømme et al., 2015). Consequently, there remains little empirical research on how supervisors interpret constraints, tailor buffering processes, and reconfigure strategies to restore performance alignment in the face of recurring winter conditions.

Together, these gaps provide a basis for approaching supervisory decision-making in a Finnish parcel delivery context qualitatively. With a focus on understanding how bundles of technological, operational, and organizational strategies are arranged and adapted in winter, this thesis aims to address how, in practice, sustainability and reliability are co-produced rather than assumed to optimally balance in abstract models.

2.11 Conceptual Framework

2.11.1 Theoretical logic and core constructs

This thesis is built on a contingency-theoretical framework to examine the co-production of sustainability performance and delivery reliability in winter last-mile logistics in Finland. Contingency theory holds that an organization's outcome depends on the fit between its internal configurations and external environmental conditions (Drazin & Van de Ven, 1985; Sousa & Voss, 2008). In this study, winter conditions (e.g., snow, ice, low temperatures, high travel-time variability) are conceptualized as structured environmental contingencies that moderate the relation between operational strategies and performance outcomes.

Based on this logic, this framework is organized along four main constructs:

1. Sustainability performance (emissions/energy performance)
2. Delivery reliability (service performance results)
3. Winter conditions of operation in Finland (contingencies)
4. Strategy bundles carried out by the case organization, structured into:

Technological strategies (e.g., EV, cargo bikes, alternative vehicles), Operational strategies (routing, scheduling, consolidation, time windows), Organizational approach (KPIs, seasonal planning, decision rights, escalation routines).

Delivery reliability is defined by four interrelated dimensions: on-time delivery and time-window compliance, first-attempt delivery success, service consistency during disruption, and recovery capability. Together, these constructs represent the extent to which performance outcomes depend on the fit between strategy bundles and the environmental uncertainty caused by winter.

2.11.2 Mechanisms linking strategy bundles to sustainability and reliability in winter

The literature reviewed in the above sections identifies four mechanisms by which strategy bundles will have an impact on sustainability and reliability under winter contingencies:

1. Travel-time variability and speed reductions pose a threat of schedule deviations when routing configurations are maximally optimized (Wong et al., 2011).
2. Energy/range uncertainty for electrics, which impacts the feasibility of routes and charging needs with low temperatures (Pelletier et al., 2019).
3. First delivery failures and re-delivery loops, which create more kilometers and emissions and lower service stability (Agatz et al., 2008).
4. Buffering and recovery practices, e.g., time slack and flexible resource assignment, which increase reliability in the face of uncertainty but may increase operational effort (Sousa & Voss, 2008; Sreedevi & Saranga, 2017).

Rather than taking these mechanisms as fixed trade-offs, the framework expects them as contingent relationships that are stronger or weaker depending on the level of environmental uncertainty. Winter conditions, therefore, affect the way in which strategy bundles translate to sustainability and reliability outcomes by moderating.

2.11.3 Framework logic and diagram

The framework's logic is summarized in Figure 1. Winter contingencies are conceptualized as moderating variables that shape the strength and direction of relationships between bundles of strategies and performance outcomes. These contingencies include snow/ice conditions, low temperatures, variable travel times, and curb or route accessibility limitations. Rather than assuming a fixed trade-off between sustainability and reliability, the framework assumes that performance outcomes depend on the degree of alignment between operational configurations and environmental uncertainty.

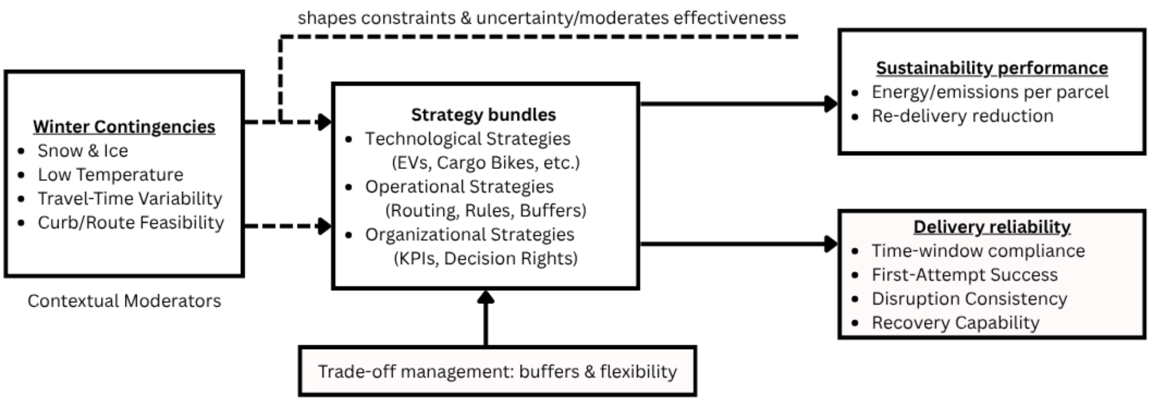

Figure 1.Conceptual framework of sustainability–reliability interaction in Finnish winter last-mile logistics.

2.11.4 Implications for the empirical case organizations

This framework provides the empirical analysis by focusing attention on: (1) what technological/operational/organizational strategies are employed in winter operations; (2) what is the impact of winter conditions on feasibility, variability and performance risk; (3) how supervisors manage the interaction between sustainability and reliability is maintained (or not) over time-window compliance, first attempt success, disruption consistency and recovery capability. The framework thus serves as a coherent connection from Chapter 3 into the case study design and the themes identified in the interviews used in the empirical chapters.

3 Methodology

3.1 Introduction

This chapter outlines the methodology of this research. This study explores the sustainability strategies and the reliability of last-mile delivery of logistics organizations in Finland during recurring winter periods. The research approach is based on the research onion framework by Saunders, Lewis, and Thornhill (2019), a model that offers a structured approach to research design by dividing the methodological decisions into six interrelated layers: research philosophy, research approach, methodological choice, research strategy, time horizon, and data collection techniques and procedures. These layers are interconnected, ensuring a link between the underlying philosophical basis and the research methods.

The chapter is structured as follows. Section 3.2 sets the research philosophy, which provides a description of the ontological and epistemological stances of the research. Section 3.3 outlines the research approach. Section 3.4 discusses the methodology. Section 3.5 explains the research design, including the rationale for selecting a multiple-case study approach and the process of case selection. Section 3.6 discusses the time frame. Section 3.7 outlines data collection techniques, starting with primary data (semi-structured interviews) and then secondary data (documents). Section 3.8 presents the data analysis approach. Section 3.9 considers the quality and rigour of the study, and Section 3.10 deals with ethical considerations.

3.2 Research Philosophy

The outermost layer of the research onion is the research philosophy, which refers to the researcher's assumptions about the nature of reality (ontology) and how knowledge of that reality can be obtained (epistemology) (Saunders et al., 2019). This influences all further research decisions, including the research approach, data collection and data analysis techniques.

This research takes an interpretivist approach. Interpretivism assumes that the world is socially constructed and that to understand social phenomena, we need access to the meaning, interpretation and experience that individuals bring to their environment and behaviours (Creswell & Poth, 2018; Saunders et al., 2019). In contrast to positivism, which attempts to identify objective laws that can be applied generally through measurement and quantification, interpretivism is premised on the idea that practices within organizations and the decisions of managers are influenced by contextual, experiential and social factors that cannot be captured by instrumented data collection (Eriksson & Kovalainen, 2008).

The interpretivist stance is suitable for this research for a number of reasons. First, the study's research question is about how sustainability strategies are executed and adapted in winter, which requires the inclusion of the knowledge, judgment, and experience of operational practitioners rather than the quantification of variables. Second, the subject of the study - the intersection of sustainability and service reliability in winter logistics - is embedded in organizational and environmental contexts in which the outcomes depend on the discretion of supervisors, adaptation to circumstances, and experience. Third, the research aims to understand the interpretations of operational constraints and decision-making in the face of uncertainty, which is consistent with the interpretivist emphasis on meaning and context (Silverman, 2021).

Ontologically, this study is subjectivist in the sense that the reality of organizations is co-constructed through interactions, meanings, and experiences of individuals in certain contexts. Epistemologically, the study is based on the premise that knowledge is constructed by looking at people and what they say about their practices, rather than through observation of people and statistical analysis of data (Saunders et al., 2019).

3.3 Research Approach

The second layer of the research onion is the research approach, which relates to the relationship between theory and data (Saunders et al., 2019). The most common approaches are deductive (testing theory), inductive (developing theory) and abductive (iterative movement between theory and data).

This research follows an abductive approach. The abductive approach involves an iterative cycle of moving from prior theory to empirical data, enabling the analysis to be informed by theory while also being open to emergent patterns and insights from the data (Saunders et al., 2019; Eriksson & Kovalainen, 2008).

The abductive approach is appropriate for this study because the research draws on contingency theory (Donaldson, 2001; Drazin & Van de Ven, 1985), which forms the conceptual framework of the study into the fit between strategy bundles and environmental contingencies. But the research does not seek to test hypotheses related to contingency theory. Instead, the conceptual framework outlined in Section 2.11 informs the themes to be explored in the interviews and provides a preliminary structure for the analysis, but the thematic analysis process is responsive to new insights that may emerge outside the scope of the framework. This dynamic interaction between theory and data is typical of abductive research and enables both refinement of the theory and discovery of new insights based on empirical evidence.

3.4 Methodological Choice

The third element of the research onion is the methodological choice, which relates to whether the study is qualitative, quantitative, or mixed methods, and whether the research uses a mono-method or multi-method approach (Saunders et al., 2019).

This research is a mono-method qualitative design. The qualitative approach is justified because the research question - what strategies of last-mile logistics support emissions reduction and delivery reliability in winter conditions - calls for an understanding of practices, processes, and adaptations that cannot be captured by quantitative measurement

(Yin, 2018; Creswell & Poth, 2018). The interaction between sustainability and reliability under winter conditions is a contextualised phenomenon, based on supervisory judgement and adaptive practice, and demands interpretative access to the judgement of practitioners instead of statistical generalisation (Eriksson & Kovalainen, 2008; Silverman, 2021).

The mono-method design reflects the nature and purpose of a Master's thesis, which involves an in-depth analysis within a single methodological approach, rather than a multi-faceted approach. The qualitative approach allows the gathering of thick descriptions about how firms assemble and modify winter strategies, offering the necessary level of detail to answer the research question.

3.5 Research Strategy: Multiple-Case Study

3.5.1 Case Study Strategy

The fourth layer of the research onion is the research strategy, which refers to the overall approach that the researcher takes to answer the research question (Saunders et al., 2019). This study uses a case study strategy. A case study is an empirical enquiry that investigates a contemporary phenomenon in depth and within its real-world context, particularly when the boundaries between phenomena and context are not clearly evident (Yin, 2018). Stake (1995) also notes that case study research offers a comprehensive view of the phenomenon under investigation by looking at its context, which is critical when operational practices are embedded in particular organizational and environmental settings.

Case study research is warranted for a number of reasons. First, the research question is a how and which question - which strategies promote sustainability and reliability and how they are applied and adapted during winter. These questions are better answered by an in-depth case study rather than a survey approach (Yin, 2018; Eisenhardt & Graebner, 2007). Second, the focus of the study - sustainability and reliability in winter last-mile operations - is embedded in its context. Sustainability strategies are dependent on operational and seasonal environments and organizational structures, making it necessary for our research to recognise the complexity (Barratt et al., 2011). Third, prior research has mostly focused on the topic of sustainability or delivery reliability separately or through modelling, leaving an empirical gap in how they interact in practice under adverse environmental conditions. A case study approach allows us to investigate this gap by understanding of the organizational practices, decision-making and context in which sustainability and reliability interact (Voss et al., 2002).

3.5.2 Multiple-Case Study Design

This is a multiple-case study, which explores last-mile logistics practices in three Finnish organizations. The study used a multiple-case design as the research question emerged during the data collection phase: whereas the research originally set out to examine a single organization, access was granted to operational staff in several logistics organizations, allowing for multiple case analysis and a wider understanding of the research phenomenon.

Multiple-case designs are preferred over single-case designs because they allow a replication logic, whereby observations in one case can be compared with observations from other cases to assess for similarities or differences (Yin, 2018). The multiple-case approach adds analytical rigour to the research by identifying both convergent (e.g. common challenges in winter operations) and divergent (e.g. differences in sustainability practices) patterns across cases (Eriksson & Kovalainen, 2008).

3.5.3 Case Selection

This research identified three case organizations in Finnish last-mile logistics that vary in size and operational model: a large, centrally operating company; a mid-sized company; and a small contractor-based company. Purposive sampling was used to select the case organizations, which refers to the selection of cases that are most informative for answering the research question (Patton, 2015). Purposive sampling is suitable in qualitative research when representativeness is not sought after, but rather the selection of information-rich cases that yield rich insight into the phenomenon of interest (Eriksson & Kovalainen, 2008) .

Cases were selected based on the following criteria. First, the case organizations deliver last-mile delivery services in Finland, which are relevant to the research focus. Second, all operate year-round, including during Finland's winter months, ensuring exposure to winter situations. Third, the case organizations represent variation in organizational size, governance model, and operational model (ranging from large, centrally operated organizations with corporate sustainability statements to smaller contractor-based organizations), allowing this study to explore how different organizational contexts influence the interaction of sustainability and reliability. Fourth, access was gained to operational practitioners who have experience in operating logistics during the winter, allowing for detailed practice narratives to be obtained.

To maintain confidentiality, all case sites are anonymised within the thesis. This allows interviewees to freely discuss operational practices, challenges, and decision-making without fear of damaging their organization's reputation.

In terms of theory, the case selection is consistent with theoretical sampling (Eisenhardt & Graebner, 2007), where cases are not selected for statistical representation, but for theoretical relevance, to deepen, extend, or refine theoretical insights. Variation in the organizational contexts allows us to investigate how contingency fit, a match between strategy bundles and environments, varies across settings (Sousa & Voss, 2008).

3.5.4 Acknowledging Limitations of Multiple-Case Design

It is worth noting that the multiple-case approach, which provides broader analytical opportunities, comes with trade-offs in terms of depth, as compared to a single-case design. This study looks for patterns across cases rather than in-depth longitudinal investigations of any one case. But this is suitable for our research question, which is to understand patterns and trade-offs of strategy across multiple firm contexts, rather than to understand organizational processes over time in a single firm. The research aim is to enable analytical generalisation, where theories are developed and refined, rather than statistical generalisation to the population of all logistics operators (Yin, 2018).

3.6 Time Horizon

The fifth layer in the research onion is the time horizon, which can be cross-sectional or longitudinal (Saunders et al., 2019).

The study has a cross-sectional time horizon. Data were gathered at one point (early 2026) to understand the operational practices, challenges and decision-making that occurred and were remembered by the participants during and after the 2025-2026 winter. A cross-sectional approach is suitable for this study as the research question relates to the identification of the strategies used and their effectiveness in the winter rather than how these strategies change over time. The cross-sectional design is also appropriate for a Master's thesis study due to the time and resource constraints on collecting longitudinal data.

It's recognised that a longitudinal approach would offer further insight into the evolution of adaptation strategies across multiple winter seasons, as electric vehicle technology and organizational practices evolve. This is discussed further in Section 5.5.

3.7 Data Collection

The core of the research onion is made up of the research techniques and procedures involved in collecting empirical data (Saunders et al., 2019). This study draws on data collected from two sources: primary data from semi-structured interviews and secondary data from reports and documents. Triangulation, which adds rigour to the research process, is facilitated by using multiple data sources (Yin, 2018).

3.7.1 Primary Data: Semi-Structured Interviews

The main source of empirical data for this research is semi-structured interviews with operational employees in last-mile logistics companies in Finland. Interviews are a core data collection method in qualitative case studies, as they offer direct insights into participants' practices, understandings and decision-making (Yin, 2018; Qu & Dumay, 2011; Silverman, 2021; Eriksson & Kovalainen, 2008).

Interview format and design: The interviews were semi-structured, using a predetermined list of themes and questions, but with the flexibility to address new themes and follow up on interesting issues (Kallio et al., 2016). The semi-structured interview format is well-suited for exploratory studies where the purpose is to identify and understand participants' practices and views (as opposed to testing hypotheses). We used the conceptual framework (Section 2.11) and the themes identified in the literature review to develop the interview guide. The main topics addressed were: (1) challenges of winter operations and associated effects on route planning, travel time, vehicle performance, and service reliability; (2) sustainability strategies in last-mile operations, such as vehicle technologies, operational practices, and organizational practices; (3) reliability management strategies, including buffer allocation, contingency planning and processes; (4) strategy adaptation and trade-offs between sustainability and reliability during winter operations; and (5) decision-making processes, and how decisions are made, information used, and competing goals managed. The interview guide is available in Appendix A.

Participant selection: Five interviews were conducted with operational staff in a variety of roles in three Finnish logistics companies. An overview of participants, their roles, case company, interview method and length is given in Table 1 below.

Table 1. Overview of participants, Role, Interview method and Length

Participant	Role	Organization	Size	mode	Duration
A	Operations Development Manager	Organization 1	Large	Face-to-Face	37 minutes
B	Terminal Manager	Organization 1	Large	Written email	10 pages
C	Frontline Supervisor	Organization 1	Large	Written email	7 pages

D	Night Delivery manager	Organization 2	Small	Face-to-Face	12 minutes
E	Multi-Product Supervisor	Organization 3	Mid-size	Face-to-Face	20 minutes

The number of interviews conducted (five) is typical for a Master's thesis and follows the depth-versus-breadth principle of case study research. The goal is not to have a statistically representative sample, but to gain detailed insights from informants who have operational experience and decision-making power in the cases (Eisenhardt & Graebner, 2007; Eriksson & Kovalainen, 2008). While the length of the interviews varied between participants, all interviews were conducted with the same interview guide and with the same set of questions, ensuring that the same data was captured across the interviews.

Our sample is small, but the cross-case patterns indicate that the results are likely to be stable. Across the six analytical themes, five of them - winter operational challenges, vehicle and technical challenges, delivery reliability practices, operational adaptation strategies, and organizational mechanisms - were common to all five interviewees; there was little that was new in the later interviews (see Table 9 in section 4.7). The remaining theme, the sustainability-reliability trade-off, did vary, but for reasons that have to do with the nature of the different types of organizations. So the sample is most effectively considered as providing analytical depth on the common patterns and suggesting the causes of variation, which are discussed in Section 5.5.

Interview procedures: Interviews were conducted one-on-one using two methods, depending on participants' availability and preferences. Three interviews (Participants A, D, and E) took place in person at participants' workplaces for 12-37 minutes, and were transcribed. The other two (Participants B and C) were asynchronous written interviews, where participants responded in writing (10 and 7 pages long, respectively) to interview questions via email. Notes were also taken during face-to-face interviews to record key observations and inform subsequent questions.

Value of interview data: The interviews contribute several forms of insight that cannot be obtained from other data sources: implementation insights on how sustainability strategies are put into practice, including informal practice and contingency responses; reliability management practices describing how supervisors ensure service delivery under winter variability; practical constraints including operational, organizational and resource constraints that affect decision-making; and contextual knowledge based on supervisors' experience and understanding of the effects of winter weather on operations.

3.7.2 Secondary Data

Secondary data were gathered from published organizational documents and reports available to the public from or about the case organizations. These reports and publications complement the interview data and allow for data triangulation. The secondary data sources include sustainability reports containing information on environmental objectives, emissions reduction targets, and fleet development strategies; annual and operational reports containing data on delivery volumes, service quality, and strategic priorities; and other company publications, such as press releases and web content, describing initiatives related to electric vehicle deployment, alternative delivery approaches, and winter operations; and policy context documents such as national and local documents on winter road maintenance, logistics regulations and environmental standards that provide information on the institutional environment within which the case organizations operate.

Secondary data play a number of roles in this research. First, they document official sustainability plans, goals and initiatives, as articulated by the organization. Second, they provide information on fleet and performance data, supplying information that provides context for the technology strategies described by interviewees. Third, they offer context that guides the interpretation of interview data by setting the high-level priorities and performance contexts in which operational decisions are made.

Secondary sources were obtained through a review of corporate websites, investor relations reports, and publicly available reports. Selection criteria were related to sustainability, last-mile operations, and winter logistics. We mainly gathered documents from 2021 to 2026 to make sure the data were up to date, but older documents were used as needed to track strategic development.

3.8 Data Analysis Method

3.8.1 Thematic Analysis

The interviews and secondary data were analyzed using thematic analysis, which is a method for analyzing qualitative data by identifying, organising and reporting patterns (themes) within the data (Braun & Clarke, 2006). This approach is appropriate for its flexibility and structure in analyzing qualitative data and its suitability for studies that seek to identify common themes across cases while recognizing their differences (Silverman, 2021).

3.8.2 Analysis Process

The analysis adhered to the six phases of thematic analysis outlined by Braun and Clarke (2006). These phases did not occur in a linear fashion, but were iterative and reflexive. The table below outlines how we implemented the phases of the analysis in this particular study, linking the analysis to the empirical data.

Table 2. Implementation of Braun and Clarke's (2006) Six-Phase Thematic Analysis in This Study

Phase	Phase Name	How it was implemented in this study	Data Sources Used	Outcome
1	Familiarization with the data	Three face-to-face interviews (Participants A, D and E) were recorded and transcribed. Participants B (10 pages)	Interview transcripts;	Thorough knowledge of the entire

		and C (7 pages) email responses were also read in their entirety several times. Additional documents - such as company sustainability reports, operational emails and industry documents - were also examined. The reading of the material was done in full before any coding was undertaken to allow the meanings and themes to emerge organically from the data.	email responses (Participants B and C); sustainability reports; operational emails and documents; industry documents	data set for the five participants; preliminary ideas about key themes were written down before coding started
2	Generating initial codes	The five interview transcripts and emails were line-coded. We assigned codes to meaningful passages of text that reflected a particular element of the practice, decision-making, challenge, or perspective. This included deductive coding (based on concepts in the contingency theory framework developed in Section 2.11, including strategy bundles, fit and environmental contingency) and inductive coding (directly from participant accounts, which were not anticipated by the original theoretical framework, such as task prioritization and route familiarity). Examples of initial codes derived directly from participants include: "EV battery capacity reduced in cold temperatures" (Participant A); "buffer time required for winter	Transcripts and written responses of all five interviews; secondary documents	A full list of initial codes that represent specific operational experiences, decisions, challenges and practices across the five participant cases

		routes" (Participant A); "reliability prioritized over sustainability in practice" (Participant A); "safety comes first, sustainability is secondary" (Participant B); "dark nights make delivery very difficult" (Participant D); "vehicles consume more fuel in winter" (Participant E); "route takes over five hours in winter versus four in summer" (Participant E); "newspapers prioritized, letters deferred when conditions are severe" (Participant D); and "only route-familiar couriers used as backup" (Participant E). Secondary documents were also coded to map the existence of sustainability statements and policies.		
3	Searching for themes	Initial codes were organised into higher level candidate themes reflecting conceptual congruence and relevance to the research question. At this point, a number of candidate themes were identified, themes that appeared across a number of participant cases. Candidates reflected both deductive themes - derived from the conceptual framework in Section 2.11 - and inductive themes - identified from participant responses and not	Coded data for all five participants	A number of candidate themes were found to span the entire dataset, combining both deductive and inductive themes

		expected based on the initial conceptual framework.		
4	Reviewing themes	Themes were checked against the entire dataset and were evaluated for internal consistency and differentiation. At this stage, vehicle and technical challenges was verified as a meaningful theme but also found to be highly related to winter operational challenges and operational adaptation strategies. Instead of a separate section of the written report for analysis, it was spread across these two sections in the report but maintained as a separate theme for the comparative analysis in Table 9. The six themes were confirmed as being supported by evidence from multiple participant cases and different from other themes.	All data reviewed against each candidate theme	Six coherent and well-supported themes confirmed
5	Defining and naming themes	All six final themes were clearly articulated, and described what the theme covers in relation to the question. The six themes are: (1) **Winter Operational Challenges** - covering route, access, safety, and variability impacts of snow, ice, cold temperatures, and reduced daylight; (2) **Vehi-**	Defined and reviewed themes	Six well-named and defined themes linked to the research question and conceptual framework

		cle and Technical Challenges - covering EV range reduction in cold, increased fuel consumption, vehicle breakdowns, and equipment failures; (3) **Delivery Reliability Practices** - covering time buffering, workforce scaling, route familiarity, real-time coordination, and task deferral; (4) **Sustainability Practices** - covering EV deployment, emissions tracking, and operational efficiency approaches varying by organizational size and capacity; (5) **Operational Adaptation Strategies** - covering modal shifts, scheduling adjustments, vehicle preparation, workforce training, and customer communication; and (6) **Trade-offs between Sustainability and Reliability** - covering how organizations balance emissions reduction goals and service performance during winter operating conditions.		
6	Producing the report	Analysis was written up in Chapter 4 structured according to the six themes. The analysis was illustrated with participant quotations. For instance, "switching EV to diesel vehicles for reliability" (Participant A) is used to illustrate the sustainability-reliability trade-off, and "more than five	Analyzed data set; conceptual framework from Section 2.11	Chapter 4 analysis narrative; Table 4 cross-case; theory connections to

		hours in winter" (Participant E) to illustrate winter operational challenges. A cross-case analysis (Table 9, Section 4.7) was also developed to illustrate the similarities and differences among the five participants. Results were linked back to the contingency theory framework from Section 2.11, exploring the relationship between the fit between operational strategies and winter environmental conditions on sustainability and delivery reliability.		contingency theory

This systematic and iterative approach ensured that the themes were focused on the research question and the conceptual framework, but also enabled the discovery of unexpected insights. The deductive and inductive coding enhanced the rigour of the analysis and helped to draw out both anticipated and unexpected insights.

3.8.3 Application to This Study

The thematic analysis centered around themes relating to the key concepts of this research. The analysis involved both deductive and inductive coding. Deductive codes were drawn from the conceptual framework (Section 2.11) and literature, and inductive codes from the data to reflect categories that were not expected based on the framework. This combination is consistent with the abductive reasoning outlined in Section 3.3, and is supported by (Fereday et al., 2006), who demonstrate a hybrid thematic analysis approach combining deductive and inductive coding within the same study. This enabled the analysis to be guided by theory while also being sensitive to the data. Table 3 outlines the approach to coding for each theme.

Table 3. Deductive and Inductive Coding Approach by Analytical Theme

Theme	Coding Type	Deductive Element–Derived From Framework	Inductive Element–Emerged From Data
Winter Operational Challenges	Deductive + Inductive	Winter explicitly understood as structured environmental contingencies as described in Section 2.11.1, such as snow, ice, cold and travel time variability	Particular operational implications not fully anticipated by this framework, including the effects of darkness on night-time delivery (Participant D), inoperable mailboxes due to frost (Participants B and C) and the importance of route familiarity in offsetting winter risk (Participant E)
Vehicle and Technical Challenges	Deductive + Inductive	EV range and power concerns in low temperatures as a key mechanism in Section 2.11.2; technological practices such as EV deployment as a strategy bundle construct in Section 2.11.1	Cold weather breakdowns, heating malfunction and use of older privately owned vehicles of smaller companies (Participants D and E) were not predicted
Delivery Reliability Practices	Deductive + Inductive	Delivery reliability defined as four interrelated constructs in Section 2.11.1 - on-time delivery, first-attempt success, service consistency,	Particular practices such as item prioritisation and non-urgent task postponement during extreme weather (Par-

		and recovery capability; buffering and recovery practices identified as a mechanisms in Section 2.11.2	ticipant D), redistribution of tasks among the workforce, and use of "local" backup couriers (Participant E) came up inductively
Sustainability Practices	Deductive + Inductive	Sustainability performance as emissions and energy performance included as a core construct in Section 2.11.1; technological and operational strategy bundles - EV use and route adjustments - from Section 2.4 and 2.11	Sustainability is not explicitly part of all organizations' strategies, and for smaller organizations, sustainability is embedded in the efficiency of operations rather than specific emissions targets (Participants D and E)
Operational Adaptation Strategies	Deductive + Inductive	Operational strategies such as routing, scheduling and time-window adjustments included as strategy bundles in Section 2.11.1; variability identified as a mechanism requiring buffering in Section 2.11.2	Operational adaptations such as mode shifts from bikes to cars at the start of winter (Participant D), the use of mobile apps to report delay information in real time (Participant D), the early start of shifts to gain more daylight hours (Participant B), and scheduled training for backup couriers before

			winter (Participant E) emerged inductively
Trade-offs between Sustainability and Reliability	Deductive + Inductive	The sustainability-reliability interaction and the four mechanisms - travel-time variability, energy uncertainty, redelivery loops, and buffering costs - explicitly theorized in sections 2.9 and 2.11.2 as varying relationships	The discovery that not all companies perceive the trade-off (Participant C claims no major trade-off and Participants D and E work in companies where sustainability is not a formal goal) extends the framework by highlighting the influence of organizational context on the recognition and management of the trade-off

Note: All themes are a mix of deductive-inductive, in line with the abductive reasoning approach taken in the study.

3.8.4 Cross-Case Analysis

The multiple-case study involved two phases of analysis. First, individual case analysis was carried out for each participant to understand the context of operation and practices of each case. Second, cross-case analysis took place to identify convergent and divergent patterns across cases (Yin, 2018; Eisenhardt & Graebner, 2007). The cross-case mapping is detailed in the results chapter (Table 9), which maps the themes across the five participant cases and summarizes the patterns across all six analytical themes.

3.8.5 Integration of Data Sources

The thematic analysis brings together interview data and secondary sources of information. Secondary data provide official statements of strategic intent and organizational context, while interview data provide insight into the implementation and management of strategy, decision-making and adaptation to circumstances. This helps triangulation and provides a richer context of the phenomenon (Yin, 2018).

3.9 Quality and Trustworthiness of Research

There are four criteria used to assess the quality of qualitative research: credibility, dependability, confirmability and transferability (Lincoln & Guba, 1985). This study considered these criteria in the research design, data collection and analysis (Eriksson & Kovalainen, 2008; Silverman, 2021).

Credibility is the extent to which the research findings are accurate (Lincoln & Guba, 1985). In this study, credibility was enhanced through data triangulation using documents from the organization combined with interview data from operational staff at various levels and various organizational settings. Selection of participants from a range of roles and organizations adds to the depth and breadth of the data. Time spent analysing the data also contributed to a better understanding of practices (Yin, 2018; Creswell & Poth, 2018).

Dependability is related to the consistency and reliability of the research process (Lincoln & Guba, 1985). Dependability was achieved via the documentation of research design, data collection and analysis in this chapter. The thematic analysis was undertaken in accordance with the six phases of analysis outlined by Braun and Clarke (2006), providing an audit trail of the coding and theme extraction process. The interview guide (Appendix A) is included to allow evaluation of the data collection tools.

Confirmability is the extent to which the results are derived from the data rather than researcher preconceptions (Lincoln & Guba, 1985). Confirmability was enhanced through reflexivity (e.g., consideration of researcher assumptions in the analysis) and through evidence-based analysis, including the use of interview quotations and documentary evidence to support themes. The conceptual framework (Section 2.11) ensured a clear connection between expectations and analysis, facilitating the traceability of interpretations.

Transferability is the extent to which results can be generalised to other settings (Lincoln & Guba, 1985). Transferability was enhanced by the description of the empirical context, including the Finnish winter logistics environment, the control centre and operating practices. This description (known as "thick description" - Geertz 1973) allows readers to judge whether and how the findings may be transferred to other cold-climate logistics settings. The research supports analytical generalisation whereby the study contributes to the development of propositions and theories that could be tested in other contexts, but not statistical generalisation to all logistics operators (Yin, 2018).

3.10 Ethical Considerations

This study adhered to the ethical principles of academic research, protecting the rights of participants and the integrity of the research.

Voluntary participation: Participation was voluntary. Participants were given prior information about the research, procedures and their participation. They were made aware they could withdraw at any stage without penalty. The researcher sought and was given informed consent to collect the data.

Anonymity and confidentiality: Both the case companies and participants are anonymised in the thesis. Names of organizations and individuals are not revealed. Details about participants are presented in generic terms (e.g., Participant A, Operations Development Manager) that do not identify them. Data containing potentially identifying information has been removed or anonymised.

Data handling and storage: Recordings and transcripts will be stored securely and will only be accessible to the researchers and the thesis supervisor. Data have been handled in line with data protection laws and institutional ethical standards. The use, storage and disposal of data have been explained to participants.

No confidential company data: This study does not access confidential company data. It uses publicly available documents and information obtained from interviews. The interview questions were related to general operations and decision-making rather than specific business information.

Academic use only: The data gathered for this study are used solely for academic research purposes - to complete this Master's thesis, and any related academic publication or presentations. This study was not commissioned by a commercial entity.

3.11 Summary

This chapter has outlined the research framework for studying sustainable last-mile logistics solutions for wintertime in Finland. Using the research onion (Saunders et al., 2019), the research philosophy is interpretivist, and the research approach is abductive, with a mono-method qualitative research design. The research strategy is a qualitative multiple-case study of three logistics companies in Finland. We used a cross-sectional time horizon and gathered data in early 2026. Primary data sources included five semi-structured interviews with operational personnel, and public documents as secondary data sources. Thematic analysis, based on the six phases proposed by Braun and Clarke (2006), was used to examine the data, with cross-case analysis to determine similarities and differences. The research ensures quality and trustworthiness via triangulation, documentation, reflexivity, and rich contextual description, and adheres to ethical considerations such as voluntarism, anonymity and confidentiality.

4 Results

This chapter presents the findings from a qualitative multiple-case study examining the relationship between transport-related emissions and delivery reliability in Finnish last-mile logistics under winter conditions. The analysis is based on thematic analysis (Braun & Clarke, 2006) of semi-structured interviews conducted with five operational personnel working in different roles within logistics organizations in Finland. Secondary data from sustainability reports, operational communications, and documentation of winter disruption events are used to provide contextual support.

All participating organizations are presented anonymously. Findings are reported as cross-case insights using aggregated terms such as "participants," "respondents," and "cases," with individual participants referred to as Participant A (Operations Development Manager), Participant B (Terminal Manager), Participant C (Supervisor), Participant D (Delivery Manager, night operations), and Participant E (Supervisor, multi-product delivery) where relevant. The chapter is structured around key themes, including winter operational challenges, delivery reliability practices, sustainability practices, operational adaptations, and trade-offs between emissions reduction and service reliability.

4.1 Overview of Data

This chapter reports the results of a qualitative multiple-case study on sustainability and delivery reliability practices of last-mile logistics companies during winter in Finland. Our analysis draws on five semi-structured interviews with operational staff from last-mile logistics firms, complemented by secondary data sources, including sustainability reports and other documents.

The results are presented under six analytical themes identified via thematic analysis. These themes offer insights into similarities and differences among cases. As outlined in Tables 5, 6, and 8, high levels of convergence are evident in themes of winter challenges, practices for reliability of delivery, and operational adaptation. There is, however, greater diversity in themes related to sustainability practices and the sustainability-reliability trade-off due to differences in organizational environment, structure, and priorities.

The findings are reported as cross-case insights, highlighting commonalities and differences across organizations. The aim is to draw out similarities and differences across cases in terms of how common environmental challenges - such as winter variability - impact operational practices and how organizational characteristics shape responses to these challenges.

In general, the results show that organizations are subject to the same environmental constraint (winter conditions), and their responses to it depend on their strategic focus and operational priorities. The next sections build on each theme, illustrating how organizations address operational challenges, ensure delivery reliability, adopt sustainability practices, adapt to winter conditions, and manage trade-offs among multiple performance goals.

The cross-case findings presented in each section identify patterns that are either shared across all five cases or vary by organizational context, following the cross-case analysis guidance of Yin (2018) and Eriksson and Kovalainen (2008), as outlined in section 3.8.4.

4.2 Winter Operational Challenges

Table 4. Cross-case comparison: Winter Operational Challenges

Participant	Role & Org	Key Finding
A	Operations Dev. Manager, Large Org.	Slower speeds, longer routes, mailbox access issues
B	Terminal Manager, Large Org.	Snow blocks mailboxes, driver fatigue, safety risks
C	Frontline Supervisor, Large Org.	Impassable roads, delivery difficulty in heavy snow
D	Night Delivery Manager, Small Org.	Darkness compounds challenges, missed pre-dawn deadlines

Participant	Role & Org	Key Finding
E	Multi-Product Supervisor, Mid-size Org.	Routes 25%+ longer, black ice most hazardous

Note: Findings shared across all five cases

Winter conditions proved a common and fundamental constraint across all cases, affecting route planning, vehicle availability, labor productivity, and service performance. As Table 4 illustrates, all participants identified similar types of challenges, suggesting a high degree of consistency.

Interviewees did not report winter as an unexpected event but a distinctive and recurring operating environment with snow, ice, cold temperatures, and short days. These impact the feasibility and variability of last-mile operations. Snow and ice reduce access to destinations and lower safe speed limits, while varying travel times create route uncertainty. Shorter days, especially for early AM and late PM job shifts, also make delivery operations more difficult due to poor visibility and safety concerns.

Other issues were related to vehicle operations. Winter adversely affects both electric and conventional vehicles. These included reduced battery range in electric vehicles, increased fuel consumption in conventional vehicles, and a greater risk of mechanical failure at low temperatures. These results suggest that winter conditions affect the operational feasibility of different types of vehicle technologies rather than being concentrated on specific vehicle models.

From a contingency perspective, these results indicate an increase in environmental uncertainty, particularly in travel-time variability and operational feasibility. This is consistent with the mechanisms outlined in the conceptual model (Section 2.11), in which variability and energy uncertainties affect the link between operational strategies and performance outcomes. The uniform challenges across all cases indicate that winter conditions can be considered as an environmental contingency in Finnish last-mile logistics.

Alongside technological and route planning issues, workforce issues were also present. Interviewees noted the additional physical toll on drivers, route duration, and the importance of experience and exposure to route knowledge under winter conditions. At times, only experienced or route-knowledgeable couriers were used as backups, pointing to the role of tacit knowledge in coping with environmental uncertainties.

In summary, the results show that winter conditions impose a multidimensional set of constraints that simultaneously affect operational feasibility, variability, and resource requirements. These constraints provide the context in which sustainability strategies and reliability practices are put in place, underlining the need for fit between operational configurations and environmental conditions, as proposed by contingency theory.

4.3 Delivery Reliability Practices

Table 5. Cross-case comparison: Delivery Reliability Practices

Participant	**Role & Org**	**Key Findings**
A	Operations Dev. Manager, Large Org.	Time buffers added to routes; seasonal capacity planning adjusted
B	Terminal Manager, Large Org.	Extra buffer time added; backup drivers deployed earlier
C	Frontline Supervisor, Large Org.	Workforce scaled up; real time route adjustments
D	Night Delivery Manager, Small Org.	Backup staff hired before winter; task deferral for non-urgent items
E	Multi-Product Supervisor, Mid-size Org.	Route-familiar couriers assigned; towing protocols prepared in advance

Note: Findings shared across all 5 cases – time buffering, workforce scaling, and flexible routes are applied across all organizational sizes.

All cases displayed a consistent set of practices to maintain delivery reliability amid winter uncertainties. These practices were shared across all participants (see Table 5), suggesting common underlying principles for managing reliability across different organizational settings.

Participants explained that reliability was achieved through a combination of practices, including time buffers, workforce scaling, familiarity with routes, real-time coordination, and task prioritization and deferral. Time buffering was commonly used to accommodate the effects of snow, ice, and variable travel times, while workforce scaling (e.g., additional staff or task redistribution) was used to ensure service levels during peak periods or extreme weather conditions. They also stressed the importance of route knowledge, noting that drivers who knew the routes well were better equipped to predict disruptions and respond accordingly.

Moreover, respondents emphasized the value of dynamic coordination and adaptability to ensure timely deliveries. This involved dynamic route planning, ongoing communication between drivers and managers, and informal decision-making to address unexpected disruptions. During more challenging weather conditions, prioritization and deferral were used, with urgent deliveries given priority and less critical tasks deferred.

Contingency-wise, these practices serve as buffer and adaptation mechanisms to cope with heightened environmental uncertainty. Time buffers and workforce adjustments create slack resources, while knowledge of routes and coordination allows for adjustments. Overall, these practices enable organizations to sustain service delivery under uncertainty through dynamic reconfigurations.

The prominent use of these practices across all cases suggests that reliability strategies are well matched to winter conditions. Rather than standardized planning, to maintain reliable delivery, organizations adopt flexible and responsive practices that adapt to variations. This suggests a high degree of contingency fit, with operational strategies well aligned with environmental factors.

But such practices for maintaining delivery reliability may involve further operational effort or resource commitments. Higher levels of buffering, staffing changes, and dynamic coordination may lower efficiency, with knock-on impacts on emissions. This suggests reliability and sustainability performance are interlinked, with practices that maintain service performance under uncertainty creating potential trade-offs.

In summary, the results show that reliability in delivering goods in winter last-mile logistics occurs not through rigid planning, but rather through a buffering and adaptive system of practices. These practices help organizations remain "fit" with the environment, highlighting the impact of contingency fit on performance.

4.4 Sustainability Practices

Table 6. Cross-case comparison: Sustainability Practices

Participant	Role & Org	Key Findings
Participant A	Operations Dev. Manager, Large Org.	Formal EV fleet operated; fossil-free target publicly committed
Participant B	Terminal Manager, Large Org.	EVs replaced by diesel in winter; formal emissions tracking maintained
Participant C	Frontline Supervisor, Large Org.	EV limitations acknowledged; seasonal emissions increase accepted
Participant D	Night Delivery Manager, Small Org.	No formal emissions targets; contractor model limits vehicle control
Participant E	Multi-Product Supervisor, Mid-size Org.	No EV mandate; sustainability not a formal organizational priority

Note: Finding varies by organizational context – larger organizations have formal electrification plans, while smaller organizations approach sustainability through operational efficiency.

Sustainability strategies in last-mile logistics were evident in all cases, but differ in form, level of formalization, and priority. As Table 6 shows, this theme exhibits significant variation among organizations, in contrast to the consistency seen in operational challenges and reliability practices.

Participants from larger firms reported formal sustainability programs focused on the electric vehicle (EV) transition, emissions tracking, and setting environmental goals. They reported more explicit sustainability strategies integrated into their operations and investments in fleet transformation and monitoring systems. But participants also highlighted that these initiatives are affected by winter conditions, including reduced battery efficiency, increased power consumption, and operational restrictions due to low temperatures.

By contrast, smaller or contractor-based transport organizations had a more implicit approach to sustainability. These organizations did not explicitly focus on emissions reduction but emphasized operational efficiency through practices such as avoiding unnecessary trips, efficient route planning, and fuel efficiency. Sustainability was not a key strategic goal but an incidental outcome of cost savings and practicality.

This discrepancy is a product of differences in capacity, governance, and strategy. Large-scale operators have greater control over fleet technology and investment, enabling them to adopt sustainability strategies driven by technological innovation. On the other hand, contractor-based fleets have less direct control over fleet and infrastructure, which limits the adoption of formal emissions-reduction strategies.

From a theoretical standpoint, this study shows that sustainability initiatives in last-mile logistics are not an across-the-board approach but depend on the fit between organizational and environmental factors. Technological approaches like electrification can reduce emissions, but their use depends on compatibility with winter conditions. In the absence of this compatibility, sustainability practices are not prioritized and are complemented by operational efficiency measures.

For instance, the results indicate that sustainability measures can be subordinate to reliability goals. While larger transport companies proactively pursue emissions reduction, they need to adjust these strategies to winter realities to maintain operability. In smaller organizations where sustainability is less institutionalized, decisions are made primarily with reliability and safety in mind, with environmental concerns taking a back seat.

In summary, the findings point to the nature of sustainability in winter last-mile logistics as context- and operationally constrained. Sustainability practices not only vary in form and effectiveness across different organizational and environmental settings, but they also highlight the critical role of fit between strategy and context in performance.

4.5 Operational Adaptation in Winter

Table 7. Cross-case comparison: Operational Adaptation Strategies

Participant	**Role & Org**	**Key Findings**
A	Operations Dev. Manager, Large Org.	Winter tires prepared; modal shift from bikes to cars
B	Terminal Manager, Large Org.	Earlier dispatch times; daylight adaptation applied to scheduling
C	Frontline Supervisor, Large Org.	Contingency plans activated; routes re-routed in real time
D	Night Delivery Manager, Small Org.	Load sharing during bad weather; delivery app upgraded for reporting
E	Multi-Product, Supervisor Mid-size Org.	Winter driving guidance provided; backup courier training conducted

Note: Finding shared across all five cases – vehicle preparation, staff training, and scheduling adjustments are consistently applied.

Adaptation was a key strategy for overcoming the challenges posed by winter conditions, enabling service delivery and operational sustainability. As shown in Table 7, these adaptation measures were widely implemented across cases, tailored to the operational environment and model.

Respondents reported a variety of adaptation practices in response to winter. These included changes in travel mode (e.g., using cars instead of bikes at the start of the winter season); adjustments to schedules (e.g., starting earlier to capitalize on daylight hours); and vehicle preparation for winter (e.g., retrofitting vehicles for winter performance). Other adaptations related to workforce management include specialized winter-driving training, deploying experienced or local drivers in key positions, and staffing adjustments to accommodate longer travel times.

Finally, participants noted the importance of dynamic operational adaptations to deal with daily variations. This involved real-time route adjustments, communication between drivers and supervisors, and the use of information systems to share information and coordinate responses. Communications with customers were also recognized as an adjustment strategy, in which firms modify delivery schedules and notify customers of potential delays due to extreme weather events.

From an analytical point of view, these are examples of dynamic adaptation practices, in which organizations modify their operational setups in response to changing conditions. After all, adaptation is not a plan or a new strategy but an ongoing process of modifying scheduling, resource allocation, and delivery to align operations amid winter-induced uncertainty. This demonstrates that adaptation processes are not one-time events but rather occur as part of ongoing operations.

This research also suggests a connection between adaptation and both reliability and sustainability. Through route adjustments, resource redeployment, and delivery process changes, they are able to maintain services despite increased variability. But at the same time, these changes may affect greenhouse gas emissions, for instance, by altering transport resource use or operational effort. This highlights the link between operational decisions during winter.

In summary, the findings demonstrate that adaptation is a key mechanism for organizations to deal with winter conditions. By dynamically adapting and making flexible decisions, the fit between operational strategies and the operational environment is maintained, enabling reliability and sustainability within the operational context.

4.6 Trade-offs between Sustainability (Emissions) and Reliability

Table 8. Cross-case comparison: Trade-offs between Sustainability and Reliability

Participant	Role & Org	Key Findings
A	Operations Dev. Manager, Large Org.	EVs switched to diesel; reliability explicitly prioritized over sustainability
B	Terminal Manager, Large Org.	Safety first; extra trips accepted as operational trade-off
C	Frontline Supervisor, Large Org.	No major trade-off experienced; both objectives maintained simultaneously
D	Night Delivery Manager, Small Org.	Urgent items prioritized first; emissions not primary concern
E	Multi-Product Supervisor, Mid-size Org.	No trade-off; no formal sustainability goal in place

Note: Finding differs by organizational context – the trade-off is clearest in organizations with formal sustainability commitments; others focus on safety and service completion.

The trade-off between sustainability and service delivery reliability didn't appear in the same way across all the cases. Rather, as illustrated in Table 8, it occurred to varying degrees across organizations, with some organizations seeing it as more pronounced than others. This suggests that the relationship between sustainability and delivery reliability is not universal but depends on organizational traits.

In institutions committed to sustainability, respondents reported observed trade-offs between reliability and sustainability strategies during cold weather. For instance, electric vehicles were linked to decreased battery efficiency, shorter range, and higher energy demand in cold weather. These limitations sometimes led to operational changes, such as reverting to traditional vehicles or altering delivery routes, to ensure reliable service. In these instances, service reliability was prioritized over sustainability, especially during extreme weather conditions that endangered the continuity of service and safety of the operation.

These insights echo the energy uncertainty and feasibility issues identified in the conceptual framework (Section 2.11), with winter weather conditions diminishing the effectiveness of technological sustainability strategies. This is a contingency scenario in which strategy and environment are misaligned (low fit), and organizations must change operational configurations to re-establish performance. The switch from electric to conventional vehicles is an example of how organizations adapt strategy bundles in response to higher environmental uncertainty to sustain reliability.

On the other hand, in smaller or contractor-based firms, the sustainability-reliability trade-off was not seen as a key operational challenge. In these settings, interviewees highlighted that operations focused on reliability and safety, with sustainability playing a more peripheral role. Relying on efficiency-oriented practices to balance service operations under constrained conditions, these organizations focused on improving service performance rather than managing trade-offs.

This difference underlines the influence of organizational context on the existence (or otherwise) of the trade-off. As shown in Table 9, while reliability practices remained similar across all cases, sustainability practices varied by organizational structure, resource base, and strategic focus. As a result, the sustainability-reliability interaction can be viewed as occurring under specific organizational circumstances rather than as an operational constant.

Trade-offs were influenced by non-technical factors as well as technological limits. Measures to ensure reliability, such as time buffering, staffing levels, and dynamic route adaptations, may increase costs and reduce efficiency, which could, in turn, affect emissions levels. Likewise, prioritizing sustainability goals may limit operational flexibility, potentially amplifying impacts during winter variability. These patterns reflect the variability, sensitivity, and buffering observed in the conceptual framework, as greater uncertainty accentuates the efficiency-robustness trade-off.

Overall, the results show that the sustainability-reliability trade-off is not universal. This interaction is amplified during winter due to increased environmental uncertainty, but the effects of trade-offs vary according to the integration of sustainability with strategy and practice. This supports the thesis's argument that last-mile performance outcomes are attributable to the fit between strategy bundles and environmental conditions, rather than optimal strategies.

4.7 Summary of Key Findings

Table 9. Summary of cross-case patterns across six analytical themes

Theme	Cross-Case Pattern	Summary
1. Winter Operational Challenges	Shared across all 5 cases	Winter conditions create significant and consistent operational constraints across all organizational contexts.
2. Vehicle & Technical Challenges	Shared across all 5 cases	Cold temperatures reduce vehicle performance and increase breakdown risk across all cases regardless of fleet type.
3. Delivery Reliability Practices	Shared across all 5 cases	Time buffering, workforce scaling, and route flexibility are consistently applied to maintain service levels.

Theme	Cross-Case Pattern	Summary
4. Sustainability Practices	Varies by organizational context	Larger organizations pursue formal electrification strategies; smaller organizations approach sustainability through operational efficiency.
5. Operational Adaptation Strategies	Shared across all 5 cases	Vehicle preparation, workforce training, and scheduling adjustments are systematically implemented across all cases.
6. Trade-offs: Sustainability vs. Reliability	Differs by organizational context	The trade-off is contingent on organizational context; explicitly experienced where formal sustainability commitments exist.

This chapter has outlined the empirical results of a qualitative multiple-case study of last-mile logistics operations in winter conditions in Finland. The findings highlight six themes that reflect both similarities and differences among the cases.

First, winter weather was identified as a pervasive and multifaceted constraint, reported to impact the feasibility of routes, travel time uncertainty, vehicle efficiency, and human resource capacity. This was common across all cases, suggesting a common context for last-mile logistics.

Second, ensuring reliability involved a series of remarkably consistent practices, such as time buffering, flexible human resources, route knowledge, real-time communication, and prioritization. These practices work in concert to buffer operational variability while ensuring service performance under uncertainty.

Third, sustainability practices varied across organizations. Large organizations had more formal sustainability approaches, such as electrification and emissions reporting, whereas small organizations or contractor-based organizations focused on efficiency. This is due to differences in capacity and priorities.

Fourth, operational flexibility was significantly important for organizations to adapt to winter. By adapting to changing conditions with ongoing adjustments to routes, schedules, resource allocation, and communication strategies, organizations kept pace with the changing environment.

Finally, the role of sustainability in relation to delivery reliability was situation-specific. Organizations with formal sustainability policies and targets experienced conflicting goals between sustainability and reliability in winter. However, in organizations with lower sustainability, delivery was primarily driven by reliability and safety concerns.

In all, the results show that environmental conditions and their effects on performance in winter last-mile logistics depend on organizational responses. Although all organizations face the same external conditions, their strategies, structures, and resources shape operational responses to sustainability and reliability.

5 Discussion

5.1 Introduction to the Discussion

This chapter discusses the research findings outlined in Chapter 4 relative to the academic literature and our theoretical approach as set out in Chapter 2. This research sought to understand which last-mile logistics strategies best meet Finland's winter emissions-reduction and reliability goals. Using a qualitative multiple-case study of five operational managers in Finnish last-mile logistics companies, this study explored the practices used to achieve sustainability and delivery reliability in recurring winter conditions.

Results show that winter is a multidimensional operational constraint that affects sustainability and reliability. Organizations adopt multi-layered reliability practices; engage in a range of sustainability strategies depending on organizational circumstances; undertake systematic adaptations; and face contingent sustainability-reliability trade-offs. This chapter seeks to interpret these patterns through contingency theory (Donaldson, 2001; Drazin & Van de Ven, 1985) and the logistics literature, to then reflect on the theoretical and practical implications.

The chapter unfolds as follows. Section 5.2 offers thematic insights into findings across five areas: challenges of winter operations, practices to ensure delivery reliability, sustainability practices, operational flexibility strategies, and the trade-off between sustainability and reliability. Sections 5.3 and 5.4 discuss theoretical and practical implications. Section 5.5 discusses the study's limitations, and Section 5.6 offers future research opportunities.

5.2 Interpretation of Key Findings

5.2.1 Winter Operational Challenges

The results suggest that winter (snow, ice, cold weather, and darkness) acts as a multifaceted constraint on operations, affecting vehicle efficiency and reliability, route planning, driver workload, and service quality across our cases. Both electric and traditional vehicles experienced impacts, with greater impacts during nighttime operations due to reduced visibility, colder nighttime temperatures, and lower road maintenance.

This is consistent with previous research on the technical impacts of cold weather on logistics. Rastani et al. (2019) demonstrated that temperature has a major influence on EV efficiency, necessitating changes in route planning. Our research builds on this by revealing that cold-weather effects do not only affect EVs: they also affect conventional vehicles, increasing fuel consumption, breaking down mechanical components, and limiting vehicle flexibility. Similarly, Dybdalen and Ryeng (2022) found that winter was a key constraint on cargo bike use in the Nordic region. Our results confirm these limitations and show that companies respond by halting or drastically reducing cargo bike deployments during the winter, undermining the sustainability potential of this transport mode.

The intensification of challenges during nighttime operations introduces a temporal dimension that prior logistics research has not extensively addressed. Sabir (2011) described the overall effect of adverse weather on transport efficiency, but the combination of winter and night-time delivery, with poor visibility, lower temperatures, and less frequent road maintenance, creates a complex operating context that requires special consideration. The temporal dimension of constraints is an important contribution to the winter logistics literature.

Crucially, these results also support the notion of winter as a structured environmental contingency, rather than a simple event. Finnish winter exhibits a seasonal regime with a consistent start and duration, but high variability (Finnish Meteorological Institute, n.d.). From a contingency theory viewpoint (Donaldson, 2001; Drazin & Van de Ven, 1985), structured contingencies allow organizations to proactively and systematically adapt to them. Our study supports this view: organizations consider winter as a structured contingency and proactively adapt - seasonal staffing, vehicle preparation procedures, scheduling - reflecting institutional memory. This underlines that cold-climate logistics sustainability and reliability planning should be based on the assumption of winter, rather than exceptionalism.

5.2.2 Delivery Reliability Practices

The findings suggest that organizations achieve delivery reliability via a complex system of interconnected practices such as time buffering (adding time to routes), workforce scaling (hiring extra drivers in winter), real-time monitoring (monitoring delivery status), route familiarity (allocating experienced drivers to complex routes), load redistribution (reallocating parcels during the day) and task deferral (postponing non-urgent deliveries when conditions worsen). If these practices are ineffective, organizations trade off service delays and incomplete delivery for safety.

This builds on the supply chain flexibility literature by revealing that reliability under environmental uncertainty is achieved through a combination of practices. Sreedevi and Saranga (2017) show that supply chain flexibility moderates the negative impact of uncertainty on operations. The current research confirms this and defines flexibility in winter logistics: time padding (slack resources), monitoring and load reallocation (dynamic adjustment), and route knowledge (knowledge-based capability). Combined, these practices create a portfolio of reliability practices.

The combination of these practices also echoes earlier findings that stress the importance of environmental uncertainty in affecting management practices. In winter logistics, reliability is achieved by synthesizing pre-planned buffers, on-time adaptations, and operational experience, rather than any single action. This underlines that reliability under uncertainty is a coordination effort across multiple time and organizational scales.

The observation that organizations make the trade-offs of delaying or reducing the load in favor of safety mirrors operational resilience. Organizations prioritize safety over strict adherence to service levels when environmental conditions exceed tolerable levels. It suggests that delivery performance in winter logistics should be viewed as a dynamic competency, comprising ongoing monitoring, real-time decision-making, and trade-offs, rather than a performance target.

5.2.3 Sustainability Practices

The research shows that approaches to sustainability in last-mile logistics are not homogeneous but vary across organizational contexts. Large organizations exhibited more formal sustainability practices, such as the use of electric vehicles, emissions measurement, and formal targets to reduce their environmental impact. This is consistent with previous studies suggesting that technological approaches, such as electrification, play a significant role in decarbonizing urban logistics (Browne et al., 2011; Comi & Savchenko, 2021). But the research also shows that the use of these strategies is limited in winter due to decreased battery efficiency and higher energy demand.

By contrast, the more operationally focused approach for smaller or contractor-based companies emphasized efficiency measures such as route planning and eliminating empty runs. Here, sustainability was not a strategic goal in and of itself but a by-product of cost efficiency. This reflects the limitations of decentralized logistics models, which lack autonomy in fleet and investment strategies.

The results indicate that sustainability practices are dependent on organizational and environmental factors. While previous research has often treated sustainability initiatives as universally applicable, the findings show that strategies must be aligned with operational practices, especially in a high-precision environment. Innovation strategies, such as electrification, can reduce emissions but are contingent on environmental conditions.

Additionally, the results suggest that sustainability is not always given equal weight to reliability. In winter conditions, companies modify sustainability practices to maintain operational viability, whereas in environments where sustainability is not institutionalized, practices are still primarily defined by reliability and safety concerns. This suggests that sustainability in last-mile logistics depends on the interplay between strategic goals and environmental conditions, rather than on individual initiatives.

5.2.4 Operational Adaptation Strategies

Our research shows that organizations undertake systematic, multi-faceted adaptations to winter. These include vehicle readiness (winterization, tire and battery maintenance), employee training (winter driving skills, safety procedures), mode switching (curtailing or ceasing cargo bike and electric vehicle use), schedule changes (starting earlier, longer delivery windows), customer communication (advance notice), and technological innovations (real-time monitoring, route planning software). Importantly, these adaptations are often preemptive, reflecting "learning" from institutional memory of past winters.

These are the types of adaptations we would expect under the conditions of recurring and structured environmental uncertainty that contingency theories of alignment assume. Finnish winter comes every year, so organizations have been able to incorporate adaptation into their practices rather than respond to events in real time. Performance monitoring and weather forecasting inform planning; the workforce and the vehicle fleet are scaled and prepared; and daily changes and adjustments to routes, schedules, and modes of travel are made within the structure of a prearranged resource configuration. Flynn et al. (2010) and Wong et al. (2011) contend that performance in uncertain environmental conditions is based on the fit between practices and the environment. The results reported here support that view and extend it: if uncertainty is predictable (in the sense of when it will occur), the fit can be anticipated.

However, the outcomes of these responses cannot be determined just by organizational actions. Infrastructure considerations (road maintenance and the provision of charging infrastructure) have a strong moderating effect. This relationship underscores that winter logistics depends not just on organizational capabilities but also on infrastructural support, adding to contingency theory by placing external infrastructure as a facilitator or constraint of organizational strategy. The policy implication is clear: public investment in road maintenance and charging infrastructure is not just a complement to logistics but a precondition for its sustainability.

5.2.5 Trade-offs between Sustainability and Reliability

Our results suggest that the tension between sustainability and delivery reliability is determined by the organizational context rather than a universal truth. In formal organizations that prioritize sustainability, there are unavoidable trade-offs in winter conditions where reliability often trumps sustainability. By contrast, in small contractor-type organizations without formal sustainability goals, trade-offs are neither acknowledged nor felt, as operational considerations are centered on reliability and safety.

This refutes the conventional view in the logistics literature of an inherent tension between sustainability and reliability. While Boysen et al. (2021) argue that logistics providers must trade off multiple goals, the current research demonstrates that the relative importance of these goals differs across organizational contexts. For larger organizations, sustainability is a competing objective alongside reliability and cost. In contractor-based firms, sustainability is not a primary concern, and reliability and cost are the primary decision-making objectives. Thus, the trade-off between sustainability and reliability is not an objective reality but rather a product of the goals that organizations pursue and measure.

Contingency arguments suggest that the relationship between sustainability and reliability depends on how strategy, environment, and performance interact. When sustainability is formally incorporated into organizational objectives, winter conditions create clear tensions between reliability and sustainability, as maintaining reliability through longer delivery times, increased vehicle usage, or non-fuel-efficient vehicles is in direct opposition to sustainability concerns. Where sustainability is not considered in decision-making, there is no tension.

The fact that smaller firms do not explicitly perceive a trade-off can also be explained by the attention-based view of the firm (Ocasio, 1997), which argues that organizational decision-making is constrained by the structural focus of managerial attention. Issues are prioritized through formalized strategies, performance indicators, and accountability mechanisms. If sustainability is not institutionalized in this manner, it is not considered in operational decision-making, and no trade-off is felt. This implies that the sustainability-reliability trade-off is not an inherent characteristic of logistics operations but rather depends on context and is shaped by organizational priorities and attention.

This research also contributes to existing understandings of the relationship between sustainability and reliability. While previous studies suggest they are becoming more interlinked, the current research suggests this can differ between contexts. In some cases, sustainability and reliability conflict and need to be explicitly prioritized; in others, reliability prevails in the absence of explicit sustainability goals.

In summary, the study adds to the knowledge base by showing that sustainability-reliability trade-offs depend on structural factors such as governance and the role of sustainability considerations in decision-making. This highlights the need for organizational diversity: policies and interventions that work in large, integrated firms may not work in small, contractor-based firms. Crucially, the trade-off is not inherent and can be shifted through measures such as implementing sustainability targets, centralizing fleet management, and providing institutional support for green technologies, thereby affecting the integration of sustainability into decision-making.

Figure 2 below maps the empirical findings from Chapter 4 back to the conceptual framework developed in Section 2.11. It illustrates how the three strategy bundles – were shaped by winter contingencies in practice and what performance outcomes resulted across the five cases. Delivery reliability was achieved consistently across all five cases, sustainability performance varied across organizational contexts, and the sustainability-reliability trade-off differed depending on whether sustainability was formally institutionalised in the organization. Dashed arrows illustrate how winter contingencies moderated the effectiveness of all three strategy bundles.

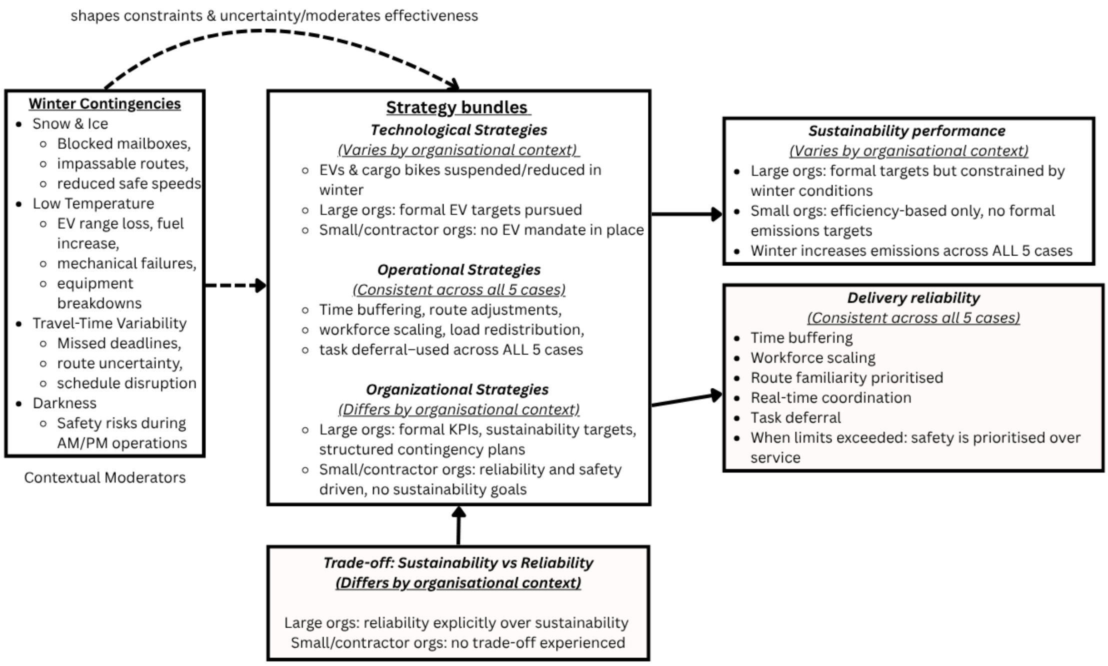

Figure 2. Empirical findings mapped to the conceptual framework.

5.3 Theoretical Implications

This study contributes to knowledge across several areas, including contingency theory, sustainable logistics, and the sustainability-reliability relationship in cold-climate logistics.

First, the research shows that the sustainability-reliability trade-off is contingent. The prevailing view in many logistics studies is that sustainability and reliability are trade-offs (Boysen et al., 2021). The current study refutes this view by demonstrating that the trade-off is present only when sustainability is institutionalized through organizational commitments, performance evaluation, and operations. This builds on contingency theory (Donaldson, 2001; Drazin & Van de Ven, 1985) by demonstrating that the relationship between organizational goals is contingent on organizational context, rather than structurally determined.

Second, the study conceives winter as a structured contingency. Previous studies have documented the effects of cold weather on vehicle efficiency (Rastani et al., 2019; Pelletier et al., 2019) and cargo bike operations (Dybdalen & Ryeng, 2022), viewing winter as an operational challenge. The current study builds on this by showing that winter is a predictable seasonal contingency that influences strategic planning, resource allocation, and expectations. This distinction between seasonal regimes and unexpected events is important for contingency theory because it affects the nature of adaptation (proactive vs reactive).

Third, the study highlights logistical impediments to sustainability in contractor-based logistics, building on green logistics frameworks (Demir et al., 2014; Halldórsson & Wehner, 2020). The majority of sustainability frameworks rely on the assumption of organizational control and coordination, which is absent in the fragmented logistics market. The contractor-based approach places vehicle and maintenance decisions in the hands of individual contractors, rather than the coordinated effort needed to support sustainability strategies based on new technologies. This sheds light on an area where current sustainability frameworks have fallen short in addressing governance.

Fourth, it adds to the use of contingency theory to explain the relationship between sustainability and reliability in the last mile for cold-climate cities. Although contingency theory has been used to investigate operations management (Sousa & Voss, 2008) and supply chain integration (Flynn et al., 2010; Wong et al., 2011), its use in the sustainability-reliability nexus under adverse environmental conditions has been overlooked. The study shows that organizational fit - between organizational characteristics, environmental conditions, and operational methods - affects not only performance but also the magnitude and nature of objective trade-offs.

Finally, the results contribute to the emerging debate about the relationship between sustainability and resilience in logistics systems (Doetsch & Huchzermeier, 2024). The study demonstrates that, rather than assuming that sustainability and resilience are either necessarily complementary or in conflict, the nature of their interaction depends on environmental and organizational conditions. At times, they complement each other, and at times, they conflict. This echoes the thesis's overarching theme: contingency fit, not structure, defines sustainability.

5.4 Practical Implications

Implications for Logistics Companies and Managers

This study highlights the need for context-specific fleet planning during winter. Organizations need to consider the effects of cold weather on electric vehicle (EV) efficiency, such as range and charging time. Electrification strategies should plan for conservative fleet planning, mid-route charging, and the maintenance of hybrid fleets incorporating traditional vehicles for extreme weather or deep-cycle trips. Wintertime conditions should be considered the default, rather than the outlier, so that fleet strategies are feasible year-round.

Companies should build multi-layered reliability strategies that include planned buffering and real-time flexibility. Time buffers and workforce adjustments allow for anticipating winter delays, while real-time monitoring, route knowledge, load shifting, and task deferrals support real-time adaptation to daily variation. Technology should be invested in to enable real-time monitoring and route management, and there should be organizational slack in staffing and scheduling to accommodate variability and maintain service operations.

Human resource development is also key to winter service performance. This should focus on winter driving techniques, safety-related decision-making, and route knowledge, as drivers are a valuable source of knowledge. Furthermore, setting realistic service expectations and providing early warning signs of potential delays can help sustain customer service levels despite performance reductions. Finally, companies with sustainability goals should recognize that contractor models present challenges to emissions reduction. Strategies to extend sustainability accountability to contractors, such as vehicle standards, emissions reporting, or incentive programs, or to increase centralized fleet management, may be needed to improve sustainability performance.

Implications for Policymakers

The research points to the need for infrastructure and regulatory enabling factors for sustainable logistics in cold climates. Government investment in rapid-charging infrastructure along major logistics routes is critical to enabling EV use, especially during winter conditions that exacerbate range anxiety. The infrastructure needs to be resilient to cold conditions and available during logistics providers' operating hours, such as early mornings and overnight.

Road maintenance during winter is also crucial to support logistics, safety, and emissions. Effective maintenance, including night work, can minimize delays, enhance road safety, and prevent unnecessary fuel consumption caused by poor road conditions. Other regulatory instruments and emissions targets should also consider seasonal limitations. Allowing flexibility in performance targets during winter, as well as providing financial and technical assistance to small logistics companies, will help overcome structural obstacles and accelerate progress toward more inclusive emissions reduction in the logistics sector.

5.5 Limitations of the Study

This study offers insights into last-mile logistics strategies in Finnish winter conditions, but it has limitations. First, with only five participants, the results lack statistical representativeness. The insights of the study are based on analytical, not statistical, generalization (Yin, 2018) - that is, the development and refinement of theoretical statements - and should be viewed in that light.

Second, the Finnish setting limits generalizability to other cold-climate settings. Regions vary in terms of climate, winter duration, infrastructure, and governance. Colder climates, regions with less infrastructure, or other governance arrangements may yield different outcomes.

Third, the qualitative methods do not allow us to quantify the size of trade-offs or test causal relationships. Quantitative research would help determine the representativeness of the practices observed and to test the links identified here.

Fourth, the cross-sectional study provides a snapshot of adaptation strategies, making it difficult to examine how these strategies evolve as EV technology advances or as winter logistics experience accumulates. Longitudinal studies would offer useful insights in this regard.

Fifth, interview responses may be affected by social desirability bias, in which participants may highlight sustainability initiatives while downplaying challenges. Cross-verifying with secondary data helped overcome this issue, but corporate reports might also reflect social desirability. Finally, the study's focus on last-mile parcel logistics may not relate to other segments such as freight transport, warehousing, or first-mile activities.

Another factor is the anonymity of participants and organizations. Although all organizations and individuals are reported anonymously in this study, the Finnish last-mile logistics industry is small, and the combination of role titles and operational details would potentially allow informed readers to guess specific organizations. This potential risk was disclosed to participants as part of the informed consent process, and when reporting the research, care was taken to avoid providing non-critical information.

5.6 Suggestions for Future Research

The results provide opportunities for future research. First, quantitative research is needed to test and extend the results on the sustainability-reliability trade-off. Large-scale surveys or operational data analysis could determine the prevalence of different organizational contexts in the industry, quantify the size of the trade-off, and test hypotheses regarding the moderating effects of organizational and environmental variables on the sustainability-reliability relationship.

Second, comparative studies across countries would reveal the impact of varying winter severity, infrastructure quality, and institutional settings on logistics strategies and performance. Comparative studies in the Nordic countries, Canada, or other cold climates could highlight best practices in winter logistics and the moderating role of institutional factors. Third, longitudinal studies are required to understand the evolution of adaptation strategies as electric vehicles advance. Technological advances in battery and charging technologies may gradually close the performance gap between EVs and traditional vehicles in cold climates, and how organizations adapt to these changes could provide insights.

Fourth, studies on sustainability governance in contractor-based logistics models are needed to overcome the structural challenges to emissions reduction found in this study. For example, research could explore governance tools - vehicle specifications, emissions reporting, incentives - that link sustainability considerations to decentralized operators, and case studies of organizations that have successfully addressed this challenge. Fifth, research on the role of digital technology and real-time data in winter logistics adaptation would add to knowledge of how organizations sense and respond to environmental variability, such as using weather information, vehicle telematics, and predictive analytics to inform winter logistics.

Sixth, studies of the effects of specific policy initiatives - such as the deployment of charging infrastructure, road maintenance standards, or regulatory regimes - on sustainability-reliability would inform policy. Quasi-experimental or comparative policy analysis could assess the effectiveness of different approaches in supporting sustainable and reliable winter logistics. Finally, studies from the customer perspective would offer valuable insights into consumer preferences, including whether customers are prepared to trade off other aspects of service (such as delivery speed or cost) for more sustainable delivery services, and how expectations of winter conditions influence these choices.

6 Conclusion

6.1 Summary of Key Findings

This multiple-case study used qualitative methods to explore last-mile logistics approaches for supporting emissions reduction and delivery reliability during winter in Finland. The thematic analysis of five semi-structured interviews with operational staff of Finnish last-mile logistics companies revealed four main themes.

First, wintertime conditions are a multifaceted and recurring operational constraint that affects vehicle operations, route planning and execution, workforce availability, and service reliability. These affect both electric and non-electric vehicles, with night-time operations presenting further challenges that further complicate operations.

Second, reliability is achieved through a multi-layered set of complementary practices, including time and workforce buffering, monitoring, route knowledge, load reallocation, and deferral. When these measures are inadequate, organizations choose to delay delivery or make partial shipments for safety reasons.

Third, sustainability practices are highly dependent on the type of organization. Large-scale companies with formal sustainability policies adopt formal electrification programs but are limited by the performance of electric vehicles in winter. Smaller, contractor-based organizations focus on efficiency measures and have less control over vehicle selection and emissions.

Fourth, the link between sustainability and reliability is not universal. In organizations with specific sustainability goals, winter conditions result in direct trade-offs between reliability and emissions. In micro-organizations without formal sustainability goals, such tensions are not acknowledged, as operational decisions are based solely on reliability and safety considerations.

6.2 Answer to the Research Question

The research suggests that several last-mile logistics strategies can be adopted to support both sustainability and reliability during the winter in Finland, but their success depends on the context and fit of the organization and its environment. Last-mile strategies like route planning, consolidation, time, and staffing levels help to support delivery reliability while enhancing resource efficiency. Reactive monitoring and scheduling also support adaptation to winter conditions, while multiple fleet management strategies provide flexibility to use electric and traditional vehicles based on operational needs.

The study also indicates that winter is a seasonal constraint that restricts the implementation of sustainability strategies, especially electric vehicles. Impacts on battery efficiency, energy demands, and charging times pose operational challenges in balancing sustainability with reliability. As such, the sustainability-reliability trade-off is not ubiquitous but instead depends on the contracting organization's size, governance, and level of sustainability integration. Organizations with stronger sustainability commitments and greater size face more explicit trade-offs, while smaller contractor-based organizations are more likely to prioritize reliability and safety without formally acknowledging trade-offs.

More generally, the research shows that there is no one-size-fits-all strategy to optimize both sustainability and reliability objectives. Last-mile logistics strategies work best when there is a fit between the organization's configurations (such as fleet size and decision making) and the environment. As a result, the research question is answered using a contingency approach: strategies that support both goals are contingent on context and need to be tailored to the organization's characteristics and the seasonal constraints of the operation.

6.3 Contributions of the Study

6.3.1 Theoretical Contributions

The study adds to theoretical knowledge in the fields of contingency theory, sustainable logistics, and the sustainability-reliability nexus in cold-climate business operations.

First, this study adds to knowledge by demonstrating that the sustainability-reliability trade-off is contingent. The trade-off is not an intrinsic phenomenon; it occurs only when sustainability is incorporated into organizational strategy and operations. This insight shows that the sustainability-reliability relationship is contingent on the organization and not structurally embedded.

Second, this research adds to the field by framing winter as a systematic rather than an ad hoc environmental constraint. The research shows that winter is a seasonal constraint that affects temporal operational strategies, resource allocation, and performance. This offers a more refined view of how environmental conditions affect logistics over time.

Third, this study adds to the literature by revealing differential sustainability practices. It shows that logistics systems based on contractors face inherent difficulties in adopting emissions-reduction measures due to decentralized control over vehicle selection and maintenance. This builds on current sustainability models by recognizing the role of governance structures in facilitating or limiting sustainability.

Finally, the research adds to our knowledge of the links between sustainability and resilience in logistics systems. The results suggest this relationship is not universal: in some firms, sustainability and reliability are in constant conflict, while in others, sustainability is not explicitly considered and reliability takes precedence in operations. This suggests that sustainability and resilience need to be considered in a context-specific, rather than universal, manner.

6.3.2 Practical Contributions

The research has implications for logistics managers regarding the importance of context-specific planning during winter. Fleet planning should account for the impact of cold weather on electric vehicle efficiency, requiring route planning, contingency plans, and mixed fleets to ensure reliability in extreme weather.

Companies should adopt multi-layered reliability strategies that include buffers and operational flexibility. Time buffering and workforce scaling can address predictable delays and variability, while real-time monitoring, route knowledge, and task prioritization can address daily variability. Training programs should also emphasize driving skills and safety considerations.

Our findings also offer policy insights into the need for infrastructure and regulatory support for sustainable logistics. Charging infrastructure and reliable winter road conditions are key to enhancing both reliability and sustainability. Moreover, policy support is needed to help small, contract-based logistics companies overcome organizational barriers to sustainability.

In summary, the practical lessons highlight the importance of multilevel collaboration between organizations and policies to improve sustainability and reliability in last-mile logistics, while accounting for the peculiarities of cold-climate last-mile logistics.

6.4 Final Reflection

This research demonstrates that there are context-specific sustainability-reliability trade-offs in last-mile logistics in cold climates that cannot be addressed by global best practices. Finnish winters serve as a contextually structured environmental constraint that affects the success of sustainability measures to reduce emissions, especially electric vehicle roll-outs, and promotes a focus on reliability and safety.

The study suggests that there is no universal solution to sustainably and reliably deliver goods in winter. The strategies used vary according to organizational size, governance, and the level of sustainability integration within the organization. While larger organizations face clear trade-offs between sustainability and reliability, smaller contractor-based organizations face structural limitations on their ability to directly control emissions.

As logistics companies strive for sustainability, such context-specific considerations are crucial. What works for one type of organization may not work for another. Therefore, strategies to enhance sustainability in last-mile logistics need to be context-specific, recognizing differences in organizational settings and seasonal challenges.

In short, sustainable and reliable logistics in cold climates can be achieved through technological innovation and realistic sustainability goals in context.

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Appendix A: Interview Guide

This appendix presents the semi-structured interview guide used for data collection. The questions were designed to explore operational challenges, sustainability practices, and delivery reliability in last-mile logistics under winter conditions.

Section 1: Background of the Respondent

1. Could you briefly describe your role and responsibilities in the organization?
    - How long have you worked in logistics or delivery operations?
    - Are you involved directly in supervising last-mile delivery routes?
2. What type of delivery operations do you supervise (e.g., parcels, mail, mixed delivery)?
    - Are your routes mainly urban, suburban, or mixed areas?
    - How many delivery drivers or routes do you typically supervise?

Section 2: Winter Operational Challenges

3. What are the main operational challenges that your delivery operations face during winter?
    - How do snow and icy roads affect delivery routes?
    - Do winter conditions change travel time significantly?
    - Are some delivery areas more difficult during winter?
4. How do winter weather conditions affect delivery schedules and route planning?
    - Do drivers need to change routes more frequently?
    - Do you need additional time buffers during winter?
    - Are some routes temporarily impossible during heavy snow?
5. How does winter affect access to delivery points such as buildings, mailboxes, or parcel lockers?
    - Do snow or ice create access problems?
    - Do drivers spend more time completing deliveries?

Section 3: Vehicle and Technical Challenges

6. What kinds of vehicle-related challenges occur during winter operations?
    - Do cold temperatures affect vehicle performance?
    - Are there issues with vehicle reliability in winter?

7. If electric vehicles are used, how does winter affect their performance?

    - Does cold weather affect battery range?
    - Do charging requirements change in winter?
    - Are EVs used differently during winter routes?

8. Are there specific technical or equipment requirements for vehicles in winter?

    - Winter tires
    - Vehicle heating
    - Battery protection
    - Maintenance requirements

Section 4: Sustainability Practices

9. Do winter conditions influence the effectiveness of sustainability strategies such as electric vehicles or fuel reduction initiatives?
   (Sustainability refers to transport-related emissions such as fuel use and CO_2 emissions.)

- Are some sustainability solutions harder to implement during winter?
- Do energy consumption or emissions change in winter?

10. Are there adjustments made to sustainability initiatives during winter?

- Changes in vehicle assignment
- Different routing strategies
- Use of alternative fuels

Section 5: Delivery Reliability

11. How do winter conditions affect delivery reliability and service performance?

- Are delays more common in winter?
- Do you experience more failed deliveries?

12. What strategies are used to maintain delivery reliability during severe winter conditions?

- Route adjustments
- Additional time buffers
- Contingency plans
- Extra staffing

Section 6: Operational Adaptation

13. How does your organization prepare for winter delivery operations?

- Winter planning
- Driver training
- Equipment preparation

14. Are there specific operational practices used only during winter?

- Route adjustments
- Vehicle allocation
- Scheduling changes

Section 7: Managerial Decision-Making

15. When winter conditions become severe, how do managers prioritise delivery reliability versus sustainability goals?

- Examples of difficult decisions
- Trade-offs between efficiency and safety

16. Can you describe a situation where winter conditions required significant operational adjustments?

- What happened
- What decisions were made
- What lessons were learned

Section 8: Reflection

17. From your experience, what are the biggest risks or challenges for delivery operations during winter?

- Safety risks
- Operational disruptions
- Technological limitations

18. What improvements could help delivery operations perform better during winter?

- Technology improvements
- Operational strategies
- Infrastructure improvements