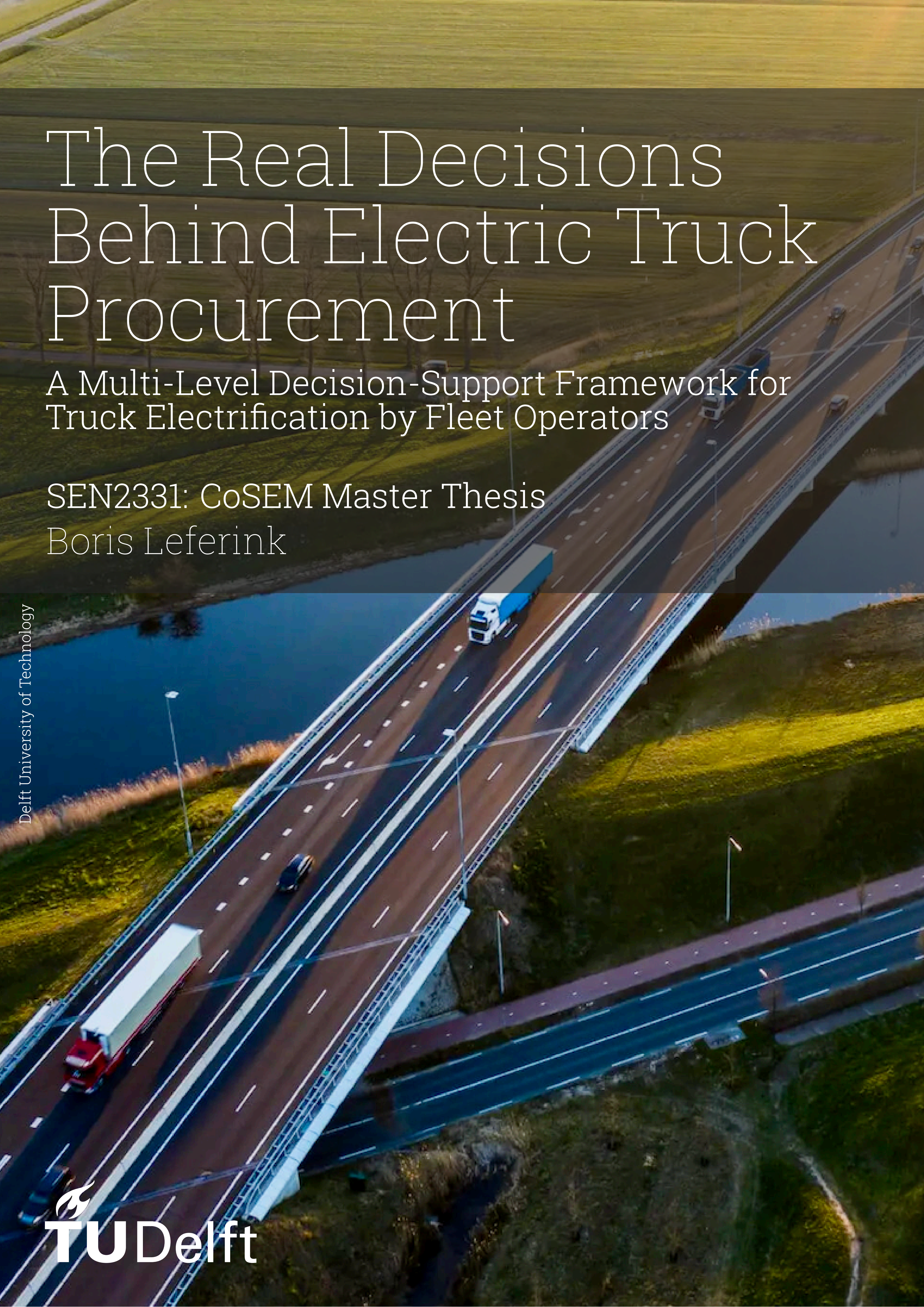

The Real Decisions Behind Electric Truck Procurement

A Multi-Level Decision-Support Framework for Truck Electrification by Fleet Operators

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The Real Decisions Behind Electric Truck Procurement

A Multi-Level Decision-Support Framework for Truck Electrification by Fleet Operators

by

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Preface

This thesis is the final contribution to my master's programme in Complex Systems Engineering and Management at Delft University of Technology. At the same time, this thesis is the end of my time as a student. Writing this thesis has been an intensive but valuable process. The topic of truck electrification allowed me to combine my interest in transport, sustainability, strategy, and complex decision-making. It also showed me how difficult transitions become when technical, operational, financial, organisational, and institutional factors all have to come together. Although the thesis process was sometimes challenging, it has been a fitting conclusion to my studies and a valuable opportunity to apply what I have learned during the CoSEM programme.

I would first like to thank my external supervisor, Drs. Pim Roest. Our discussions helped me to sharpen the focus of the thesis and to connect the academic perspective with practical relevance. I appreciated the feedback, the opportunity to discuss ideas, and the way in which he challenged me to think more critically. His knowledge of the transport sector and practical perspective were very valuable for me.

I would also like to thank my supervisors at TU Delft. First, Prof.dr.ir. Lóri Tavasszy, my chair and first supervisor, for his guidance and constructive feedback during the research process. His opinion helped me strengthen the academic structure of the thesis and keep the broader transport system perspective in mind. I would also like to thank Prof.dr.ir. Machteld van den Broek for her feedback and reflections throughout the process as my second supervisor. Finally, I would like to thank Dr. Jan Anne Annema for his feedback and support as my advisor.

Moreover, I would like to thank all interview participants who contributed to this research. Without their experiences, insights, and reflections, it would not have been possible to develop a framework that is grounded in both literature and practice.

Lastly, I would like to thank my family and friends for their supportive attitude throughout my studies and during the thesis process. In particular, my parents for their financial support, patience, and continued confidence in me throughout my time as a student. Their support gave me the opportunity to focus on my studies and complete this final step.

Boris Leferink
Delft, July 2026

Summary

Background

While Battery Electric Trucks (BETs) are becoming cost-competitive, successful adoption by fleet operators does not depend on fleet costs alone. We argue that BET procurement changes the wider decision-making context of fleet operators, forcing them to align the vehicle fleet with charging infrastructure, grid capacity, routes, customers, business models, energy use, and logistics operational routines.

Objective

The objective of the study is to develop a framework that helps fleet operators structure BET procurement decision-making. The framework should clarify which decisions need to be made, how these decisions relate to one another in the context of fleet electrification, and which adoption barriers and drivers influence the transition. The central research question is: *How can a multi-level decision-support framework guide fleet operators in structuring the interdependent strategic, tactical, and operational decisions of BET implementation across transport profiles, while accounting for adoption barriers and drivers?*

Scientific background

Existing literature on the Heavy-Duty Vehicle (HDV) electrification identifies many adoption barriers and drivers but the relation to concrete BET procurement decision-making has not been addressed. Especially, the multitude and interdependence of relevant logistics decisions have not yet been recognised in electrification studies. BET studies often focus on route planning, charging scheduling, fleet replacement, or infrastructure and rarely integrate these issues into a complete decision-making structure. Additionally, freight transport heterogeneity is often reduced to broad profiles such as short-haul, line-haul, and long-haul. Yet the practical feasibility of BETs depends on seven operational factors: route predictability, return-to-base frequency, charging control, daily distance, payload sensitivity, planning flexibility, and utilisation intensity. These factors differ within each profile and may even point to new profiles. The goal of this thesis is to help overcome this knowledge gap by providing a comprehensive view for decision-making by fleet operators, sketching the relevant interacting decisions around BET adoption.

Methodology

This study follows a research design that combines a literature review, conceptual modelling, and semi-structured expert interviews. Academic and grey literature were used to map BET procurement decisions, identify adoption barriers and drivers, and define relevant transport dimensions. The conceptual modelling has structured relationships between decisions, barriers, drivers, and transport dimensions. The insights were developed, tested, and refined together with fleet operators, consultants, an original equipment manufacturer, and a freight forwarder. Interviews were conducted in two rounds: the first to develop parts of the conceptual model, the second to refine the final framework. Interview data were analysed through deductive and inductive coding around four themes: barriers, drivers, BET procurement decisions, and transport dimensions.

Findings, conclusions, and implications

The central finding is that BET procurement is not a vehicle-replacement decision but an organisational decision-making problem: the purchasing decision introduces an interdependent web of strategic, tactical, and operational decisions that must be aligned before deployment is feasible. The resulting practical multi-level decision-support framework is summarised in Figure 1, which shows how transport dimensions shape BET decision-making, how fleet operator decisions are structured across strategic, tactical, and operational levels, and which barriers and drivers affect the decision-making. The framework starts with transport dimensions that determine the transport profiles. These dimensions will change when using BETs. Additionally, in traditional diesel-based transport, fleet operators replace

vehicles within an established system of fuel infrastructure, operational routines, and planning assumptions. BET procurement introduces new decisions and changes existing transport decisions. For example, charging availability, payload capacity, energy costs, grid capacity, customer requirements, and service reliability become increasingly interdependent. BET adoption, therefore, should not be treated as a single procurement decision, but as a coordinated transition process in which strategic, tactical, and operational decisions are aligned before deployment is feasible.

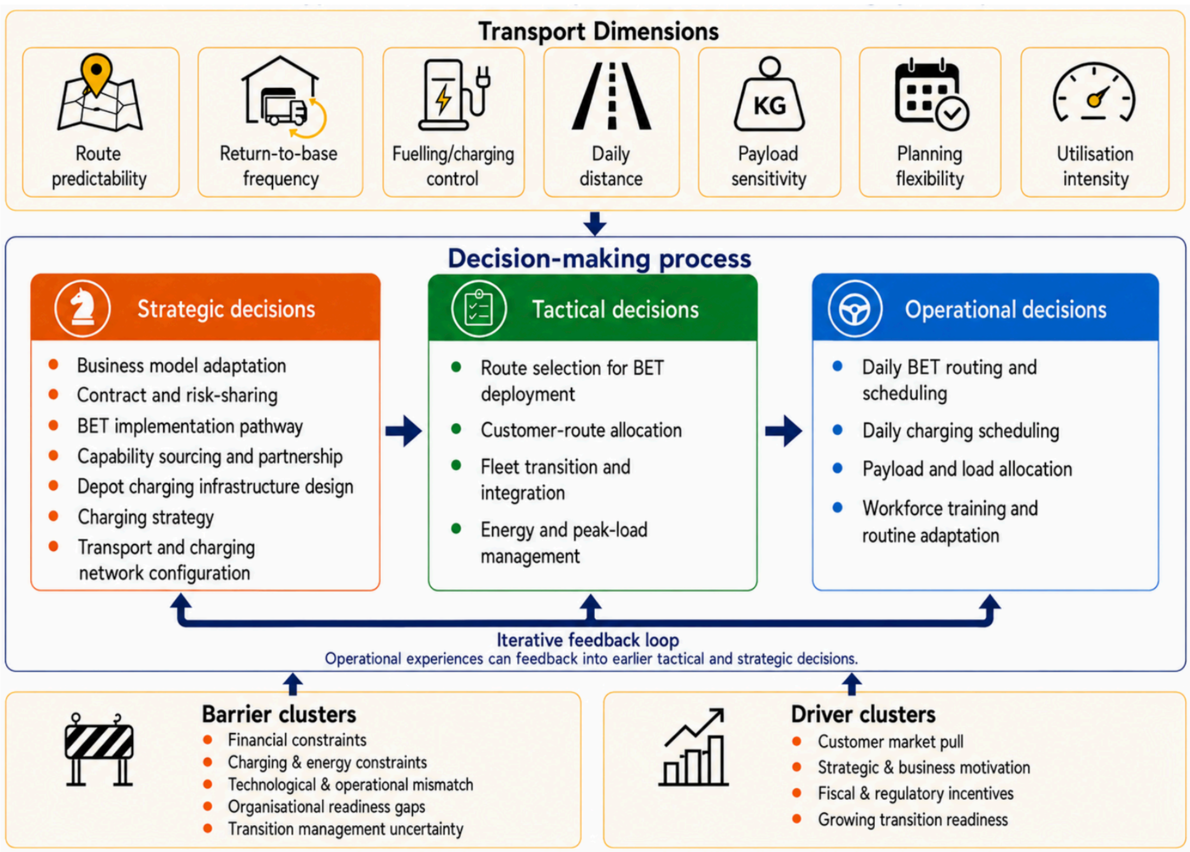

Figure 1: Multi-level decision-support framework for fleet operator BET procurement decision-making

The framework structures this transition across three decision-making levels. At the strategic level, fleet operators decide how the organisation should prepare for BET adoption. Seven decisions apply here: 1) business model adaptation, 2) contracting and risk-sharing, 3) BET implementation pathway, 4) capability sourcing and partnership, 5) depot charging infrastructure design, 6) charging strategy, and 7) transport and charging network configuration. These decisions are choices between alternatives and determine whether the organisation can create a feasible basis for electrification before vehicles are deployed. At the tactical level, these strategic decisions are translated into concrete deployment decisions: 1) route selection for BET deployment, 2) customer-route allocation, 3) fleet transition and integration, and 4) energy and peak-load management. This level is essential because fleet operators need to decide where BETs can be deployed, how to integrate BETs into the diesel fleet, and how charging demand and peak loads should be managed. At the operational level, BET deployment is implemented through 1) daily BET routing and scheduling, 2) daily charging scheduling, 3) payload and load allocation, and 4) workforce training and routine adaptation. Operational implementation, therefore, functions not only as the final execution stage, but also as a feedback mechanism: repeated operational problems may indicate that earlier decisions in the strategic and tactical decision-making phases about route suitability, charging capacity, customer assignment, or implementation pace need to be reconsidered. The directed relationship matrix shows that these decisions are not separate but feed into one another, with charging-related decisions shaping many of the others

The empirical results further show that barriers and drivers should not be treated as isolated external factors, but as factors that shape both the feasibility of specific procurement decisions and the order in which fleet operators make them. Five barrier clusters were identified: 1) financial constraints, 2) charging and energy constraints, 3) technological and operational mismatch, 4) organisational readiness gaps, and 5) transition management uncertainty. Four driver clusters were identified: 1) customer market pull, 2) strategic and business motivation, 3) fiscal and regulatory incentives, and 4) growing transition readiness. These clusters affect fleet operators differently depending on their transport context. Customer demand can strengthen the business case and trigger early deployment, while grid capacity can constrain depot charging infrastructure, energy management, and operational charging schedules.

In summary, this study develops a multi-level decision-support framework that helps fleet operators translate a general electrification ambition into a phased and context-specific implementation pathway. The framework starts with transport dimensions and structures decisions across strategic, tactical, and operational levels. It helps identify initial deployment cases, such as predictable routes with sufficient charging control and manageable daily distances, while making explicit how operational experience can feed back into earlier decisions. This supports stepwise scaling when key commercial, infrastructural, organisational, and operational requirements are sufficiently addressed. Ultimately, the hardest part of electrification is not buying the truck but managing the connected decisions around it. The contribution of this framework is to make that web explicit and turn a vague ambition into a phased, context-specific pathway.

Limitations and future research

This study has several limitations that also point to future research. The research is qualitative and exploratory, based on a limited set of interviews, so the framework should be read as an analytical and structuring tool rather than a statistically validated model. It also reflects the researcher's own choices in how the decisions were identified, grouped, and linked, and it was discussed in expert refinement interviews rather than tested in a real procurement process. This means that the practical value is proposed but not yet demonstrated. Future research should therefore test the framework in practice, for example through case studies that follow fleet operators over time, examine the relationships between decisions in more detail with a larger sample or a dedicated method such as DEMATEL, validate it across different transport profiles and firm sizes, and combine it with quantitative tools such as TCO analysis, route optimisation, and grid capacity assessment.

Contents

Abbreviations

Abbreviation	Definition
BET	Battery Electric Truck
BEV	Battery Electric Vehicle
EEA	European Environment Agency
EMS	Energy Management System
EU	European Union
GHG	Greenhouse gas
HDV	Heavy-Duty Vehicle
OEM	Original Equipment Manufacturer
TCO	Total Cost of Ownership

1 Introduction

This chapter introduces the topic of this thesis and explains the relevance of truck electrification within road freight transport. Section 1.1 describes the context of the problem. Section 1.2 defines the relevant core concepts used throughout this paper. Section 1.3 reviews the existing literature and is used as input for the definition of the knowledge gap (Section 1.4). Based on these gaps, Section 1.5 defines the main research question and the research objective. Section 1.6 defines the sub-questions. Section 1.7 explains the relevance of this research within the CoSEM programme. Finally, Section 1.8 provides an outline of the remaining chapters of this thesis.

1.1. Problem description

Road freight transport is one of the main drivers of the European economy. However, this sector increasingly conflicts with the climate targets set by the European Union. The demand for freight has grown by 65-66% between 1995 and 2022, reaching around 1,900 billion tonne/km in 2022 (Eurostat, n.d.-b), and is expected to continue growing until 2030 (European Environment Agency, 2023). The modal share of road transport will reach 68% by 2030 (European Environment Agency, 2023), with Heavy-Duty Vehicles (HDVs) accounting for over 80% of the road freight tonne/km (Eurostat, n.d.-a). Although HDVs represent only around 2% of the vehicles on European roads, they are responsible for roughly a quarter of road transport CO_2 emissions and about 6% of the EU's total greenhouse gas (GHG) emissions (European Environment Agency, 2024). At the same time, a legally binding climate target has been set in the European Climate Law which states that transport should be climate neutral by 2050 and that there should be a minimum reduction of GHG emissions of 55% by 2030 (European Union, 2021). Similarly, the European Commission introduced new CO_2 emission regulations for new HDVs (European Commission, 2024). While this regulation has been introduced, the European HDV fleet still consists of around 6.2 million trucks, of which 96% (roughly 6.0 million) are diesel, with an average lifetime of 14 years (European Automobile Manufacturers' Association, 2024). These technical characteristics of the current HDV fleet create a technical and infrastructural lock-in in the current system. HDV-related investment decisions made today determine future emissions for over a decade, resulting in path dependency within the diesel-combustion truck system.

BETs can be seen as one of the most promising solutions to achieve net-zero emission transport. BETs could reduce the lifecycle GHG emissions compared to diesel trucks by 75-85% (Smit et al., 2024). In some BET cases the Total Cost of Ownership (TCO) achieves a more favourable value compared to diesel trucks (Basma and Rodríguez, 2023; Cheng and Lin, 2024). However, the adoption of electric trucks across Europe remains limited: battery-electric trucks account for only 0.3% of the EU truck fleet, around 18,000 vehicles, and just 2.3% of new truck registrations in 2024 (European Automobile Manufacturers' Association, 2024; Luman, 2026). One of the main arguments for this is the difference in operational feasibility between transport profiles (short-haul, line-haul and long-haul transport). Short-haul transport generally offers the most favourable conditions for BET adoption because routes are more predictable and charging can be planned more easily. Line-haul transport occupies an intermediate position, as operations are often repetitive and structured, but still involve longer distances and a greater dependence on corridor-based charging infrastructure. Long-haul transport is the most challenging profile for electrification because it combines long distances, greater route variability, and a strong dependence on public charging infrastructure.

The transition towards electric HDVs changes the nature of the fleet operator decision-making process. Diesel truck procurement is primarily a vehicle replacement in a relatively stable system of fuel infrastructure, routines, operational planning, and established procurement criteria. However, BET procurement introduces new decisions related to charging strategy, depot layout, or energy management and changes existing transport decisions (such as route selection, scheduling, or load planning). As a result, the transition from diesel trucks to BETs is not a simple replacement decision, but a complex multi-level decision-making process in which strategic, tactical, and operational decisions affect one another.

The complexity of the fleet operator decision-making process is shaped by the combination of adoption barriers and adoption drivers. Fleet operators have to face several adoption barriers (e.g., infrastructural constraints, regulatory uncertainty, financial risk, or technical limitations). However, fleet operators also face drivers that could increase the attractiveness of BETs or raise the urgency to electrify trucks. Examples could include the implementation of environmental zones, the introduction of diesel taxes, and fiscal investments (subsidies and/or tax reductions for BETs). The adoption drivers could strengthen the BET business case or increase the pressure to shift from diesel trucks. These barriers and drivers do not affect the decision-making process equally or at the same phase within the transition. Some factors could primarily influence the decision-making process in the early stage, such as starting a pilot or renewing part of the existing fleet, whereas other factors become relevant in later stages, such as operational implementation or scaling. In fact, the same external conditions (barriers or drivers) could affect the decision-making process differently based on the context of the fleet operator. Environmental zones could act as a strong adoption driver for short-haul fleet operators, while limited public charging access could act as a strong barrier for less controlled line-haul or long-haul fleet operators. Currently, the combined impact of barriers and drivers on strategic, tactical, and operational decision-making remain insufficiently described in existing literature.

In conclusion, fleet operators face barriers and drivers that impact the decision-making processes for BETs. External uncertainties, combined with an insufficient understanding of how adoption barriers and drivers relate to strategic, tactical, and operational decisions, result in a risk of fragmented implementation and ineffective decision-making by fleet operators, which slows down the adoption of BETs. This creates a need for a systematic and comprehensive multi-level decision-support framework that guides fleet operators by structuring the decision-making process, clarifying which actions are required at the different stages, and explicitly accounting for the feasibility conditions across short-haul, line-haul, and long-haul transport.

1.2. Definitions

To create a uniform understanding of the main concepts discussed in this thesis, this section defines four core concepts: 1) fleet operator, 2) logistics decision-making, 3) transport profiles, and 4) adoption barriers & drivers.

Fleet operator

Fleet operators are organisations that own, lease, manage, or operate HDVs for the transportation of goods. They are responsible for translating transport demand into transport services by making decisions regarding fleet composition, scheduling, load planning, or, in the case of BETs, charging strategies and energy use. Therefore, fleet operators could be vehicle purchasers and logistics decision-makers who align vehicle characteristics with operational demands and organisational capabilities. In this thesis, fleet operators are the decision-making actors as they directly manage, operate and implement BETs in their day-to-day operations.

Logistics decision-making

Decision-making in logistics can be divided into different levels, namely: strategic, tactical, and operational decisions (Langevin and Riopel, 2005). Strategic-level decisions can be seen as long-term and high-impact decisions that shape the structural composition of the logistics system. Strategic decisions are long-term decisions that are often characterised by uncertainty and financial intensity.

Tactical decisions translate strategic plans into a more practical approach by specifying how capacity, infrastructure, and resources should be organised to support operational demand and service requirements. These decisions are less capital-intensive and usually focus on medium to long-term horizons. These decisions enable the alignment of strategic long-term visions with the execution of daily operations.

Operational decisions in logistics are related to day-to-day activities, e.g., vehicle routes, load planning, scheduling, and resource allocation (Langevin and Riopel, 2005). While these decisions are short-term and more focused on the daily operations of logistics, they are shaped by strategic and tactical decisions.

Transport profiles

Transport profiles are determined by six operational dimensions: route predictability, return-to-base frequency, charging control, daily distance, payload intensity, and operational flexibility. Together, these dimensions indicate how suitable different freight operations are for BET deployment. Three typical transport profiles can be distinguished: short-haul, line-haul, and long-haul transport. These profiles are not purely distance-based categories, but operational contexts that differ in charging feasibility, range requirements, and planning flexibility.

Adoption barriers and drivers

Adoption barriers are factors that make the adoption of BETs more difficult for fleet operators. These barriers can be financial, technological, operational, organisational, or institutional. In the context of HDV electrification, examples include high upfront investment costs, limited grid capacity, insufficient charging infrastructure, range limitations, payload constraints, and uncertainty about the business case. These barriers reduce the feasibility of BET adoption because they make it harder for fleet operators to justify investments, organise charging, maintain service reliability, or scale beyond pilot projects.

Adoption drivers are factors that make the adoption of BETs more attractive, urgent, or feasible for fleet operators. In the context of HDV electrification, examples include subsidies, fiscal incentives, environmental zones, customer demand for zero-emission transport, strategic sustainability goals, and improvements in charging infrastructure and vehicle technology. These drivers support BET adoption because they can improve the business cases using BETs, increase pressure to electrify, reduce uncertainty, or create concrete opportunities for early deployment.

1.3. Literature review

The reviewed literature provides insights into the main adoption barriers to HDV electrification. Table 1.1 provides a brief overview of some barriers identified in the BET transition, such as high upfront costs, too high TCO, limited charging infrastructure, range limitations, and operational constraints (Konstantinou and Gkritza, 2023a; Rubal and Almutairi, 2025). Rubal and Almutairi, 2025 argue that policy and economic factors could limit BET deployment. Konstantinou and Gkritza, 2023a argue that barriers should not be treated as isolated factors, as they influence and reinforce each other. The literature also shows that BET adoption is shaped by drivers that accelerate or support the transition, such as supportive policy measures, financial incentives, environmental zones, and technological improvements. BET adoption should therefore be understood as the result of both barriers and drivers and how fleet operators respond to these barriers and drivers through their procurement and implementation decisions.

To understand the relationship between electrification and BET decision-making, it is necessary to place transport decision-making within logistics decision-making. Langevin and Riopel, 2005 have described logistics decision-making as a network of interconnected decisions across the strategic, tactical, and operational levels. Within the logistics decision-making network, transport decision-making includes decisions in transportation modes, types of carriers, degree of consolidation, transportation fleet mix, assignment of customers to vehicles, vehicle routing and scheduling, and vehicle load plans (Langevin and Riopel, 2005). The framework developed by Langevin & Riopel reveals the interdependency of decisions within diesel truck freight systems. However, in the diesel truck system, the decisions are made in a relatively stable context. In this environment, the fuel infrastructure leads to operational

Table 1.1: Overview of identified adoption barriers in literature

	Regulations & subsidies	TCO	Charging infrastructure	Vehicle range	Fleet composition	Operating costs	Energy costs	Short-term constraints	Route complexity	Grid capacity
Roman & Zadek (2024)	X	X	X							
Cheng & Lin (2024)			X			X			X	
Yu et al. (2026)			X			X				
Karam & Rich (2026)			X						X	
Bakker et al. (2025)			X		X					
Hoffler et al. (2025)			X				X			
Amiri et al. (2023)				X					X	
Suneson et al. (2025)		X	X					X		X
AllChiefs (2025)		X	X		X			X	X	

flexibility.

The introduction of electrification changes this stable context, as BET procurement introduces decisions that are absent in diesel truck procurement. Karam and Rich, 2025 argue that the adoption of BETs in line-haul transport must be planned together with the development of charging infrastructure. Similarly, Bakker et al., 2025 show that BET purchasing decisions are interdependent with charging opportunities (private and public charging). Simultaneously, Cheng and Lin, 2024 show that the charging strategy (charging schedules and driving schedules) is essential to improve BET viability, meaning that the decision-making process should also be operationally focused rather than solely technical. Finally, Amiri et al., 2023 emphasise the importance of uncertain energy consumption, resulting in additional routing decisions. In general, these articles reveal that the BET decision-making process extends the diesel truck decision-making process by adding decisions in the operational, tactical, and strategic levels. However, although these studies identify important BET-related decisions, the current literature does not bring all decisions together into a systematic overview of how strategic, tactical, and operational decisions interact within the broader BET decision-making processes.

The BET decision-making process for fleet operators differs across transport profiles according to the literature. Short-haul operations are characterised by high predictability due to repetitive routes and high return-to-base frequencies. However, uncertain energy consumption remains challenging within this segment (Amiri et al., 2023). According to Karam and Rich, 2025, the transition problem of multiple depots and evolving charging possibilities could be a potential problem in line-haul transport. Within long-haul transportation, challenges arise due to long distances, low charging coordination, and driver rest regulations. This affects the economic and operational feasibility of BETs (Cheng and Lin, 2024). These studies show that transport profiles, each with different operational conditions, result in different considerations regarding BET decision-making.

Despite the available literature on barriers, drivers, decisions, and transport profiles, it remains limited in combining the four aspects. Konstantinou and Gkritza, 2023a analyse the interrelationships between barriers but do not elaborate the impact of barriers on decisions within BET decision-making. Langevin and Riopel, 2005 map the interdependencies of logistics and transport decisions but do not address the BET-related decisions. The studies of Karam and Rich, 2025, Bakker et al., 2025, Cheng and Lin, 2024, and Amiri et al., 2023 elaborate on the effect of electrification of trucks on decision-making. However, these articles do not elaborate on the connected impact between barriers, drivers, decisions, and transport profiles. Overall, the literature provides limited insights into how adoption barriers and drivers affect the BET decision-making process across different stages and transport profiles.

1.4. Knowledge gaps

The reviewed literature has revealed a wide range of BET adoption barriers and drivers. However, the reviewed literature offers limited practical guidance for fleet operators, as it does not sufficiently explain how these barriers and drivers should be taken into consideration when executing the BET procurement

This gap is important because barriers and drivers do not impact electrification in an abstract way but they enable, constrain, delay, or accelerate decisions on strategic, tactical, and operational levels. To support fleet operators in overcoming barriers and responding to drivers, it is necessary to examine the electrification transition from a decision-making perspective.

Existing studies insufficiently explain how adoption barriers and drivers affect BET procurement decision-making. Konstantinou and Gkritza, 2023a show that adoption barriers are connected and can reinforce each other, but they do not explain how these barriers affect specific decisions within the BET decision-making process. Other studies show that BET procurement involves interdependent decisions, such as truck replacement, charging infrastructure planning, and network design (Karam and Rich, 2025; Bakker et al., 2025). However, these studies do not systematically link these decisions to the barriers and drivers that impact BET adoption. As a result, the existing literature lacks a clear overview of which barriers and drivers impact which BET procurement decisions, at what stage, and from the fleet operator perspective. Without this overview, it remains difficult for fleet operators to determine how and when to respond to which adoption barriers and drivers.

The second knowledge gap concerns the limited understanding of BET procurement as a decision-making process itself. While existing studies identify specific electrification-related issues, such as charging infrastructure, vehicle performance, or operational planning, they do not address which decisions are newly introduced by BET adoption, how existing diesel truck procurement and transport decisions are changed, and how these are interdependent. As a result, existing literature provides limited insights into the sequencing and dependencies of BET procurement decisions from the fleet operator perspective. This gap becomes more relevant across different transport profiles, as the transport profiles differ in predictability, charging dependence, operational flexibility, and planning constraints. Therefore, differentiation across decisions is needed to create a clear understanding of BET decision-making and how this varies across transport profiles.

Overall, these knowledge gaps reveal a need for mapping the BET decision-making process in which adoption barriers and drivers are linked to strategic, tactical, and operational decisions from the fleet operator perspective, while considering the different operational characteristics of transport profiles.

1.5. Main research question & research objective

This thesis addresses both knowledge gaps by developing a multi-level decision-support framework that links adoption barriers and drivers to the BET procurement decision-making process while explicitly accounting for differences between transport profiles. A systematic multi-level decision-support framework is needed to support fleet operators in BET procurement to accelerate the adoption of BETs. The following main research question (MRQ) is formulated:

How can a multi-level decision-support framework guide fleet operators in structuring the interdependent strategic, tactical, and operational decisions of BET implementation across transport profiles, while accounting for adoption barriers and drivers?

The objective of this study is to develop a multi-level decision-support framework to guide fleet operators in electrifying road freight transport. To achieve this, this research will analyse the decision-making process for BET procurement from the perspective of fleet operators. All relevant decisions within fleet operating organisations will be mapped to identify the decisions and the interrelationships between them (Figure 1.1). Afterwards, adoption barriers and drivers will be identified and analysed to examine which factors affect fleet operators (Figure 1.2). Finally, a multi-level decision-support framework will be designed. This framework will map decisions over time, show how each decision relates to another, and identify where adoption barriers and drivers impact the decision-making process (Figure 1.3).

The potential adoption barriers and drivers for fleet operator truck electrification will be identified through a literature review and tested during expert interviews. The BET procurement decision-making process of fleet operators will be defined by conducting expert interviews and an additional review of the literature will be used to complete the mapping of the BET procurement decision-making process. The final multi-level decision-support framework will be designed iteratively with experts to ensure the usability and applicability of the framework.

Many fleet operators are considering truck electrification, but the decision-making process for BET procurement is insufficiently understood and mapped. Fleet operators can understand individual elements (e.g., vehicle range, total cost of ownership, or charging infrastructure), but they are unable to identify which decisions drive other decisions and where key interdependencies lie. This makes it challenging to structure and compare electrification decisions, resulting in more uncertainty, longer decision-making periods, and a delayed transition.

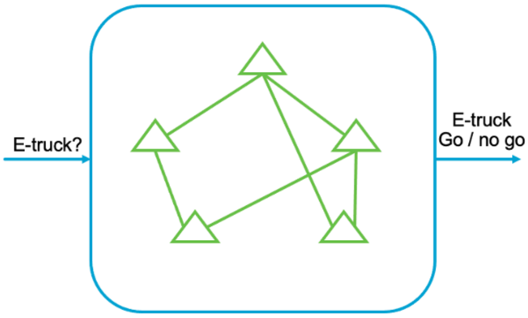

Figure 1.1: Simple visualisation of decision-network for truck electrification (green triangles = decisions and green lines = the interdependency between decisions)

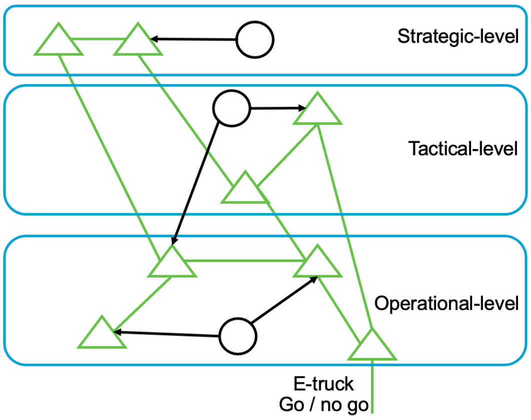

Figure 1.2: Visualisation of decision-network with adoption barriers/drivers (black circle = barrier/driver, black arrow = impact of barrier/driver, green triangle = decisions, and green lines = connection between decisions)

This research addresses these gaps by developing a multi-level decision-support framework that makes the BET procurement decision-making process explicit. The framework should clarify which decisions need to be made, how these decisions relate to each other in the context of fleet electrification, and which adoption barriers and drivers influence the transition.

1.6. Sub-questions

Four sub-questions have been formulated to answer the main research question and guide the different phases of this thesis:

Sub-question 1: *How can the BET procurement decision-making process of fleet operators be characterised across transport profiles?*
The purpose of this sub-question is to develop an understanding of BET procurement as a multi-level, interdependent, and organisational decision-making process that differs from the procurement of diesel trucks. Within this sub-question, BET adoption is not treated as a single vehicle replacement decision, but is treated as a broad set of strategic, tactical, and operational decisions. New decisions are identified and existing transport decisions are changed. Additionally, this sub-question assesses the feasibility and sequencing of decisions across transport profiles by comparing long-haul, line-haul, and short-haul transport through several transport dimensions. Therefore, this sub-question provides the basis needed to understand which decisions remain relevant for BET decision-making and how transport profiles affect BET decision-making.

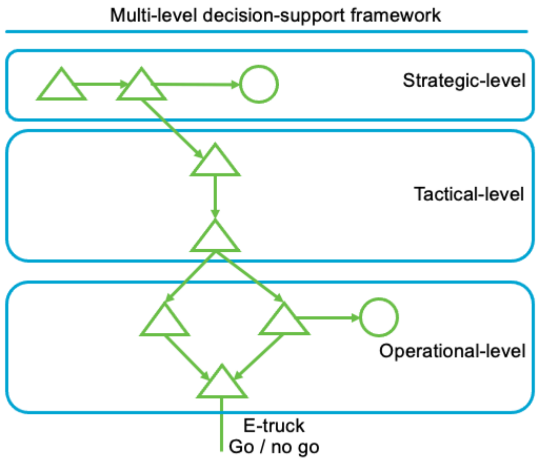

Figure 1.3: Generalised example of multi-level decision-support framework for truck electrification for freight operators (green triangle = decisions and green circle = end of decision-making process)

Sub-question 2: ***What are the adoption barriers and drivers of HDV electrification?***
The second sub-question identifies key barriers and drivers of HDV electrification and structures these in an overview. The aim is to show that BET adoption is impacted by a broad set of economic, technological, infrastructural, operational, organisational, behavioural, and institutional barriers & drivers. The insights from this sub-question reveal that HDV electrification should be understood as a socio-technical system in which barriers and drivers interact and shape the conditions under which BET adoption becomes feasible.

Sub-question 3: ***Which strategic, tactical, and operational fleet operator BET procurement decisions are affected by adoption barriers and drivers?***
This question connects the insights from the decision-making process (sub-question 1) and the adoption barriers and drivers (sub-question 2) by synthesising insights from both questions. Barriers and drivers will be analysed in relation to the strategic, tactical, and operational levels. First, the BET procurement decision-making process is used as the foundation. Second, the barriers and drivers are mapped in this decision-making structure to determine which decisions are affected by these barriers and drivers and at which stage. Third, these literature-based findings are tested and refined through insights from expert interviews with industry experts. Therefore, this sub-question creates an empirical understanding of the relationship between barriers, drivers, and BET decision-making.

Sub-question 4: ***How can fleet operators structure BET procurement decision-making across strategic, tactical, and operational levels to overcome adoption barriers and respond to adoption drivers?***
The focus of this sub-question is to design and refine the multi-level decision-support framework. This framework is based on the identified adoption barriers and drivers, the characteristics of BET decision-making, and the interrelations between these decisions. The framework examines how the decision-making process of fleet operators is structured across strategic, tactical, and operational levels to overcome barriers and respond to drivers. As a result, this sub-question develops a decision-support framework based on empirical insights combined with literature-grounded insights.

1.7. Relevance to Complex Systems Engineering & Management programme

This thesis topic aligns with the CoSEM programme as truck electrification is not treated as a solely technical vehicle replacement but as a complex socio-technical transition within the road freight system. The transition from diesel trucks to BETs requires fleet operators to make decisions regarding vehicles, charging infrastructure, grid capacity, route planning, operational flexibility, financial feasibility, customer requirements, and regulatory pressure. These decisions are strongly interdependent and involve both technical and organisational considerations. Therefore, the electrification of HDVs reflects the type of complex system problem that is central to CoSEM.

The relevance to CoSEM is especially visible in the multi-level decision-making perspective of this thesis. BET procurement requires strategic decisions, such as implementation pathway, business model adaptation, and charging infrastructure design. These decisions are connected to tactical decisions, such as customer-route allocation, route selection for BET deployment, and fleet transition. At the same time, these choices affect operational decisions, such as scheduling, load planning, and daily charging operations. By analysing the dependencies across strategic, tactical, and operational levels, this thesis applies a systems perspective to a transition problem within transport and logistics.

This thesis also reflects the management dimension of CoSEM, as the adoption of BETs depends on the interaction between multiple actors, uncertainties, and institutional conditions. Fleet operators, OEMs, grid operators, customers, governments, and charging infrastructure providers all influence the feasibility of BET adoption. Individual adoption barriers and drivers, such as high investment costs, grid constraints, environmental zones, subsidies, and customer sustainability demands, do not affect fleet operators alone. Instead, these factors interact with each other and shape the decision-making process over time. This makes the transition towards BETs not only an engineering challenge but also a governance, organisational, and management challenge.

Finally, this research is design-oriented, which further strengthens the connection with the CoSEM programme. The thesis does not only describe adoption barriers and drivers but translates them into a multi-level decision-support framework for fleet operators. This framework aims to structure the BET procurement decision-making process and to clarify where adoption barriers and drivers affect the decision-making process. By combining literature review, conceptual modelling, and expert interviews, the thesis connects scientific analysis with practical applicability. Therefore, this research represents a CoSEM approach by analysing a complex socio-technical transition and developing a structured framework that supports decision-making in practice.

1.8. Thesis outline

Chapter 2 describes the methodology, explaining the research flow, research approach, and research methods, and shows how the literature review, knowledge mapping, conceptual modelling, and semi-structured interviews are used to answer the sub-questions and develop the multi-level decision-support framework. Chapter 3 provides the literature-based foundation of the BET procurement decision-making process from the fleet operator perspective. It positions BET procurement within logistics and transport decision-making, explains how the transition from diesel trucks to BETs introduces new strategic, tactical, and operational decisions, and discusses how this process differs across short-haul, line-haul, and long-haul transport profiles. Chapter 4 identifies and structures the main adoption barriers and drivers of HDV electrification from the literature, providing the basis for understanding which factors hinder or accelerate BET adoption. Chapter 5 presents the empirical insights from the expert interviews, which verify, refine, and extend the theoretical findings on adoption barriers, drivers, BET decision-making, and transport dimensions. Chapter 6 combines the theoretical and empirical insights into the multi-level decision-support framework, mapping the interdependencies between decisions and linking adoption barriers and drivers to the strategic, tactical, and operational decisions that fleet operators face during BET procurement. Chapter 7 then reflects on the findings by discussing their contribution to the literature, the main limitations and assumptions, and the implications for research and practice. Finally, Chapter 8 concludes the thesis by answering the main research question.

2 Methodology

This chapter explains the methodology to answer the research questions and develop the multi-level decision-support framework. Section 2.1 presents the Research Flow Diagram (RFD). Section 2.2 describes the qualitative research approach used in this thesis. Finally, Section 2.3 explains the research methods used in this thesis, namely: 1) literature review, 2) conceptual modelling, 3) semi-structured interviews, and 4) interview coding process.

2.1. Research flow diagram

To answer the main research question, this study is divided into four connected research phases. Figure 2.1 provides an overview of these phases by showing the required input, process steps, output, sub-questions, and methods. The research flow diagram is the backbone of this research and shows how the study moves from a problem to the desired framework development and synthesis.

The first phase of this study aims to create the literature-based foundation of the research. Literature and industry reports are used to structure the BET procurement decision-making process, identify transport profiles, and define the key adoption barriers and drivers. This output addresses sub-questions 1 and 2 and provides the basis for the empirical phase (phase 2). In the second phase, the concepts from phase one are tested and refined based on empirical interviews. The barriers, drivers, decisions, and transport dimensions are refined based on the empirical insights. The identified barriers and drivers are connected to the BET procurement decision-making process and examined to see how these relationships are affected across transport profiles. Within this phase, literature insights are combined with expert interviews, resulting in a literature-based and empirically grounded conceptual model and additional empirical insights on transport profile heterogeneity. Therefore, the second phase addresses sub-question 3.

Phase 3 aims to develop and refine the multi-level decision-support framework. This phase first connects the individual decisions to one another and then translates the conceptual model and interview insights into a framework to support fleet operators during BET procurement decision-making, using knowledge mapping. The framework will be assessed with industry experts to refine it, based on their practical knowledge and experiences. This phase answers sub-question 4. The final phase, phase 4, synthesises all insights by reflecting on the findings, discussing the limitations and contributions, formulating recommendations for future research, and answering the main research question (MRQ). Overall, these four phases show that the research starts by defining the problem from a literature-based perspective, then tests and refines the insights empirically, develops the decision-support framework, and finally reflects on the results to answer the main research question.

2.2. Research approach

This thesis follows a qualitative and sequential research approach to understand and structure the BET procurement decision-making process from the fleet operator perspective. One of the central starting points of this research is that BET procurement cannot be seen as a single vehicle replacement deci-

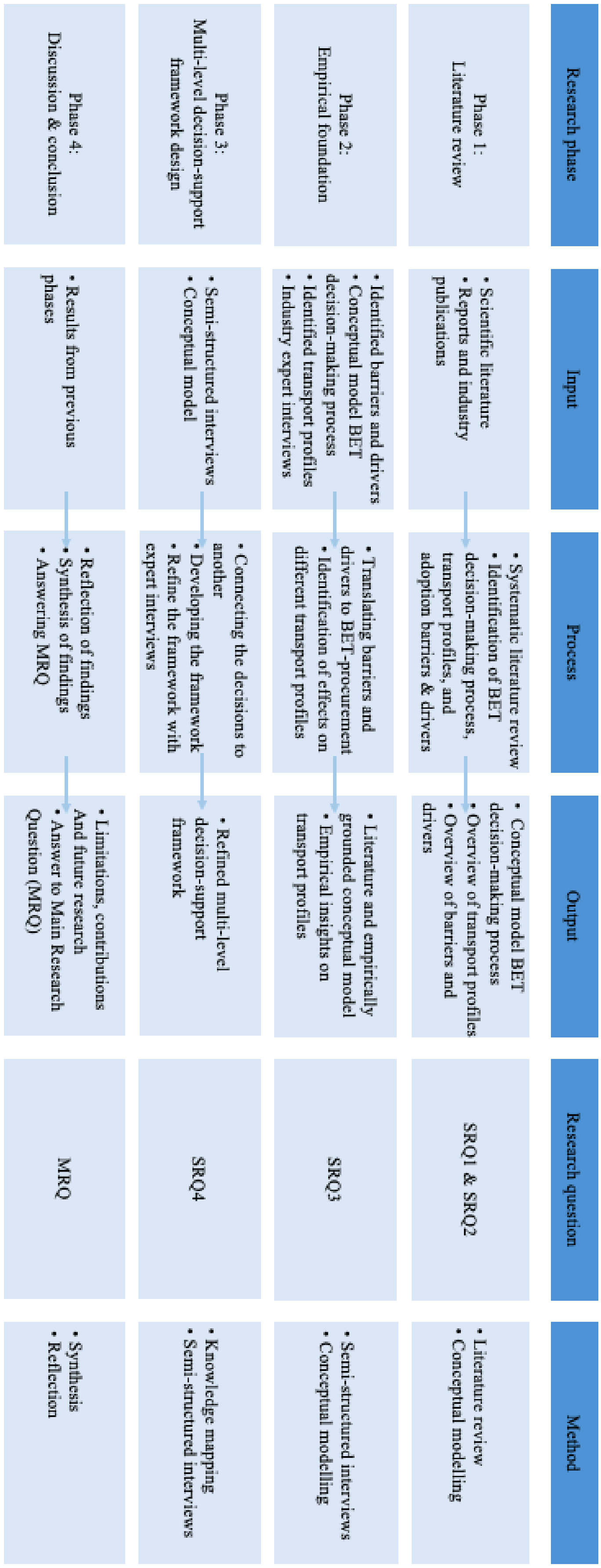

Figure 2.1: Research Flow Diagram

sion but must be viewed as a broader organisational and operational decision-making process shaped by transport profiles, adoption barriers, and adoption drivers. As the literature on BET procurement decision-making remains limited and fragmented, this research focuses first on theoretical insights before applying practical experiences from industry experts. The research improves the theoretical understanding of BET procurement decision-making while providing practical insights.

The research is conducted in different steps, starting with a literature exploration of the three core elements: BET procurement decision-making, heterogeneity of transport profiles, and adoption barriers & drivers. These elements are identified separately to create an understanding of these concepts and relationships from the literature. These theoretically formulated elements are needed as the current literature remains fragmented and explains only individual barriers, specific decisions, or limited transport profiles. By combining these elements, the research creates a conceptual understanding of BET procurement across strategic, tactical, and operational levels.

The second step is to test and refine the literature-based insights through semi-structured expert interviews. The goal of the interviews is to confirm findings from the literature, but also to identify missing links, practical considerations, and differences across transport profiles. By doing so, the interviews act as an empirical test of the initial conceptual models. This provides the opportunity for this research to move beyond literature and develop a decision-making structure with practical insights.

The final step is to combine theoretical and empirical insights into the multi-level decision-support framework. The framework is based on the synthesis of the decision-making structure, the identified barriers and drivers, and differences between transport profiles. The framework should clarify which decisions need to be made, how these decisions relate to one another in the context of fleet electrification, and which adoption barriers and drivers influence the transition. This forms the foundation for the methods of this thesis, as described in the next section.

2.3. Research methods

This study utilises qualitative methods to answer the sub-questions and design the multi-level decision-support framework for BET procurement from the fleet operators' perspective. The qualitative nature of the methods suits this research as this thesis investigates not a single measurable variable but a complex and content-dependent process shaped by technological, infrastructural, operational, economic, organisational, and institutional barriers & drivers. The methodological design of this thesis consists of three methods: conceptual modelling, a structured literature review, and semi-structured interviews. These methods are used sequentially and iteratively. The literature review provides the theoretical foundation to identify adoption barriers and drivers, and to analyse the BET procurement decision-making process for fleet operators. Semi-structured interviews are used to verify, refine, and extend the literature-based insights through an empirical lens from industry experts. The results from both methods are synthesised through conceptual modelling. A conceptual model has been constructed for both BET procurement decision-making and the multi-level decision-support framework. By combining literature, practical knowledge, and conceptual modelling, the analytical character and practical relevance of this thesis have been strengthened.

Conceptual modelling

Conceptual modelling is used in this thesis to structure, synthesise, and visualise the relationships between BET procurement decisions, adoption barriers & drivers, and transport profile characteristics. This method is needed because the aim of this research is not only to identify relevant decisions, barriers, and drivers separately but also to understand how they relate to one another in a comprehensive decision-making structure. Conceptual modelling, therefore, serves two purposes in this study: first, it is used to construct the conceptual model of the BET procurement decision-making process in Chapter 3. This model maps the relevant strategic, tactical, and operational decisions involved in BET procurement and shows how these decisions are interdependent across these levels. Second, conceptual modelling is used in Chapter 6 to integrate the decision-making structure with the identified barriers and drivers into a multi-level decision-support framework. In this way, the multi-level decision-support framework development moves from a descriptive representation of the decision-making process towards an all-encompassing framework that clarifies which decisions, barriers & drivers, and sequences are relevant for fleet operators in practice. The conceptual models are based on the data gathered from the literature review and semi-structured interviews. As a result, conceptual modelling functions as the synthesis method through which theoretical and empirical insights are translated into the final framework.

Literature review

The literature review mainly supports RQ1 and RQ2 and provides a basis for RQ3. The literature review is used to identify and analyse the BET procurement decision-making process, barriers, and drivers. The review includes both academic literature and grey literature. The scientific articles are used to create conceptual and analytical depth. The grey literature contains reports from research institutes, industry associations, and established consultancy firms that are used to capture market developments and empirical insights. This is needed as the context around BET adoption is evolving rapidly and certain operational experiences are not yet included in academic research or are outdated in these papers.

The literature was identified using different methods: a search string in Scopus, forward and backward snowballing, and papers recommended by experts. After selection, the literature is analysed in a systematic way. For each source, information on barriers, drivers, and procurement-related decisions is extracted to identify patterns in the literature. This resulted in a structured overview of adoption barriers and drivers, as well as a structured overview of the characteristics of BET procurement decision-making.

One of the main limitations of the literature review is the heterogeneity of the available papers. The papers differ in scope, as some studies focus only on BET, while other papers analyse battery electric vehicles (BEV) in general. The quality of the papers varies, as some are peer-reviewed studies, while industry reports are generally more descriptive. Finally, the contextual factors of the papers may differ, as studies are based in different geographical contexts. In general, the literature on BETs remains fragmented and is unable to connect barriers and drivers to BET procurement decision-making. To reduce the risk of this limitation, the literature review is verified and refined through expert interviews. Therefore, the literature review functions as a theoretical starting point rather than the primary source of evidence for this thesis.

Knowledge mapping

Knowledge mapping is used in phase 3 to structure and visualise the relationships between the identified BET procurement decisions. Knowledge mapping is a technique for representing knowledge elements and the connections between them in a structural and visual form. Therefore, complex and fragmented information can be organised into a coherent overview (Wexler, 2001). It is particularly suited to situations in which the individual elements are already known but their interdependencies are not yet explicit, which is the case for the decisions in this study.

In this research, knowledge mapping was applied to translate the coded interview material and the conceptual model into a structured representation of how the decisions influence one another. Concretely, the decisions were placed in a directed relationship matrix, in which each link represents an influence of one decision on another based on the interview data. This mapping made the interdependencies between the strategic, tactical, and operational decisions explicit and formed the basis for the multi-level decision-support framework. The construction of the relationship matrix is documented in Appendix B / Section 6.3.

This method also has limitations. Knowledge mapping is interpretive: both the existence and the direction of a link depend on how the researcher reads the interview material, so the resulting map reflects relative, qualitatively grounded relationships rather than statistically measured effects, and another researcher could map them differently. It also simplifies a complex reality and can suggest more structure than the data fully support.

Semi-structured interviews

Semi-structured interviews are used to complement the literature review with empirical insights from experts and to verify the multi-level decision-support framework by industry experts. This method is suitable as BET procurement decision-making is an actor- and context-dependent process that involves strategic, tactical, and operational decisions. These decisions are insufficiently discussed in the existing literature. Therefore, interviews play both an exploratory and a refining role throughout this research. During the first round of interviews, industry experts are interviewed, and insights are used to complement the literature review. Therefore, the first round of interviews supports answering sub-questions 1, 2, and 3. During the second interview round, industry experts are interviewed to translate their insights into a multi-level decision-support framework, and to evaluate and refine the framework to their practical experiences. By applying the interviews in this way, they form a bridge between the analytical and design parts of this thesis.

Using a sampling strategy, relevant respondents with experience in BET adoption and procurement decision-making have been selected. The number of interviews is not based on statistical representativeness but on analytical relevance and a variety of perspectives. The respondents are selected from organisations that are involved in or knowledgeable about truck electrification, such as truck manufacturers, consulting firms, or fleet operators. However, the main priority is on fleet operators as these actors are the most relevant to this study. Within organisations, the respondents are involved in fleet strategy, procurement, sustainability, operations, or financial decision-making. This makes it possible to capture differences across organisations, roles, and decision levels. Table 2.1 shows the participants overview.

Table 2.1: List of interviewees

Interview #	Related stakeholder	Job title	Interview round	Firm size (# employees)
1	Original Equipment Manufacturer	Strategy Manager	1	> 5,000
2	Consultant	Principal Consultant	1	50-200
3	Fleet operator	Senior Director Fleet Management	1	> 5,000
4	Fleet operator	Operations Manager	1	500-1,000
5	Fleet operator	Director	1	50-200
6	Fleet operator	Manager Fleet & Sustainable Innovation	1	500-1,000
7	Fleet operator	Financial Controller	1	50-200
8	Fleet operator	Planning/Sales	1	50-200
9	Fleet operator	Director	1	50-200
10	Fleet operator	Fleet Manager	1	1,000-5,000
11	Fleet operator	Fleet Manager	1	500-1,000
12	Fleet operator	Director	1	1-50
13	Fleet operator	Managing Director	1	200-500
14	Fleet operator	Procurement Manager	1	200-500
15	Freight forwarder	Manager Green Business & eMobility	2	1,000-5,000
16	Fleet operator	Sustainability Manager	2	1,000-5,000
17	Fleet operator	Operational Manager	2	50-200
18	Consultant	Partner	2	1-50

The interviews are semi-structured, due to the interview protocol with questions to ensure consistency across interviews, while flexibility is granted to explore new insights and case-related experiences. The protocol is organised around different themes: general information, barriers and drivers, BET procurement decision-making processes, and reflections on the multi-level decision-support framework.

The main strength of interviews is the ability to reveal new knowledge, perceived interdependencies, and the reasoning behind choices, which are often absent in the literature. However, interviews have limitations. Participants may emphasise their own or organisational perspectives, withhold details, or frame certain interpretations. In addition, interview findings are context- and organisation-dependent and cannot automatically be generalised to the entire road freight sector. To mitigate these limitations, the interviews are compared with the literature, and respondents are selected to cover different profiles, perspectives, and transport contexts.

Interview coding process

The analysis of the interviews followed a structured deductive and inductive coding process that contains seven steps. Table 2.2 summarises each step of the coding process. First, all interviews were recorded and transcribed before being imported into ATLAS.ti. To ensure a comprehensive analysis that aligns with previous chapters, the initial codebook was created from the insights of Chapters 3 and Chapter 4. This resulted in a codebook based on four themes: 1) barriers, 2) drivers, 3) BET procurement decisions, and 4) transport dimensions. By structuring the codebook around these themes, the interview material can be compared directly to the insights from Chapter 3 and Chapter 4.

Table 2.2: Step-by-step explanation of coding process

Step	Description
1. Transcription and import	Transcribing interviews and importing them into ATLAS.ti
2. Decision codebook construction	Decisions were added from Figure 3.2 as sub-codes in code theme 'decision-making process'.
3. Barrier and driver codebook construction	Added barriers and drivers from Table 4.1 as sub-codes in the 'barriers' and 'drivers' theme. Factors that could act as both barrier and driver were sub-coded under both themes when applicable.
4. Transport dimension codebook construction	Added transport profiles from Table 3.2 as sub-codes in theme 'transport dimensions'.
5. First-cycle coding	The first interviews were coded line-by-line with the starting codebook to test the usability of the theoretical categories.
6. Inductive refinement and iterative recoding	New drivers, barriers, decisions, and dimensions emerging from the interviews were added as sub-codes and iteratively applied across all interviews.
7. Interview-level aggregation and synthesis	For each code, the number of interviews in which it was mentioned was counted to indicate how widely it was shared across respondents, supporting the synthesis of barriers, drivers, decisions, and transport dimensions and the mapping in Chapter 6.
8. Mapping decision interdependencies	The coded interview material was used as input to identify directed relationships between decisions: for each link, the interviews evidencing an influence of one decision on another were identified and counted, which formed the basis for the directed relationship matrix in Section 6.3.

Within the deductive part of the process, all decisions from Figure 3.2 were entered as sub-codes under the theme 'decision-making process' and the transport dimensions from Table 3.2 were added as sub-codes under 'transport dimensions'. Simultaneously, all barriers and drivers identified in Chapter 4 (Table 4.1) were added under the themes 'barriers' and 'drivers'. Some of these factors were coded under both themes, as the interviews and literature revealed that certain factors can act as both barriers and drivers depending on the context. Business model innovation and customer demands and expectations are examples of factors that could serve as both a barrier and a driver.

The first three interviews were coded line by line using this codebook. The purpose of the first coding round was to test whether the literature-based themes were sufficiently clear and complete to create a starting point for comparing the interviews. By using ATLAS.ti, systematic coding was possible at the level of individual citations, after which the coded segments were aggregated per code and theme and, for each code, traced back to the interviews in which it occurred.

Simultaneously, the coding process remained inductive. During the coding of the interviews, new decisions, barriers, drivers, and transport dimensions were added as new sub-codes to the initial codebook. These new codes were then iteratively applied across all interviews to maintain consistency in the interview analysis. Examples of added sub-codes are: energy & peak-load management (decision), workforce training & routine adaptation (decision), growing availability of public chargers (driver), and growing knowledge & experience (driver).

After coding all interviews, the number of interviews in which each barrier, driver, decision, and transport dimension was mentioned was counted. These interview counts are presented in Chapter 5 and indicate how widely each factor was shared across respondents. They should not be interpreted as statistical values of sector-wide importance. Instead, they structure the prominence within the data set and support the synthesis and the mapping of barriers, drivers, decisions, and transport dimensions in Chapter 6. Finally, the coded material was not only aggregated per code, but also used to map the relationships between decisions. For each pair of decisions, the interviews indicating that one decision influences another were identified, which formed the input for the directed relationship matrix in Chapter 6.

3

Fleet Operator BET Decision-Making Process

This chapter answers the first sub-question of this research: *How can the BET procurement decision-making process of fleet operators be characterised across transport profiles?* The objective is to build the literature-based foundation to understand BET procurement as a decision-making process that goes beyond the vehicle replacement decision. To achieve this, BET procurement decision-making is analysed from a multi-level perspective in which strategic, tactical, and operational decisions are identified.

The added value of this chapter lies in structuring the decisions that fleet operators have to face when considering BETs and revealing how these decisions differ from traditional diesel-truck procurement. Section 3.1 positions BET procurement within logistics and transport decision-making while identifying which decisions are new and how traditional decisions may change. Section 3.2 elaborates on why BET procurement cannot be seen as a uniform process across all freight operations by analysing heterogeneity through transport dimensions and transport profiles. Finally, Section 3.3 contains a synthesis that brings the insights together to create a conceptual model of BET procurement decision-making.

3.1. BET within logistics and transport decision-making

This section positions BET procurement within the broader logistics decision-making process, as truck procurement is not an isolated purchasing decision but part of a wider network of decisions. Afterwards, the focus is narrowed down to transport decision-making, as not all logistics decisions are controlled by fleet operators. This step identifies which transport decisions remain relevant from the fleet operator perspective. Building on this distinction, BET procurement is analysed to identify new decisions and how existing transport decisions change in the context of BETs.

Logistics decision-making

Within the logistics literature, a well-known framework is provided by Langevin and Riopel, 2005, who designed a conceptualisation in which 48 logistics decisions are framed in a network, emphasising the relations between the decisions (Figure 3.1). Their conceptualisation contains decisions across three levels: 1) strategic level, 2) tactical level, and 3) operational level. Within these levels, decisions vary in time horizon, manager responsibilities, and resource demands, but remain highly connected. The high connectivity of decisions is an important insight within fleet operator decision-making as transport-related decisions are part of the wider logistics system rather than separate decisions.

Langevin and Riopel, 2005 define the following key decisions at the strategic level: the definition of customer service, the setting of customer service standards, and the degree of vertical integration & outsourcing. These decisions shape the organisational context in which transport and vehicle procurement decisions are made. The customer service decision is relevant to determining the level of delivery performance, while outsourcing and vertical integration decisions affect how transport is performed (internally or externally) and represent the level of control the company has over logistics activities. Based on these decisions, Langevin and Riopel, 2005 show that logistics decision-making starts with high-level decisions about service, structure, and governance before transport decisions are made.

The perspective of Langevin and Riopel, 2005 aligns with the view of Meixell and Norbis, 2008. According to Meixell and Norbis, 2008, transport decisions (such as carrier selection and mode choice) are multi-criteria decisions shaped not only by costs but also by reliability, transit time, flexibility, service quality, and responsiveness. Small and medium-sized fleet operators make interrelated choices about mode choice, carrier type, and vehicle type, which are shaped by shipment characteristics, as well as organisational structure (Ahmed and Roorda, 2022). Combined, the papers reveal that logistics decision-making is both multi-criteria and organisationally shaped. This indicates that fleet operators do not simply choose the cheapest transport option but align the options with their operational model and customer commitments.

Langevin and Riopel, 2005 take this insight a step further, as the authors explicitly map the links between decisions. Decisions regarding strategic planning and network design influence decisions made in later stages, while some operational decisions are interdependent and have to be made every day. This nuance is important as it shows that truck procurement is not an isolated purchasing decision, but it requires a variety of logistics decisions, such as network design, transport planning, and fleet management.

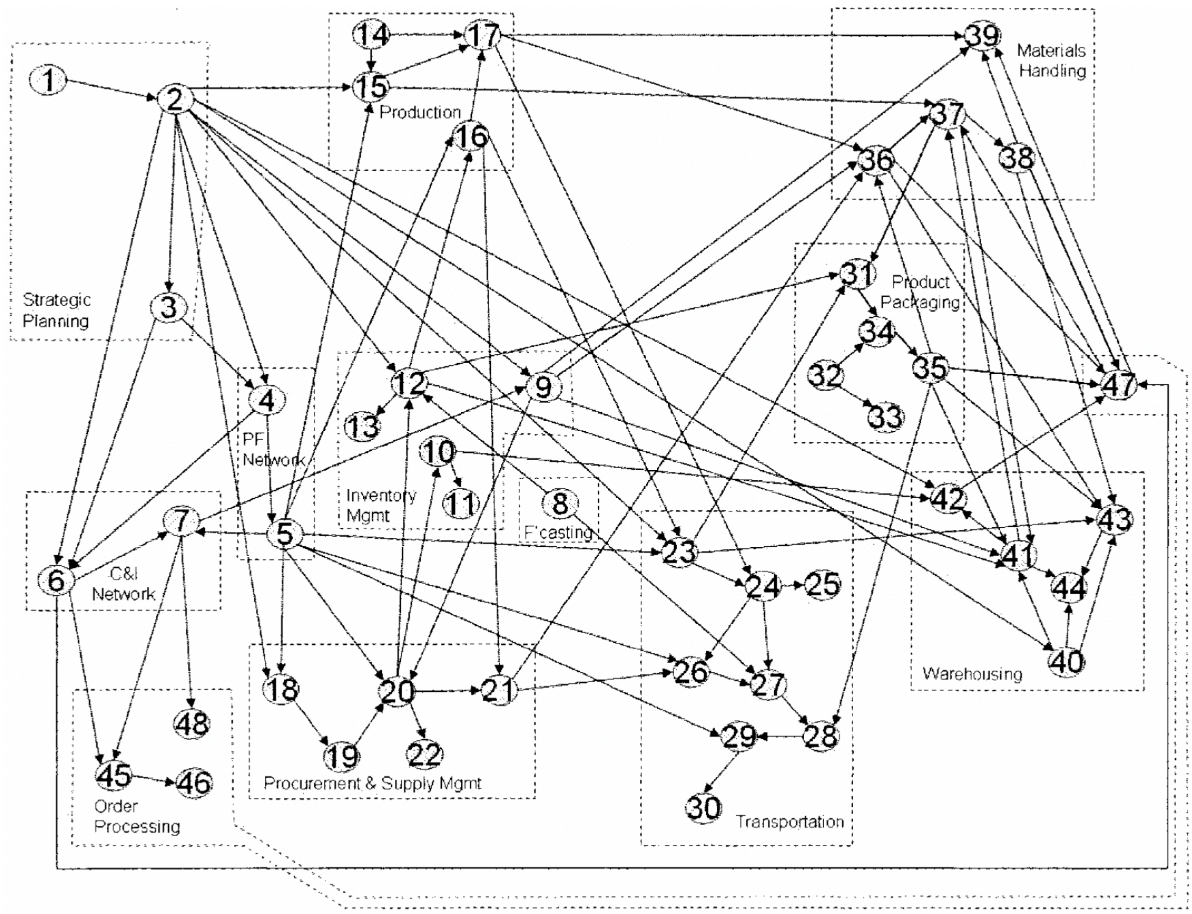

Figure 3.1: Visualisation of logistics decision-making and relations between the 48 decisions (Langevin and Riopel, 2005)

In conclusion, the logistics decision-making process is the broader context in which transport procurement takes place and is characterised by three main features. The first feature is the hierarchical nature of the logistics decision-making process, involving strategic, tactical, and operational levels (Langevin and Riopel, 2005). Second, decisions are interdependent and influence each other over time (Langevin and Riopel, 2005). Finally, the decision-making process is multi-actor in nature, as decisions are divided among different departments and managerial levels rather than concentrated in a single role (Ahmed and Roorda, 2022; Meixell and Norbis, 2008). The broader logistics perspective is important for truck electrification because BET procurement cannot be understood as an isolated vehicle purchase. Rather, it is embedded in a wider set of logistics and transport decisions, meaning that choices about vehicles, routes, charging infrastructure, customers, and operational routines become increasingly interdependent. The next section builds on the logistics perspective by focusing specifically on transport decisions and identifying how these decisions are affected, redefined, and extended by BET procurement.

Transport decision-making

Transport decision-making should be understood as a subset of logistics decision-making that concerns the movement of freight and goods through the transport system. Langevin and Riopel, 2005 reveal that transport decisions are embedded in a broad logistics decision-making network and are connected to strategic, tactical, and operational decisions. The framework of Langevin and Riopel, 2005 is useful as it shows that transport decisions are interdependent rather than isolated. However, the framework of Langevin and Riopel has an important limitation. The framework is general within logistics, meaning that it does not make any distinction between decisions made by fleet operators, shippers, carriers, or customers. Since this thesis focuses on BET decision-making from the fleet operators' perspective, this general framework should be translated to the fleet operator environment. The paper by Ahmed and Roorda, 2022 supports this interpretation, as it reveals that vehicle and carrier-related decisions are shaped by organisational and shipment characteristics. This means that transport-related decisions are influenced by the operational context and the role of the decision-maker. Meixell and Norbis, 2008 reveal that transport decisions are guided and framed by service criteria (e.g., reliability, flexibility, and transit times).

The interdependence between transport decisions and logistics decision-making is also visible in studies regarding production, inventory, and distribution planning. Hrabec et al., 2022 reveal that production, inventory, and routing decisions are connected during the operational phase. Similarly, Moons et al., 2017 show that production scheduling and vehicle routing are highly interrelated. These insights are relevant as they show that transport planning is affected by upstream logistics constraints. However, production scheduling and inventory management are not direct decisions for fleet operators but act more as contextual constraints. Therefore, this thesis uses transport decision-making literature as a starting point but narrows these decisions to those that fleet operators can control or influence when procuring and deploying BETs. Table 3.1 translates general transport decisions into relevance for truck fleet operators.

Table 3.1 reveals that the entire set of transport decisions from logistics literature should not be seen as direct fleet operator decisions. This thesis labels 1) fleet transition & integration, 2) customer-route allocation, 3) daily BET routing & scheduling, and 4) payload & load allocation as highly relevant decisions for fleet operators. These four decisions are directly shaped by BET characteristics such as range, charging needs, and payload sensitivity. Other decisions, such as production schedules and inventory management, remain relevant as they shape transport planning. However, they are not treated as core fleet operator decisions, as they are determined outside the fleet operator organisation. This means that these decisions act more as contextual constraints rather than decisions. Transportation modes, types of carriers, carrier selection, and degree of consolidation reveal low relevance for fleet operators. Therefore, these decisions are not carried forward to the next section.

This distinction is important because BET procurement does not reshape the entire logistics decision-making system in the same way. Its main impact is in the decisions where fleet operators have to align vehicle characteristics with operational requirements. For BETs, this alignment becomes more complex because route feasibility, charging availability, payload constraints, planning flexibility, and service requirements are closely interrelated. Therefore, the fleet-operator perspective helps to define the relevant scope of transport decision-making. It focuses on the decisions that fleet operators can directly control or influence. These decisions provide the basis for the next section, in which BET procurement is analysed as an extension of traditional transport decision-making.

Table 3.1: Truck fleet-operator relevance of transport decisions

General transport decision	Meaning in transport literature	Truck fleet operator relevance	BET decision relevance
Transportation modes	Decide which mode is used to move freight.	Low	Low
Types of carriers	Decide whether transport is performed in-house or outsourced (own fleet vs subcontractors).	Low / Medium	Low / Medium
Carrier selection	Select the carrier that performs the transport.	Low / medium	Low /medium
Degree of consolidation	Determine how shipments are combined to increase efficiency.	Indirect	Low
Fleet transition and integration	Select the composition of the fleet.	High	High
Customer-route allocation	Allocate customers and routes to vehicle types.	High	High
Vehicle routing and scheduling	Assign vehicles to routes and plan transport activities.	High	High
Payload and load allocation	Decide how freight is distributed and loaded across vehicles.	High	High
Production schedule	Align transport with production timing.	Low	Low
Inventory management	Align stock availability with delivery planning.	Low	Low

BET procurement decision-making

BET procurement decision-making refers to the set of decisions that fleet operators must consider when transitioning from diesel trucks to BETs. In the diesel-based transport system, procurement is largely an asset replacement decision: a vehicle can be assessed fairly independently because refuelling infrastructure, operational routines, and planning assumptions are already well established. BET procurement is different. Because BETs must function within a more constrained and interdependent system, fleet operators have to align vehicle deployment with charging infrastructure, energy systems, organisational capabilities, contractual arrangements, and operational requirements. This turns procurement from a straightforward replacement into a system-level decision-making process.

BET procurement affects fleet operator decision-making in two ways. First, it introduces new decisions that do not occur, or are far less prominent, in diesel-transport decision-making, such as charging infrastructure design, contract adaptation, and organisational capability development. Second, it changes existing transport decisions by making them more dependent on vehicle range, charging requirements, and energy availability. An overview of these decisions, including which are literature-based and which emerged from the interviews, is presented together with the empirical findings in Table 5.6 (Chapter 5). These decisions show that BET procurement is not merely an extension of diesel-truck procurement, but part of a broader organisational technology adoption process that is influenced not only by economic factors (Özlü and Çelebi, 2024), but also by organisational readiness, partnerships, managerial perceptions, and infrastructure availability (Konstantinou and Gkritza, 2023b; Bae et al., 2022).

Taken together, this means the feasibility of BET adoption cannot be assessed at the vehicle level alone. It should be understood as a system-level process that aligns strategic, tactical, and operational decisions within the broader operational and organisational system of the fleet operator.

3.2. Dimensions that determine the transport profile

BET procurement decision-making cannot be understood as a uniform process across all transport operations. It involves a network of interrelated decisions, in which the outcomes of decisions influence one another through causal order and information dependency (Langevin and Riopel, 2005). For example, vehicle-route feasibility must be assessed before vehicle load plans can be operationalised, while charging plans depend on vehicle routing and scheduling. This indicates that BET procurement

Table 3.2: Literature-based transport profiles characterised through operational dimensions

Transport profile	Route predictability	Return-to-base frequency	Fuelling / charging control	Daily distance	Payload sensitivity
Short-haul / depot-based transport	High	High	High	Low to medium	Low to medium
Line-haul / corridor-based transport	High	Medium	Medium	Medium to high	Medium to high
Long-haul transport	Low	Low	Low	High	Medium to high

decisions are shaped by the operational system in which the BET is deployed.

This is particularly relevant for road freight transport, as freight operations (transport profiles) differ across fleet operators. For example, distance is an important factor in freight transport choices, while break-even distances depend on drayage costs, travel time, and transport infrastructure (Zgonc et al., 2019). Similarly, urban-freight transport literature reveals that transport decision-making is context-dependent and should take behavioural, technical, operational, organisational, and financial factors into consideration, as well as the culture, structure, and evolution of the city (Gatta et al., 2017). These studies show that BET procurement decision-making is not only focused on the truck technology itself, but also on the operational context in which the technology operates.

However, the literature does not provide a uniform way to describe transport dimensions for BET adoption. Instead, several recurring operational feasibility factors can be derived from studies on BET deployment and freight transport. These dimensions are therefore used in this section as a first draft of literature-informed analytical dimensions to compare transport profiles. They should not be interpreted as a final classification but as an analytical starting point that is further tested and refined through the empirical interview findings in Chapter 5.

Based on the introduction above, transport profiles can be compared through the preliminary set of operational dimensions. These dimensions provide a structured way to compare different freight operations beyond classifications such as short-haul and long-haul transport. The dimensions reveal that transport profiles are not static or distance-based categories but combinations of operational characteristics that affect the feasibility, sequencing, and complexity of BET decision-making. An overview of these preliminary, literature-based dimensions, including their meanings and sources, is presented together with the empirical findings in Table 5.7. In this chapter, Table 3.2 only characterises the resulting transport profiles.

From dimensions to transport profiles

In practice, these operational dimensions appear in recurring combinations that form transport profiles. Although the literature does not offer universally accepted transport profiles for BET freight transport, most studies distinguish between short-haul or depot-based transport (Amiri et al., 2023, Gatta et al., 2017), line-haul or corridor-based transport (Bakker et al., 2025, Karam and Rich, 2025), and long-haul (Basma and Rodriguez, 2022, Cheng and Lin, 2024, Mareev et al., 2018, Sader et al., 2025). Table 3.2 summarises how these literature-based transport profiles can be preliminarily characterised through the operational dimensions identified above.

Short-haul or depot-based transport is characterised by high route predictability, high return-to-base frequency, and high fuelling/charging control, combined with relatively low to medium daily distances and low to medium payload sensitivity. These conditions make short-haul operations the most attractive environment for BET deployment, as charging can often be integrated within existing depot-based routines and is easier to assess.

Line-haul or corridor-based transport has an intermediate position. These operations are often repetitive and relatively structured but involve larger distances, lower return-to-base frequency, and more limited fuelling/charging control than short-haul operations. As a result, BET feasibility in line-haul transport depends more strongly on coordinated corridor-based charging solutions, charging partnerships, and the alignment between routes, schedules, and charging opportunities.

Long-haul transport is the most challenging profile for electrification. It combines lower route predictability, low return-to-base frequency, low fuelling/charging control, and high daily distances while often involving medium to high payload sensitivity. This combination affects vehicle-route feasibility, charging access, scheduling, and operational risk. Therefore, long-haul electrification depends more strongly on public charging infrastructure, charging access, route planning, and the ability to combine charging with driving and rest times.

Although Table 3.2 characterises three broad transport profiles, these profiles should not be treated as homogeneous categories. The same profile can contain different operational configurations, and the feasibility of BET adoption may vary strongly between fleet operators within the same profile. Therefore, the dimensions presented in this section function as a starting point rather than a final framework. Chapter 5 uses the interview findings to assess whether these initial dimensions sufficiently explain transport heterogeneity in practice and whether additional dimensions are needed.

3.3. Synthesis and conceptual model

This chapter identifies fleet-operator decisions relevant to BET procurement from a logistics perspective. The following sub-question is addressed in this chapter: *How can the BET procurement decision-making process of fleet operators be characterised from the literature, and how does this differ across transport profiles?*

In conclusion, BET decision-making is characterised by multi-level, interdependent, and organisational decisions that differ from traditional diesel-truck procurement. Rather than simply making a single vehicle replacement decision, BET procurement becomes part of a transition process that requires a systematic approach in which strategic, tactical, and operational decisions must be aligned. Table 5.6 shows that BET procurement introduces both new decisions and changes to existing transport decisions. This demonstrates the extension of BET procurement decision-making beyond the purely technical decision of whether an electric truck can replace a diesel truck on paper. Figure 3.2 visualises this conclusion by presenting BET procurement as a connected decision-making structure, revealing that decisions across organisational levels are interdependent and cannot be made individually. Therefore, the literature suggests that BET procurement should be understood as a complex, multi-level, and interdependent organisational decision-making process in which fleet operators reconfigure their existing transport system to make electrification technically, economically, and operationally viable.

The conceptual model in Figure 3.2 represents a structure for BET procurement decision-making for fleet operators. However, this structure should not be interpreted as equally applicable across all freight operations. The operational dimensions identified in Section 3.2 function as a contextual layer that shapes how the model is applied in practice. Transport profiles do not introduce a completely different set of decisions, but they influence which decisions become most critical, how these decisions are sequenced, and where complexity arises.

For short-haul or depot-based transport, high route predictability, frequent return-to-base operations, and high charging control make BET deployment relatively more manageable. In this profile, the most critical decisions are route selection for BET deployment, depot charging infrastructure design, daily charging scheduling, and customer-route allocation. For line-haul or corridor-based transport, route structures are often repetitive, but daily distances are higher and charging control is more limited. As a result, decisions concerning charging strategy, capability sourcing & partnerships, implementation pathway, and contract & risk-sharing become more important. For long-haul transport, low route predictability, low return-to-base frequency, low charging control, and high daily distances increase uncertainty around vehicle-route feasibility, public charging access, scheduling, and risk allocation.

This interpretation is important for the remainder of this thesis. Chapter 5 empirically assesses whether these literature-informed operational dimensions sufficiently explain transport heterogeneity in practice. Chapter 6 then translates these insights into the multi-level decision-support framework.

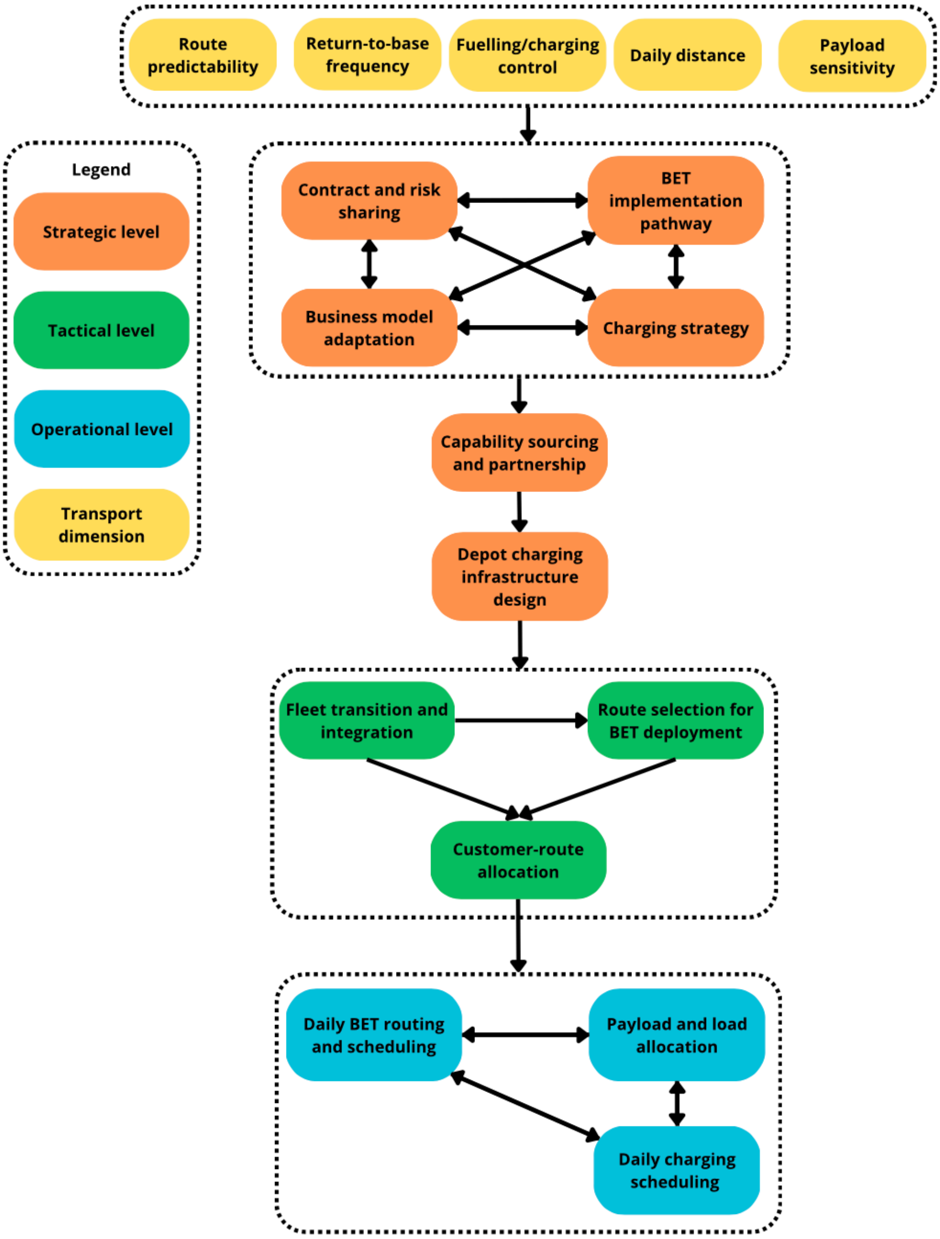

Figure 3.2: Visualisation of BET decision-making process based on literature insights

4
Adoption Barriers and Drivers for BET Electrification

This chapter addresses sub-question 2: *What are the adoption barriers and drivers of HDV electrification?* In doing so, Section 4.1 explains how the literature search process is used to identify relevant sources. Section 4.2 discusses the identified barriers and drivers across six categories: economic, technological, infrastructural, operational, organisational and behavioural, and institutional & policy. Finally, Section 4.3 synthesises these findings into the overview Table 4.1 containing the adoption barriers and drivers for HDV electrification.

4.1. Literature search process

A structured literature search has been used to identify key barriers and drivers of HDV electrification. The following search string has been used in the Scopus database up to 26 April 2026: *TITLE-ABS-KEY ((”heavy-duty truck” OR ”heavy duty truck” OR ”electric truck” OR ”electric trucks” OR ”freight truck” OR ”HDVs” OR ”HDV” OR ”heavy-duty”) AND (”electric” OR ”electrification” OR ”battery electric” OR ”BEV” OR ”zero emission”) AND (”barrier” OR ”driver” OR ”adoption”)).* The search term is designed to balance the broad perspective while focusing on the aim of this chapter. The first cluster of terms focuses on HDVs in the road freight context, the second cluster focuses on electrification and zero-emission transport, and the third cluster targets adoption-related barriers and drivers. By doing so, the search term covers the emerging and fragmented literature on electric freight transport while focusing on the adoption of BETs in road transport.

After the initial Scopus search, the literature selection process consisted of multiple screening steps (Figure 4.1). First, several publications were excluded, such as publications before 2023, non-English papers, and papers with missing authors. The remaining studies were screened based on their titles, after which the relevant papers were assessed based on the abstracts. Finally, some papers were excluded as they were not retrievable. As the literature on HDV electrification is developing rapidly and may not be fully covered by academic sources alone, additional papers have been added to the literature review. These papers were identified through Google Scholar, forward and backward snowballing, grey literature, industry reports, and papers received from supervisors. Overall, these different sources provide a broad and up-to-date basis to analyse the adoption barriers and drivers of HDV electrification.

4.2. Adoption barrier and driver themes

Economic

High upfront investment costs

BETs are significantly more expensive to buy than diesel trucks. European-made models cost €250,000 to €350,000, two to three times a comparable diesel truck, while US prices run 50-250% higher (Luman, 2026). Chinese-made BETs are up to 36% cheaper thanks to larger production volumes (Suneson et

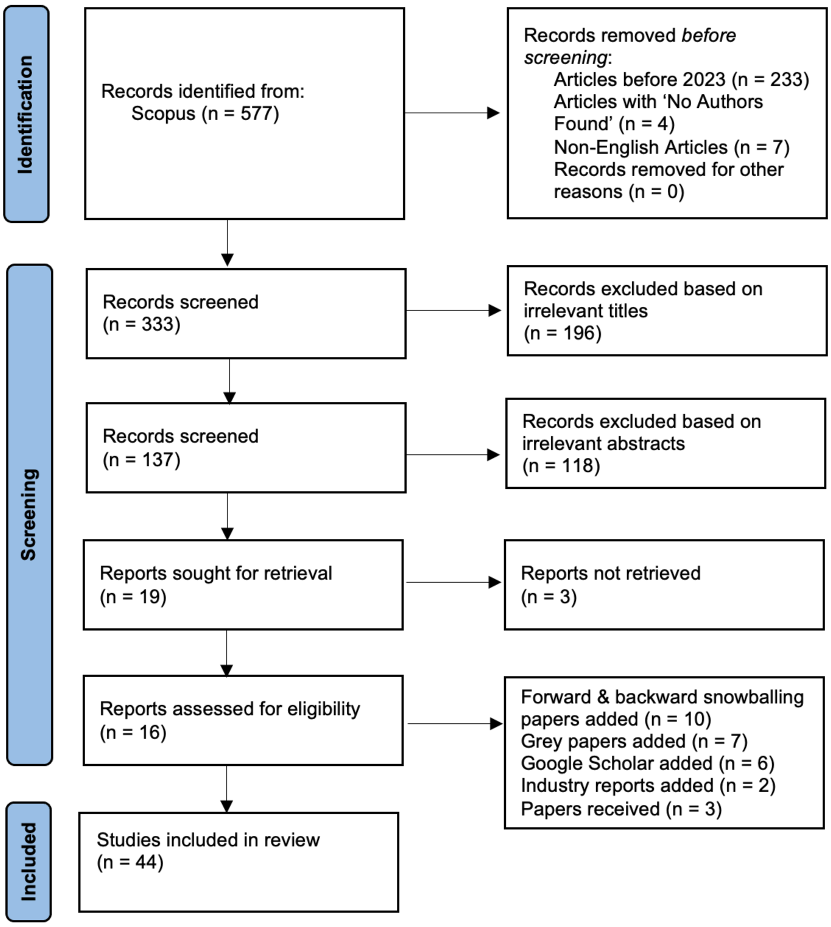

Figure 4.1: Visualisation of literature selection process

al., 2025). Because transport margins are tight and customers resist paying more, operators cannot pass these costs on, which hits small and medium-sized fleet operators hardest (Sugihara et al., 2023).

Total Cost of Ownership uncertainty

Evidence on the Total Cost of Ownership (TCO) of BETs is mixed. Under favourable assumptions, high annual mileage, low and stable electricity prices, accessible charging, predictable maintenance, and secure subsidies, BETs can match or outperform diesel on TCO (Mareev et al., 2018; Nykvist and Olsson, 2021). In practice, however, the variables driving TCO are uncertain: residual value, battery degradation, electricity prices, and operational practices cause realised costs to deviate from model projections (Basma and Rodríguez, 2023; Danielis et al., 2025). Because outcomes are highly sensitive to these inputs, small deviations can flip the result and raise financial risk, so decision-makers must judge not only whether BETs are cost-competitive but whether the assumptions behind that conclusion are reliable enough to act on.

Financial risk and market uncertainty

The main financial-risk barrier is the mismatch between freight contract structures and the BET investment horizon. Strong competition between fleet operators keeps freight rates low and margins tight, so operators struggle to pass BET costs on to customers, who can move volume to cheaper fleet operators (Sugihara et al., 2023). This makes operators reluctant to commit to the long-term agreements that BET investments require (AllChiefs, 2025). Contracts typically run from single trips to two years (Suneson et al., 2025), while a truck is used for around 14 years (European Automobile Manufacturers' Association, 2024) and its high upfront cost must be recovered over much of that life. A two-year horizon cannot provide that certainty, making the contract structure a barrier separate from the vehicle's cost-competitiveness.

Technological

Limited driving range

BETs are constrained by battery capacity, whereas diesel range easily exceeds 1,000 km. Link and Plötz, 2022 show that range limits affect feasibility on routes beyond 300-400 km: a 600 kWh battery could electrify about 60% of diesel trucks by vehicle count but only around 40% of tonne/km, since the remainder consists of heavier, long-distance trips that need intermediate charging. Larger batteries extend range but add weight and cut payload (Nykvist and Olsson, 2021). Range is also weather-sensitive. In Minnesota (USA) winters, battery performance dropped 25-40% (Khani and Emami, 2022). Even when the average daily distance is manageable, operators must absorb day-to-day variability in distance and energy use per kilometre, driven by weather, temperature, payload, and traffic, which can disrupt tightly planned schedules.

Battery weight and payload reduction

BET batteries are heavy: the Mercedes-Benz eActros 600 carries a 621 kWh battery weighing 4.5 tonnes (Mercedes-Benz Trucks, 2026). To compensate, the EU's Weights & Dimensions Directive (Council Directive 96/52/EC) raised the maximum weight of zero-emission trucks to 42 tonnes (European Commission, 2026). Even so, a payload penalty remains. Khani and Emami, 2022 compute a 12-17% reduction, Mareev et al., 2018 estimate roughly 80% of comparable diesel payload for an 825 kWh battery (a figure based on 2018 energy density), and Sader et al., 2025 expect 27% more BETs are needed to move the same freight as a diesel fleet. Mareev et al., 2018 note this must be read in context, as average long-haul payload utilisation is around 70%, making the loss manageable in many cases, though it still constrains high-load long-haul transport.

Charging time

Unlike the few minutes needed to refuel a diesel truck, BETs require long charging times even on high-power chargers. This adds stops, lowers vehicle utilisation, and complicates route planning (Nykvist and Olsson, 2021; Konstantinou and Gkritza, 2023b; Otero-Palencia et al., 2026). In long-haul operations, charging can clash with delivery windows and driver working-hour legislation, turning a technical limitation into an operational barrier and a source of planning uncertainty.

Technological uncertainty

Rapid development of zero-emission vehicles complicates long-term investment, because future performance, cost, and standards are still evolving and their timing is hard to predict. Improvements in battery density and efficiency may cut the required capacity. Basma and Rodriguez, 2022 find most EU truck applications in 2022 could be covered by a 1,000 kWh battery, possibly falling to 700 kWh by 2030. This pace pushes operators to postpone investment in anticipation of longer range or lower cost (Nykvist and Olsson, 2021; Scherrer et al., 2026), while competing pathways such as hydrogen and synthetic fuels develop in parallel (Müller, 2024; Roman and Zadek, 2024). Uncertainty over future performance, the pace of innovation, and competing technologies therefore raises investment uncertainty and can slow BET adoption.

Infrastructural

Limited public charging infrastructure

Low availability of public charging along highways is a major barrier, since long-haul transport depends on corridor charging where regional transport can rely on depots. Shoman et al., 2023a argue that Germany needs charging stations every 25-35 km to create an attractive environment. That is far denser than the 120 km spacing required on the TEN-T network by the Alternative Fuels Infrastructure Regulation (EU 2023/1804), which shows that current rules fall short in places. The scale is large. A 15% BET share in European long-haul by 2030 would need roughly 40,000 overnight chargers (50-100 kW) and 9,000 megawatt chargers (0.7-1.2 MW)(Shoman et al., 2023b). For Germany alone, Speth et al., 2025 estimate 124 stations with 12,000 charging points. Today, Europe has only around 1,100 public HDV charging points (ACEA, 2025). Expanding this network is needed to improve operational flexibility, avoid detours, and reduce planning uncertainty (Konstantinou and Gkritza, 2023b).

Electricity grid capacity & operation

High-power charging requires grid capacity that is often not yet available. Under AFIR, a single hub needs 4.2 MW (one-way road) to 8.4 MW (two-way road) by 2030 (Karsten et al., 2023), and large-scale charging can cause excessive voltage deviation, substation overloading, and power-quality problems for other network loads (Then et al., 2025). Grid expansion is costly and slow and requires coordinated public-private action (Bernard et al., 2022). Without it, large-scale electrification of the transport sector may be infeasible and could cause grid congestion (International Energy Agency, 2025).

Private depot charging infrastructure

While long-haul transport depends heavily on public infrastructure (Shoman et al., 2023a), larger fleet operators with depot networks across Europe can develop depot charging hubs (Hacker et al., 2023). This requires substantial upfront investment in chargers, grid connections, and site-specific modifications (Engelhardt et al., 2023; Hacker et al., 2023; Bernard et al., 2022), and operators willing to invest report feasibility problems with grid-connection capacity, connection lead times, and site requirements (Sugihara et al., 2023).

Operational

Complexity of mixed fleets

Adding BETs to diesel fleets removes the homogeneity that current operations and planning tools assume (Otero-Palencia et al., 2026). During the transition, operators must run mixed fleets, which differ in fuelling, maintenance, planning, and driver training (Özlü and Çelebi, 2024), and cannot be used interchangeably. BETs must be assigned to routes matching their range and depot or corridor charging access, while diesel trucks cover the longest and least predictable trips (Melander et al., 2022). Poor alignment leads to inefficient operations and higher costs (Bakker et al., 2025).

Route planning constraints

Diesel routing is constrained by distance and time, where electric routing adds an energy constraint. BETs are technologically feasible for long-haul transport on predictable, predefined routes, but journey time rises 16-32% from charging stops (Cheng and Lin, 2024). Energy use per kilometre is not fixed as it varies with payload, road gradient, and ambient temperature, with cold weather cutting usable range 25-40% (Khani and Emami, 2022), so it is uncertain in advance whether a route can be completed on a single charge (Amiri et al., 2023). Electrification thus shifts routing from a scheduling problem, where range is effectively unconstrained, to a feasibility problem, where the route must first be checked against available range and charging opportunities.

Operational reliability

Reliable freight transport depends on predictable vehicle performance: range, energy consumption per kilometre, and availability, which operators rely on to meet delivery windows and free vehicles for the next assignment. BET performance is less predictable, as range and energy use vary in real operation with payload, terrain, and climate (Khani and Emami, 2022; Mareev et al., 2018; Sader et al., 2025), with extreme weather reducing usable range 25-40% (Khani and Emami, 2022) and Corguillé et al., 2025 confirming a statistically significant effect of vehicle weight, temperature, and altitude. Diesel trucks face the same variability, but it rarely threatens reliability because their range exceeds 1,000 km and refuelling is fast and widely available. For BETs the same variation directly decides whether a route can still be completed, since range is limited and recharging is slow and not always accessible. Energy uncertainty therefore becomes schedule uncertainty, which is why operators remain concerned about whether BETs can meet daily mileage and payload demands (Link and Plötz, 2022). Charger availability and waiting times add further delay risk, leaving operational reliability a barrier that lowers fleet operators' confidence in the transition.

Organisational and behavioural

Lack of knowledge and experience

Limited experience with BETs is an important organisational barrier. Where diesel operations are well understood, BETs require operators to master charging strategies, battery performance, electricity procurement, route-energy parity, and the interaction between operations and charging infrastructure (Axsen and Pickrell-Barr, 2024; Sugihara et al., 2024). Electrification is therefore not only a vehicle replacement but an organisational learning process. Without it, operators are less able to achieve operational fit and financial feasibility and more likely to interpret uncertainty as risk (Axsen and Pickrell-Barr, 2024). This gap also reinforces other barriers as fleet operators may overestimate range or overstate infrastructure uncertainty, and because BET procurement involves several organisational actors (Sugihara et al., 2024) and stakeholders with differing needs (Ïmre et al., 2021), knowledge gaps appear not only individually but in routines such as procurement, replacement cycles, maintenance, and scheduling that are built around diesel and must be relearned.

The result is a risk of a gap between strategic intent and operational implementation as management may back BETs while adoption stalls for lack of internal confidence, which helps explain hesitation even among interested operators (Konstantinou and Gkritza, 2023b). It is unlikely to be the leading barrier on its own. Though, when the TCO is clearly favourable and reliable charging is available, operators can adopt despite limited experience. Lack of knowledge and experience is thus a secondary barrier that amplifies the economic and infrastructural barriers and slows the learning curve, reinforcing reliance on diesel (Axsen and Pickrell-Barr, 2024; Konstantinou and Gkritza, 2023b).

Lack of social proof

Firms adopt innovations more readily when they observe successful implementations by peers with comparable commercial and operational characteristics (Rogers, 2003). For BETs such examples are still scarce, especially in a demanding sector focused on reliability, flexibility, and cost control (Axsen and Pickrell-Barr, 2024), so adoption is seen as a high-risk transition rather than a proven pathway. Operators do not decide on technological evidence alone; they look for real-world cases, and Foda and Mohamed, 2026 show that stakeholders also seek awareness, education, planning and operational tools, and data sharing. While adoption stays concentrated among early movers and innovators, BETs may be perceived as exceptional rather than established, slowing the shift from pilots to sector-wide deployment (Axsen and Pickrell-Barr, 2024; Foda and Mohamed, 2026).

Corporate strategy and motivation

Corporate strategy and motivation can be both a barrier and a driver. Melander et al., 2022 show operators are driven by management priorities such as sustainability, support for fossil-free transport, and positioning themselves ahead of competitors, as well as by the chance to strengthen their image with customers, investors, and employees. Without such commitment it becomes a barrier, because adoption requires coordination across procurement, operations, infrastructure planning, and customer relations. Gillström et al., 2024 show the transition needs broader organisational and business-model adaptation, not just a technological shift, and Axsen and Pickrell-Barr, 2024 find that organisational support for sustainability matters for alternative-fuel vehicles. Internal strategy and motivation can therefore accelerate or delay adoption depending on their maturity.

Customer demands and expectations

Customer demand is primarily a driver but turns into a barrier when commercial arrangements do not adapt. Melander et al., 2022 describe several channels through which customers shape operators' views: public customers and public procurement pushing for fossil-free transport, private customers requesting a transition, and larger private customer groups setting environmental demands. Adoption is therefore shaped not only by regulation or internal targets but by direct market demand, making it part of maintaining market share, winning tenders, and sustaining strategic client relationships. These pressures are already visible in road freight (Melander et al., 2022) and, as Foda and Mohamed, 2026 note, stakeholder expectations on sustainability can exceed technology readiness, sometimes driving adoption even before the financial case closes. The same demand becomes a barrier when it brings transition costs, revised service conditions, and contractual friction, since average contracts cannot cover BETs' long-term risks, opening a gap between market demand and economic feasibility.

Business models

Business models can function as both a barrier and a driver. Traditional freight models assume diesel with short refuelling stops, high flexibility, accessible fuelling, and pricing that ignores BET-specific costs such as charging time, charging infrastructure investment, and depot energy management. Electrified freight needs a broader reconfiguration of contracts, service standards, and pricing for the system to be profitable even when the vehicle itself is viable (Gillström et al., 2024). Rigid models are thus an organisational barrier as an operator may see the strategic value and feel customer or policy pressure yet be unable to shift if contracts are too short to recover costs, customers expect diesel flexibility without cost increases, or systems cannot support coordinated charging. The barrier becomes a driver when operators adapt, for example through 'green' service contracts, longer contract terms, collaborative charging agreements, or cost-sharing with customers who demand zero-emission transport. Gillström et al., 2024 find operators redesign their business models to manage transition uncertainty and create value in electrified road transport.

Institutional and policy

Regulatory uncertainty

Regulatory uncertainty is an institutional barrier. BET investments are long-term, but the policy environment shaping their costs and operating conditions can change within that horizon. Standards can be tightened, incentives withdrawn, and announced measures delayed. The barrier is the instability itself rather than any single instrument (subsidies, carbon pricing, and road pricing are discussed below as drivers); what matters here is that their direction and timing are hard to predict, which can delay diffusion and complicate stakeholder alignment (Ïmre et al., 2021). Raoofi et al., 2025 show BET adoption and charging infrastructure are interdependent and strongly shaped by policy, and that uncertainty across subsidies, infrastructure planning, and diesel disincentives lowers operators' ability to coordinate investment across depots, contracts, and vehicles. Regulatory uncertainty thus removes the predictability that effective BET adoption needs.

Subsidies and fiscal incentives

Subsidies and financial incentives are a leading driver. Leung and Peace, 2020 call incentives the most critical factor in BET procurement because they improve financial competitiveness while BETs remain expensive, bridging the gap between strategic desire and economic feasibility. Melander et al., 2022 identify higher diesel taxes, lower BET taxes, and BET subsidies as key drivers, which cut costs directly and improve investment timing. Axsen and Pickrell-Barr, 2024 find financial incentives are important motivators for alternative-fuel vehicles while prices, charging investments, and risk remain high. The Dutch heavy goods vehicle charge (from 1 July 2026) illustrates this: diesel trucks pay more per kilometre driven and much of the revenue funds sustainability, including subsidies for zero-emission trucks and private charging infrastructure (Ministerie van Infrastructuur en Waterstaat, 2026).

CO_2 taxation and low-carbon fuel standards

CO_2 taxation and carbon-pricing mechanisms are institutional drivers because they change the relative economics of diesel trucks and BETs (Raoofi et al., 2025). Where subsidies raise the attractiveness of BETs, carbon pricing lowers that of fossil-fuel trucks, shifting the business-case comparison especially for high-mileage, fuel-intensive operations. Foda and Mohamed, 2026 and Ïmre et al., 2021 stress that tailored, coordinated policy is essential for fleet electrification as operators electrify not only when BETs are cheaper but when diesel becomes less competitive through taxes, road pricing, and standards such as the EU CO_2 emission standards for heavy-duty vehicles (European Union, 2024), which require new heavy trucks to cut CO_2 emissions by 45% by 2030 and 90% by 2040 compared with 2019. These instruments are most effective within a wider policy mix, for example carbon pricing combined with charging infrastructure support and early-phase subsidies (Raoofi et al., 2025).

Environmental zones

Environmental (low-emission) zones drive BET adoption, especially for operators serving urban and regional areas, by restricting access for polluting vehicles (Melander et al., 2022). Their power is that they translate environmental policy into direct operational consequences. For city-logistics, retail-distribution, or other access-sensitive customers, BETs become attractive not only for sustainability but economically, because tight-margin operators cannot absorb the access charges, fines, and restrictions that diesel increasingly faces. Ïmre et al., 2021 note that urban freight electrification is shaped strongly by local stakeholders and policy design, and Mirhedayatian and Yan, 2018 show these zones significantly affect logistics costs and externalities such as air pollution, noise, and CO_2 emissions. By redefining which modes remain economically feasible in an area, environmental zones can turn a long-term electrification ambition into an immediate strategic opportunity.

4.3. Synthesis

This chapter identifies the key barriers and drivers affecting the adoption of BETs by addressing sub-question 2:

What are the adoption barriers and drivers of HDV electrification?

According to the existing literature, the electrification of HDVs is not shaped by a single dominating barrier or driver but is shaped by a broad and interrelated set of adoption barriers and drivers. Table 4.1 summarises all the key barriers and drivers of BET adoption. This chapter reveals that economic and charging-infrastructure barriers are the most persistent. These are: high upfront investment costs, TCO uncertainty, financial and market risk, limited public charging, constrained grid capacity, and high investment in private charging. These barriers are reinforced by technological and operational constraints, namely limited driving range, payload challenges, charging times, technological uncertainties, mixed-fleet complexity, route planning constraints, and concerns regarding operational reliability. Next to these barriers, literature argues that organisational and behavioural factors play an important role. A lack of knowledge and experience, weak social proof, and insufficient internal motivation can slow the adoption speed, even when the technology is technically feasible. On the other hand, certain drivers are identified that accelerate the transition. These drivers are subsidies and fiscal incentives, CO_2 taxation and low-carbon fuel standards, environmental zones, customer demand and expectations, corporate sustainability strategies, and evolving business models.

This suggests that HDV electrification should be seen as a socio-technical adoption problem in which several barriers and drivers interact across different dimensions and could affect the fleet operator's decision-making processes for BET adoption. BET adoption is not only determined by vehicle performance or cost-competitiveness, but is determined by the alignment of technological feasibility, economic viability,infrastructural access, organisational capability, and institutional support. Therefore, this chapter illustrates that the literature points to one central insight: successful electrification of HDVs requires addressing interrelated barriers to mitigate the effect of adoption barriers, while simultaneously embracing policy, market and organisational drivers that enable acceleration of BET adoption.

Table 4.1: Overview of barriers and drivers with sources.

Category	Barrier/driver	Source
Economic	High upfront investment costs	Luman, 2026; Mareev et al., 2018; Nykvist and Olsson, 2021; Sugihara et al., 2023; Suneson et al., 2025
	Total Cost of Ownership uncertainty	Basma and Rodríguez, 2023; Danielis et al., 2025
	Financial risk and market uncertainty	AllChiefs, 2025; Brito, 2022; Suneson et al., 2025
Technological	Limited driving range	Khani and Emami, 2022; Link and Plötz, 2022; Nykvist and Olsson, 2021
	Battery weight and payload reduction	Khani and Emami, 2022; Mareev et al., 2018; Sader et al., 2025
	Charging time	Konstantinou and Gkritza, 2023b; Nykvist and Olsson, 2021; Otero-Palencia et al., 2026
	Technological uncertainty	Basma and Rodriguez, 2022; Müller, 2024; Nykvist and Olsson, 2021; Roman and Zadek, 2024; Scherrer et al., 2026
Infrastructure	Limited public charging infrastructure	ACEA, 2025; International Energy Agency, 2025; Konstantinou and Gkritza, 2023b; Shoman et al., 2023a; Shoman et al., 2023b; Speth et al., 2025
	Electricity grid capacity & operation	Bernard et al., 2022; International Energy Agency, 2025; Karsten et al., 2023; Then et al., 2025
	Private depot charging infrastructure	Bernard et al., 2022; Engelhardt et al., 2023; Hacker et al., 2023; Shoman et al., 2023a; Sugihara et al., 2023
Operational	Complexity of mixed fleets	Bakker et al., 2025; Melander et al., 2022; Otero-Palencia et al., 2026; Özlü and Çelebi, 2024
	Route planning constraints	Amiri et al., 2023; Cheng and Lin, 2024
	Operational reliability	Basma et al., 2021; Corguillé et al., 2025; Khani and Emami, 2022; Link and Plötz, 2022; Mareev et al., 2018; Sader et al., 2025
Organisational and behavioural	Lack of knowledge and experience	Axsen and Pickrell-Barr, 2024; Konstantinou and Gkritza, 2023a; Sugihara et al., 2024
	Lack of social proof	Axsen and Pickrell-Barr, 2024; Foda and Mohamed, 2026
	Corporate strategy and motivation	Axsen and Pickrell-Barr, 2024; Gillström et al., 2024; Melander et al., 2022
	Customer demands and expectations	Foda and Mohamed, 2026; Melander et al., 2022
	Business model innovation	Gillström et al., 2024
Institutional and policy	Regulatory uncertainty	Ïmre et al., 2021; Raoofi et al., 2025
	Subsidies and fiscal incentives	Axsen and Pickrell-Barr, 2024; Leung and Peace, 2020; Melander et al., 2022
	CO_2 taxation and low-carbon fuel standards	Foda and Mohamed, 2026; Ïmre et al., 2021; Raoofi et al., 2025
	Environmental zones	Ïmre et al., 2021; Melander et al., 2022; Mirhedayatian and Yan, 2018

5

Empirical Insights on Barriers, Drivers, Decisions, and Transport Dimensions

The previous chapters developed a literature-based understanding of the adoption barriers and drivers, the decisions within BET decision-making, and the transport dimensions. However, the decision-making process of fleet operators cannot be fully understood from literature alone. BET adoption takes place in a rapidly emerging environment. Therefore, empirical insights are needed to understand how fleet operators experience BET decision-making in practice.

The purpose of this chapter is to show how respondents in the semi-structured interviews experience BET adoption, which barriers and drivers they identify, which decisions they consider relevant, and how they distinguish between transport operations when assessing BET feasibility. This results in the empirical foundation of this study. The interview material has been coded around three themes: adoption barriers and drivers, BET procurement decisions, and transport dimensions. During the coding process, additional themes were added when respondents discussed decisions, barriers & drivers, and transport dimensions that were not sufficiently captured by the initial codebook. These additions are important because they show where the interview material provides empirical insights regarding the experiences and organisation of BET procurement by fleet operators.

The interviews in this chapter are used to show the empirical coding process in a transparent way and to indicate which themes were observed in each interview. The interpretation in this chapter is based on the content of the interview transcripts and the way respondents connect barriers, drivers, decisions, and transport dimensions to BET procurement based on their practical experiences.

Section 5.1 presents the coding overview and explains which empirical themes were observed in the interview material. Section 5.2 groups the observed barriers and drivers into empirical clusters and discusses how respondents described these barriers and drivers. Section 5.3 presents the BET procurement decisions that emerged from the interviews and structures them within the strategic, tactical, and operational levels. Section 5.4 discusses how respondents described transport heterogeneity and which operational dimensions they use during the feasibility assessment of BET deployment.

5.1. Coding overview

The interview material was analysed by coding the transcripts around three main empirical themes: adoption barriers and drivers, BET procurement decisions, and transport dimensions. The coding process defined in Chapter 2 was used to structure the interview material and identify recurring themes in how respondents described BET adoption in practice. To make transparent which empirical themes were observed in the interview data, Tables 5.1, 5.2, 5.3, and 5.4 present the coding overview.

Table 5.1 presents the adoption barriers observed during the interviews, with the number of respondents (out of 14) who raised each barrier. This breadth measure is reported as this indicates how widely a barrier is shared across respondents and is less sensitive to how extensively an individual respondent spoke. The barriers cover economic, technological, infrastructure, operational, organisational & behavioural, and institutional & policy barriers of BET adoption. These barriers may delay decisions, limit feasibility, increase uncertainty, or prevent fleet operators from adopting BETs. The economic, technological and infrastructure barriers were raised by nearly all respondents, while operational and behavioural barriers such as the complexity of mixed fleets and a lack of social proof were mentioned by a smaller group.

Table 5.1: Adoption barriers across interviews (X = elaborated in interviews) 1= OEM, 2= consultant, and 3-14= fleet operator

Item	1	2	3	4	5	6	7	8	9	10	11	12	13	14	n
Financial risk and market uncertainty	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
High upfront investment costs	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
Total Cost of Ownership uncertainty		X	X	X	X	X	X	X	X	X	X	X	X	X	13
Battery weight and payload reduction	X	X		X	X	X		X			X	X	X	X	10
Charging time	X	X	X		X	X	X	X	X	X	X	X	X	X	13
Limited driving range	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
Technological uncertainty	X	X	X		X	X	X	X	X	X	X	X	X	X	13
Electricity grid capacity		X	X	X	X	X	X	X	X	X	X		X	X	12
High investment in private charging infrastructure		X	X	X	X	X	X	X	X	X	X	X	X	X	13
Limited public charging infrastructure	X	X	X	X	X	X	X	X	X	X	X		X	X	13
Complexity of mixed fleets							X				X		X		3
Operational reliability			X			X	X	X	X	X	X	X		X	9
Route planning constraints	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
Business model innovation			X	X					X					X	4
Corporate strategy and motivation	X	X			X	X	X	X	X	X	X	X	X	X	12
Customer demands and expectations	X			X	X	X	X	X	X	X	X	X	X	X	12
Lack of knowledge and experience	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
Lack of social proof	X						X	X	X	X	X		X	X	8
Regulatory uncertainty					X	X			X	X	X		X	X	7

Table 5.2: Adoption drivers across interviews (X = elaborated in interviews) 1= OEM, 2= consultant, and 3-14= fleet operator

Item	1	2	3	4	5	6	7	8	9	10	11	12	13	14	n
Total Cost of Ownership		X	X	X	X	X	X		X	X	X	X	X	X	12
Growing availability of public charging		X			X	X		X		X			X	X	7
Business model innovation		X	X		X	X	X		X	X	X	X	X	X	11
Corporate strategy and motivation	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
Customer demands and expectations	X	X		X	X	X	X	X	X	X	X	X	X	X	13
Growing knowledge & experience	X	X			X	X	X			X	X	X	X	X	10
Less dependence on fossil fuels		X	X	X	X	X	X				X	X	X	X	10
CO_2 taxation and low-carbon fuel standards		X			X	X	X			X	X		X	X	8
Environmental zones		X		X	X	X		X	X		X	X	X		9
Subsidies and fiscal incentives	X	X		X	X	X	X	X	X		X			X	10

Table 5.2 presents the adoption drivers observed in the interviews, again expressed as the number of respondents who raised each driver. These drivers represent factors that respondents associated with increasing the attractiveness, urgency, or feasibility of BET adoption. The drivers are separated into economic, infrastructure, organisational & behavioural, and institutional & policy themes. Similar to the barriers, these drivers are not interpreted as ranked factors, but as empirical themes that emerged from the interview material. The breadth values show that some drivers, such as corporate strategy and customer demands, were shared across almost all respondents, whereas others, such as environmental zones and CO_2 taxation, were raised by a more specific group.

Table 5.3 presents the BET procurement decisions observed in the interviews. The table shows which decisions were discussed and by how many respondents, rather than how often they appeared in the material. This breadth analysis indicates that BET adoption was not discussed as a single procurement decision, but as a broader set of interrelated decisions that extend beyond vehicle replacement alone, with most decisions raised by nearly all respondents. During the coding process, three additional decisions emerged from the interviews that were not included in the initial codebook: 1) workforce training and routine adaptation, 2) energy and peak-load management, and 3) transport and charging network configuration. Therefore, the initial codebook was adapted by adding these inductively identified decisions.

Table 5.3: BET procurement decisions across interviews (X = elaborated in interviews) 1= OEM, 2= consultant, and 3-14= fleet operator

Item	1	2	3	4	5	6	7	8	9	10	11	12	13	14	n
BET implementation pathway	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
Business model adaptation	X				X		X		X		X	X		X	7
Capability sourcing & partnership	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
Charging strategy	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
Contract and risk-sharing					X	X	X		X	X	X	X	X	X	9
Customer-route allocation	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
Daily BET routing & scheduling	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
Daily charging scheduling	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
Depot charging infrastructure design		X	X	X	X	X	X	X	X	X	X	X	X	X	13
Energy & peak-load management	X		X		X	X	X	X	X	X	X		X		10
Fleet transition & integration	X	X	X	X	X	X	X	X	X	X	X		X	X	13
Payload & load allocation	X	X		X	X	X	X	X	X		X	X	X	X	12
Route selection for BET deployment	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
Transport & charging network configuration		X	X		X	X	X	X	X		X	X	X	X	11
Workforce training & routine adaptation	X				X		X		X		X	X		X	7

Table 5.4: Transport dimensions across interviews (X = elaborated in interviews) 1= OEM, 2= consultant, and 3-14= fleet operator

Item	1	2	3	4	5	6	7	8	9	10	11	12	13	14	n
Route predictability	X	X	X		X	X	X		X	X	X	X	X	X	12
Return-to-base frequency		X	X	X	X	X	X	X	X	X	X	X	X	X	13
Fuelling/charging control	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
Daily distance	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
Payload sensitivity	X	X		X	X	X		X			X	X	X	X	10
Planning flexibility	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
Utilisation intensity	X	X	X		X	X	X		X	X	X		X	X	11

Table 5.4 presents the transport dimensions observed in the interviews, with the number of respondents associated with each dimension. These characteristics were used to analyse how respondents differentiate between short-haul, line-haul, and long-haul transport. The interview material indicates that BET feasibility is related to distance, route predictability, return-to-base frequency, payload requirements, fuelling/charging control, and operational flexibility. Compared to the preliminary dimensions defined in Section 3.2, planning flexibility and utilisation intensity were identified during the interviews and have been added to the initial codebook.

Overall, the coding overview shows that the interview material provides empirical input on all four themes of this chapter: barriers, drivers, BET procurement decisions, and transport dimensions. Reporting breadth, the number of respondents who raised each theme, shows that most themes were shared across nearly all respondents, while a smaller set was raised by a more specific group. The barriers and drivers indicate which conditions respondents associate with BET adoption, while the decisions and transport dimensions show where these conditions become relevant in the fleet operator decision-making process. The coverage matrices in Tables 5.1 to 5.4 make transparent which respondent raised which theme, but breadth is not interpreted as a ranking of importance. Therefore, the coding overview forms the empirical basis for the remainder of this chapter, in which these themes are analysed in more detail.

5.2. Empirical insights on adoption barriers & drivers

The individual barrier and driver codes are useful for transparency, but they are too detailed to structure the analysis of the interview results. For the analysis, the related codes were consolidated into broader empirical barrier and driver clusters, as presented in Table 5.5. These clusters provide the structure for the discussion in this section. The table should be read as a qualitative structuring of observed interview themes. It does not imply that the clusters are statistically validated or that their relative importance can be inferred directly from the coverage across the interviews.

The clusters show that barriers and drivers do not always act separately in practice. Some factors can limit adoption in one situation and stimulate adoption in another. For example, TCO uncertainty can be a barrier when the payback period is unclear, but decreasing TCO uncertainty can become a driver when operators gain experience and cost structures become more predictable. Similarly, customer demand can stimulate adoption when customers are willing to commit to zero-emission transport, but weak customer commitment can make it difficult to justify the investment.

Barrier clusters

The financial constraints cluster is the first barrier cluster that is reflected in the interviews and addresses the following question: Can BET procurement be justified as an economically viable investment? Respondent 1 explained that companies first ask the following question: *"how much is the upfront purchase cost?"* and mentioned that *"financial aspect is the most important criterion"* in the BET procurement decision. Simultaneously, during the early stages of BET adoption, high costs are inevitable. Respondent 7 emphasised *"it is necessary to accept the learning burden of early adoption if your company is willing to be at the front of the market"*. However, respondent 7 nuanced this with the following argument: *"a whole lot of extra money upfront is needed, even though the TCO is improving"*. The BET transition is highly cost driven, according to respondent 5. The respondent elaborated that costs are rising due to kilometre charging, rising diesel costs, European levies, zero-emission zones, and subsidies. In conclusion, the interviews revealed that financial viability is not only the outcome of a cost calculation per vehicle, but also depends on the investment attitude of the fleet operator. Several respondents treated the purchase of a BET not as a one-to-one, cost-driven replacement of a diesel truck, but as a strategic investment that they were willing to make ahead of a fully proven business case. This attitude includes accepting early losses, learning costs, and uncertainty about residual values as the price of positioning the company for an electric future and building operational experience. Financial viability is therefore shaped both by the calculated costs of a BET and by the operator's willingness to bear the risk of investing before the business case is certain.

The second barrier cluster is charging and energy constraints. The charging and energy barriers appear not only as a technical bottleneck but also as a sequencing challenge. Respondent 1 described this situation as a *"chicken and egg problem"* where trucking companies argue that there are no chargers, while charging companies argue that there are no trucks. Respondent 2 added that routes with private charging opportunities are easier and cheaper to electrify than those that depend on public charging infrastructure. Respondent 5 placed this barrier in a broader perspective by arguing that electricity may become the main barrier after 2030 as the business case becomes more viable. Finally, respondent 9 mentioned that electricity will be central in the future transport system because it is less geopolitically dependent compared to other fuels. Taken together, the interview insights support the interpretation that the charging and energy constraints cluster is one of the main barrier clusters affecting BET decision-making, which can make BET deployment feasible or infeasible.

The third barrier cluster merges technological and operational barriers into the technological and operational mismatch cluster. This cluster is connected to the following question: Can a BET execute a route, load pattern, and achieve an expected service level? Respondent 1 mentioned this during the interview by asking: *"when to charge, where to charge, how much to charge ... how long can I drive, how much can I carry?"*. Respondent 2 argued, from the corridor-based and international transport per-

Table 5.5: Interview-based barrier and driver clusters derived from observed barriers and drivers

Barrier/driver cluster	Observed barriers/drivers	Interpretation in the interview data
B1 Financial constraints	High upfront investment costs Financial risk and market uncertainty TCO uncertainty	Respondents framed BET procurement as difficult when investment costs, uncertain payback periods, or unclear TCO outcomes make adoption financially risky.
B2 Charging & energy constraints	Electricity grid capacity Limited public charging infrastructure High investment in private charging infrastructure	Respondents described charging availability, depot capacity, and grid constraints as conditions that determine whether BET deployment is feasible.
B3 Technological & operational mismatch	Limited driving range Charging time Battery weight/payload reduction Technological uncertainty Route planning constraints Operational reliability	Respondents often discussed technical and operational limitations together, especially when assessing whether BETs can perform specific routes, loads, and service requirements.
B4 Organisational readiness gaps	Lack of knowledge and experience Lack of social proof	Respondents indicated that limited internal experience and the absence of proven examples in similar operations reduce their confidence in BET adoption.
B5 Transition management uncertainty	Regulatory uncertainty Mixed-fleet complexity	Respondents described the transition period as difficult because diesel and electric trucks need to be managed simultaneously while external conditions remain uncertain.
D1 Customer market pull	Customer demands and expectations	Respondents described customer demand as a potential trigger for electrification, especially when customers are willing to discuss zero-emission transport or long-term commitments.
D2 Strategic & business motivation	Corporate strategy and motivation Business model innovation	Respondents linked BET adoption to strategic positioning, sustainability ambitions, and the development of new service propositions.
D3 Fiscal & regulatory incentives	Subsidies and fiscal incentives CO_2 taxation and low-carbon fuel standards Environmental zones	Respondents described policy instruments as factors that can improve the business case or increase pressure to adopt BETs.
D4 Growing transition readiness	Growing knowledge and experience Less dependence on fossil fuels Decreased TCO uncertainty Growing availability of public charging	Respondents indicated that adoption becomes more realistic as knowledge, infrastructure, and market maturity improve.

spective, that long and less predictable routes remain challenging to electrify due to limited charging availability, range constraints, and poor alignment of logistics requirements. A fleet manager (interviewee 10) noted that there is still no planning system that integrates range constraints, indicating that planners and drivers experience operational challenges in practice. Together, these interviews show that technological and operational fit is not only about truck specifications, but about the interaction between truck capabilities, route structures, and planning practices.

The fourth barrier cluster concerns organisational readiness gaps. These gaps do not primarily trigger or prevent the initial consideration of BETs, but they affect whether organisations are able to implement BETs in daily operations. This is explicitly mentioned by respondent 1, who argued that truck drivers need to feel comfortable with the truck and require training to be able to *"drive the new technology, charge, and adapt to new routines"*. This argument is supported by respondent 7, who added the governance structure to this cluster. Respondent 7 argued that BET decisions in the company are made jointly by a three-person director team, indicating that organisational readiness also concerns the decision-making structure through which complex and uncertain decisions are evaluated, rather than leaving such decisions to individuals. Respondent 10 mentioned that after the procurement decision has been made, daily operational decisions are handled by planners and drivers. These examples reveal that the readiness of organisations and individuals could limit the adoption of BETs in their operations.

The fifth barrier cluster is transition management uncertainty. Respondent 5 argued that scale, battery technology, and market development are uncertain. This indicates that the time horizon of BET investments is hard to predict. Respondent 9 was willing to buy a BET *"to be prepared in advance"*, while still framing the decision as a financial gamble under uncertainty, with long-lasting lead times and dependencies on subsidies. Respondent 12 translated this challenge into concrete decision-making, as the company first needs a commitment from customers to support the business case before deploying BETs. This sequence reveals that companies experience uncertainty during the transition and therefore prefer small, customer-contract-based roll-outs of BETs over large-scale deployment.

Driver clusters

Customer market pull is the first identified driver cluster. This driver cluster acts as a trigger that turns an electrification ambition into actual demand for BET replacement. This is directly stated in interview 12, where the respondent argued that early adoption has emerged from customer demand and that client commitment is needed before BETs become feasible. Respondent 6 elaborated that customers, over time, are becoming more willing to pay a premium because BETs are visible and fit into their sustainability strategies. Respondent 9 argued from a different perspective, as they used their first truck *"as a piece of marketing"* towards their customers and noted that clients *"definitely had that demand"*. These examples show that customer demand is not just a small driver; it is a mechanism that reduces the risks of BET adoption and turns strategy into financially viable opportunities.

The second driver cluster is strategic and business model motivation. This cluster reflects the internal motivation of fleet operators to move early to differentiate, learn, and redesign their strategy. Respondent 7 supported this interpretation as the company aims *"to be at the front of the market"* and sees early adoption as an opportunity to achieve *"a head start in knowledge"*. The director in interview 9 reinforced this argument. The company bought a BET, not only due to the subsidy, but *"to be prepared in advance, to gain experience with the technology, and to show customers that the company is ready for electric transport"*. Even cost-driven companies see differentiation, marketing value, and future positioning as legitimate reasons to support their sustainability motivation (interview 5). These examples demonstrate that strategic motivation is not only driven by customer demands or policy support. The ambition to electrify trucks can also stem from first-mover positioning, internal ambition, and repositioning of business models.

The third cluster is fiscal and regulatory incentives. This cluster summarises different policies and regulatory environments that stimulate truck electrification. During the interview with respondent 2, the effects of this cluster were discussed in the Dutch context. The respondent explained that zero-emission zones create markets in which electrification becomes unavoidable for city logistics, retail, service logistics, and construction flows. Respondent 5 argued that the government steers the transition through kilometre charging, diesel excise, European levies, subsidies, and environmental zones. Respondent 6 linked the company's sustainability goals to policy pressure to decarbonise transport. Finally, respondent 9 revealed how subsidies can directly affect procurement decisions by stating: *"if you can get the AanZET subsidy, then you really have to do it"*. Overall, these interviews show that policies and regulations not only lower costs but also push the transition forward by increasing urgency and time pressure to accelerate the transition.

The fourth driver cluster is growing transition readiness. This cluster reveals that BET adoption becomes more realistic when knowledge, infrastructure, technology, and markets become more mature. According to the interviews, practical experiences reduce uncertainty and improve confidence to adopt BETs. Respondent 1 explained that *"if they have tested the product, it is more likely that they will* *choose the product to test it more or even try to include it in the operations"*. This indicates that transition readiness grows through pilots and learning-by-doing. Respondent 2 described this development at the market level, arguing that the adoption curve is becoming steeper and that *"more and more markets will emerge where electric transport becomes attractive over the full vehicle lifetime"*. Similarly, Respondent 5 argued that charging during routes is becoming less constraining because *"the range is increasing and the availability of charging infrastructure is improving"*. These findings show that transition readiness does not stimulate adoption in the same way as customer demand or regulation, but it reduces uncertainty and improves the enabling conditions for BET deployment. Therefore, this driver cluster supports adoption by making the transition increasingly familiar, technically feasible, and economically viable for fleet operators.

5.3. Empirical insights on BET decision-making

The previous section grouped the observed barriers and drivers into empirical clusters. This section shifts the focus to the decisions that respondents associated with BET procurement in practice. The interview material shows that fleet operators do not describe BET adoption as a single purchasing decision, but as a set of strategic, tactical, and operational decisions that must be addressed throughout the transition process. In addition to the predefined decisions (Chapter 3), the interviews highlighted three new decisions in the BET procurement process: 1) transport & charging network configuration, 2) energy & peak-load management, and 3) workforce training & routine adaptation. Table 5.6 shows an overview of the decisions observed during the interviews. These decisions are categorised according to the strategic, tactical, and operational levels to show how respondents framed BET procurement across decision-making levels.

Strategic decisions

Business model adaptation emerged as a relevant decision during the interviews. The design and restructuring of business models is important because it demonstrates that BET adoption is not merely experienced as a truck selection problem. Instead, BET procurement is experienced as a question of how economic feasibility can be achieved without losing the economic structure of current diesel-based operations. This is emphasised by respondent 12, who explained that BETs are more expensive and therefore require commitment from customers. This commitment is needed to achieve a positive business case, a key condition before purchasing BETs. This argument is supported by respondent 9, who mentioned: *"if the market demand is not there, we will not do it"*. Even the early adopters (respondent 7) who want to remain at the forefront of the market, argued that a strong business case is necessary to justify the high upfront costs. Overall, these interviews show that business models need to shift to justify BET procurement, as the business models should align with external demand, internal ambition, and cost structures.

Another decision is charging strategy, which concerns not only where to charge but also how dependent the fleet operator will be on public charging, depot charging, or customer site charging. This decision affects the degree of control a fleet operator has over the costs and design of routes. Respondent 2 argued that routes with the opportunity to charge at the home base or on customer-sites are *"faster to electrify"* and financially more attractive compared to routes that depend on public charging. Interviewee 6 mentioned that the fleet operator's strategy is to charge *"as much as possible on our own sites and only use public charging if that is the only possibility to charge"*. This preference is driven by the high cost of public charging infrastructure, which weakens the business case. Overall, charging strategy focuses on how BETs should be charged to support the business models and corporate visions.

Contract and risk-sharing is related to business model adaptation. The operations of BETs are characterised by charging dependence, high upfront costs, uncertain utilisation patterns, and rapidly evolving technology. Compared with diesel trucks, this creates additional risks for fleet operators that must be allocated contractually. This is challenging under the existing contract structures of fleet operators, as emphasised by respondent 10: *"there is currently no room in those contracts"*. This suggests that fleet operators must account for these additional costs and risks themselves. Respondent 7 argued that long-term contracts are needed, as BETs are tied to long-term high financial risks and require secured utilisation. Additionally, respondent 9 elaborated that truck electrification becomes more realistic when

Table 5.6: Overview of BET procurement decisions observed in the interview material and literature

Decision	Decision level	Meaning of the decision	Derived from	Academic sources	Change relative to diesel procurement
Business model adaptation	Strategic	Decide how the business model should adapt or extend to fit the BET context, including changes in cost structures, pricing, revenue opportunities, and value creation.	Literature and interviews	Özlü and Çelebi, 2024; Sugihara et al., 2024	BET-specific added decision
Charging strategy	Strategic	Decide how charging will be organised, including depot charging, public charging, charging at customer sites, or partnerships.	Literature and interviews	Sugihara et al., 2024; Karam and Rich, 2025; Kin et al., 2021	BET-specific added decision
Contract and risk-sharing	Strategic	Decide how contracts can be aligned with long investment periods, adjusted service levels, charging-related agreements, pricing models, cost-sharing structures, and new partnerships.	Literature and interviews	Synthesis of this section	BET-specific added decision
BET implementation pathway	Strategic	Decide the pace and scale of adoption, such as pilot deployment, phased roll-out, or broader replacement.	Literature and interviews	Sugihara et al., 2024	BET-specific added decision
Capability sourcing and partnership	Strategic	Decide whether internal capabilities, including knowledge, resources, and information, are sufficient or whether external support and partnerships are needed.	Literature and interviews	Bae et al., 2022; Konstantinou and Gkritza, 2023a	BET-specific added decision
Depot charging infrastructure design	Strategic	Decide how charging infrastructure is designed and implemented at private facilities, including layout and grid capacity.	Literature and interviews	Sugihara et al., 2024; Karam and Rich, 2025	BET-specific added decision
Transport & charging configuration	Strategic	Decide how to align own routes, hubs, and depots with accessible charging, including own, partner, and selected public charging points, within the operator's control rather than the public charging rollout.	Interviews	–	BET-specific added decision
Route selection for BET deployment	Tactical	Decide which routes and duty cycles are suitable for BETs based on range, payload, and charging possibilities.	Literature and interviews	Sugihara et al., 2024; Petroni and Getachew, 2025	BET-specific added decision
Customer-route allocation	Tactical	Decide which customers, routes, and transport profiles can be allocated to BETs based on range, payload, charging availability, contractual conditions, and service requirements.	Literature and interviews	Petroni and Getachew, 2025	BET-adapted existing decision
Fleet transition & integration	Tactical	Decide how the fleet is transitioned to BETs and integrated with the existing diesel fleet, including the number and type of BETs, replacement timing, vehicle availability, and maintenance.	Literature and interviews	Konstantinou and Gkritza, 2023a	BET-adapted existing decision
Energy & peak-load management	Tactical	Decide how electricity, charging demand, peak loads, and energy costs are managed.	Interviews	–	BET-specific added decision
Payload & load allocation	Operational	Decide how freight is distributed across vehicles while accounting for battery weight and reduced payload capacity.	Literature and interviews	Özlü and Çelebi, 2024	BET-adapted existing decision
Daily charging scheduling	Operational	Decide how charging is integrated into daily operations.	Literature and interviews	Sugihara et al., 2024; Karam and Rich, 2025; Cheng and Lin, 2024	BET-specific added decision
Daily BET routing & scheduling	Operational	Decide on daily planning and schedules while taking BET range, charging time, driver rest periods, truck planning, and trailer planning into consideration.	Literature and interviews	Karam and Rich, 2025; Cheng and Lin, 2024; Amiri et al., 2023	BET-adapted existing decision
Workforce training & routine adaptation	Operational	Decide how drivers, planners, and other employees are trained to work with BETs and how routines are adapted.	Interviews	–	BET-specific added decision

Note. "Derived from": "Literature and interviews" = literature-based (found in the literature, confirmed in the interviews); "Interviews" = emerged from the interviews only. "Change relative to diesel procurement": BET-specific added = new to procurement; BET-adapted existing = already in diesel procurement but changed by BET constraints (e.g., range, charging, payload, grid capacity).

BETs can be placed under fixed multi-year client contracts. This means that contract redesign cannot be addressed after a truck has been purchased, but is itself a strategic choice that creates the financial foundation needed to stabilise the business models.

Another strategic decision is the BET implementation pathway, as fleet operators do not simply decide whether to electrify, but also at what pace, scale, and with how much learning and risk. This is captured by respondent 6 during the interviews as the interviewee positioned themselves as *"smart follower"*, allowing them to move early enough to learn and remain relevant to customers. The scaling logic is elaborated by respondent 5, as the fleet operator mentioned that the implementation of the first BET is easier compared to the second and third. The first BET may still fit within the existing grid connection, whereas scaling can create additional challenges in charging infrastructure and investment budgets. Respondent 11's company formulated a different approach, where the company followed a structured sequence by outlining conditions for adoption: *"first make sure you have electricity and customers, then make a plan for the future, then start with a few trucks and a few chargers, and then pay learning money"*. These interviews revealed that the implementation pathway is a strategic decision, as it structures the company's transition pathway and determines how barriers and drivers are encountered during the implementation.

Capability sourcing & partnership is a strategic decision, as successful BET adoption requires fleet operators to determine whether they have sufficient internal knowledge, resources, and coordination capacity, or whether external support (partnerships) is needed. The interviews showed that electrification is handled by different departments across the organisation. Respondent 3 explained that *"different functions are involved across the decision-making"*. Similarly, respondent 6 argued that internal coordination is needed between sustainability, fleet management, commercial departments, and operations. This indicates that knowledge could be divided across the organisation and that internal coordination is needed. External partnerships are crucial to increase the potential of BETs. Respondent 5 described that the OEM did *"more than just sell a vehicle, as they transferred knowledge"*. Interviewee 7 even entered a partnership to increase charging opportunities. These interviews revealed that capability development and partnerships are not only supportive decisions, but determine the feasibility of BET adoption for organisations by organising knowledge, internal coordination, and needed external relationships.

If fleet operators decide to use private charging, BET deployment depends on whether sufficient private charging capacity can be secured. Therefore, depot charging infrastructure design is a relevant decision. Respondent 4 linked vehicle procurement to infrastructure by arguing: *"if you start with those trucks, you also have to make sure you have your charging infrastructure" and that "buying trucks if you cannot charge them is not smart".* This shows that depot charging infrastructure could act as a precondition for BET procurement rather than an operational issue. This is supported by respondent 6, who elaborated that they prioritise depot charging and only use public charging when there is no other option, as it *"does not support the business case"*. Interviewee 7 added a long-term perspective as the company requested *"a grid connection upgrade before we ordered the first truck"* and thereby created *"the room to grow in electric transport"*. Therefore, depot charging infrastructure investment in practice includes decisions regarding grid capacity, charging equipment, site layout, and future scalability.

The final strategic decision is transport & charging network configuration. This decision is particularly relevant for fleet operators that do not rely solely on charging at their home base but also use public charging locations across their wider network. Respondent 7 explained that the company started a joint venture to develop charging hubs in the south-east of the Netherlands and that its BETs are mainly deployed in that area. Interview 9 supported this observation, as the firm mainly uses its BET between the company hubs and customers due to limited range and capacity. Respondent 5 added that a detailed understanding of the company's routes is essential for deciding which public charging locations are relevant and where collaboration with public charging operators may reduce charging costs. Together, these interviews show that transport & charging network configuration is an enabling decision for fleet operators who have to think outside of the box due to limited charging at home bases.

Tactical decisions

Route selection for BET deployment assesses whether a BET can perform a specific route or duty cycle while maintaining service reliability. Respondent 3 framed this decision as the question, *"what is* *operationally possible with a vehicle without needing to charge too much"* while taking costs, charging infrastructure, and the operational process into account. Respondent 4 expressed a similar logic in more practical terms. The company used the advertised range of the truck and subtracted a small margin because *"the ideal world is not the real world"* to calculate the potential range. Besides, the company conducted test runs to simulate route feasibility in practice. Interviewee 12 tested the route suitability through operational experience while weighing cost, performance, and vehicle weight. Finally, respondent 13 argued that this decision involved *"puzzling out"* whether the number of kilometres driven fits the vehicle type, the activity, and the charging plan. In conclusion, this tactical decision is not merely a static technical check. It is also a decision in which transport operations are tested for suitability.

Customer-route allocation is also part of the tactical decision-making layer, as the roll-out of BETs typically occurs in stages. Fleet operators first determine which customers, routes, or transport services are suitable for BET deployment. Respondent 12 mentioned this decision explicitly, explaining that the firm first approached existing and high-potential customers, developed the business case, and then began the procurement of BETs. Interview 7 showed that the allocation of BETs to specific customers and routes is often linked to contractual agreements between the fleet operator and the customer, as the company required customer commitments before purchasing BETs. Respondent 9 argued that BET adoption becomes feasible when the truck can be assigned to a specific customer or fixed route. Interviewee 3 broadened this issue in the context of networked operations, where assigning a truck to a single route is not enough. The operator must also consider how the truck can be used beyond that single movement for the client. Therefore, customer-route allocation is tactical, as it determines the fit between strategic intentions and operational possibilities.

Fleet transition & integration is part of the tactical layer, as the implementation pathway needs to be translated into concrete choices about the fleet. This decision includes which vehicle types are procured, how many trucks are electric, which diesel trucks remain necessary, and how BET availability is secured. Respondent 6 argued that the company aims to buy BETs when it is technically, operationally, and infrastructurally feasible. The respondent mentioned that diesel trucks are still needed for specific transport activities. However, respondent 2 emphasised that fleet replacement must be spread over time to mitigate financial risk. Finally, respondent 1 linked fleet replacement to existing routines, where vehicle age and productivity determine when a new truck or technology is taken into consideration.

Although energy & peak-load management was not part of the initial codebook, it was introduced during the interviews and is therefore empirically relevant. The interviews revealed that energy & peak-load management involves actively managing contracted capacity, charging priorities, storage options, electricity prices, and the timing of demand. Respondent 11 elaborated on how they manage energy: the firm installed solar panels, a 3 MW charger, implemented an Energy Management System (EMS), and even started trading energy. According to the respondent, the main purpose of the EMS is to *"throttle as much as possible during expensive hours and only charge what is really necessary"*. Interviewee 13 supported this perspective by describing how the firm actively considers charging, storage, and timing because it operates large energy assets and flexible contracts. Respondent 1 emphasised the importance of this decision by noting that fluctuating energy prices result in charging-planning difficulties. These examples show that energy & peak-load management is a tactical decision in which infrastructure, cost, and flexibility are continuously balanced.

Operational decisions

Daily BET routing & scheduling is one of the operational decisions. Respondent 1 captured this decision during the interview by asking: *"when to charge, where to charge, how much to charge ... how long can I drive, how much can I carry?"*. The interviewee made clear that operations affect the entire business case because vehicle utilisation determines financial viability. Interviewee 10 argued that planning itself can become a barrier and that poor planning creates risks when BETs need to charge, resulting in inefficient operations and higher costs. In the transport operations of respondent 8, planners must take into account that a BET *"simply does a lot less in a day than a diesel truck"*. Once an expensive truck enters the fleet, the transport planners of fleet operator 11 start thinking about how to use the BET *"seven days a week, day and night, as efficiently as possible"*. The interviews show that daily BET routing & scheduling is not decided downstream. Instead, it is an operational decision that can determine whether the business case succeeds or fails.

Daily charging scheduling is another operational decision. Daily charging scheduling differs from charging strategy. Whereas charging strategy concerns broader choices about where to charge and under what arrangements, daily charging scheduling focuses on the concrete planning and scheduling of charging moments for specific trucks. This distinction is emphasised by interviewee 2, as the respondent linked rest times, depot returns, and route structures to actual charging plans. Respondent 5 argued that national route planning becomes possible when the planner knows which charging locations can support the operation. Interview 13 reinforced this point by explaining that operators have to *"plan charging into the route and therefore plan differently than diesel planning"*. Daily charging plans belong to the operational layer because they translate transport strategy into the day-to-day execution of operations.

Payload & load allocation is empirically relevant for operational decision-making. Due to the weight of BETs' battery, operations become more vulnerable to payload limits, axle distribution constraints, and the interaction between payload and range. Respondent 11 emphasised that transport planners have to monitor weight distribution more closely than they would for diesel trucks because the payload capacity is reached more quickly. The fleet operators in interviews 7 and 11, who both transport heavy goods such as building materials and garden tiles, experience restrictions related to payload capacity and therefore pay close attention to vehicle load plans. However, respondent 5 nuanced this problem, as this company is not experiencing load restrictions because the goods it transports are relatively light. In that sense, this is not an entirely new decision but one whose importance increases because payload capacity is reached earlier due to battery weight. Whether this decision is relevant depends strongly on the transport profile and the goods being transported by the fleet operator.

The final operational decision concerns workforce training & routine adaptation. This decision matters, as electric transport requires changes in routines for both drivers and planners. Respondent 1 directly noted that drivers need to be able to use the new technology. The fleet manager in interview 10 argued that the trucks represent a completely new technology and that drivers must understand this technology to maximise range. Besides, this fleet manager pointed out that current support systems do not yet incorporate range into transport planning, which means that planners need to be educated on how to work with BETs. Finally, respondent 5 argued that, even when payload is not a major challenge, *"the driver still needs to know how to handle weight"*. Therefore, workforce training & routine adaptation is an operational decision that supports the effective functioning of the other operational decisions.

Influence of organisation type

The interviews also show that the type of organisation shapes how the BET decision-making process unfolds. Smaller and family-owned operators can often decide quickly, because decisions are made more directly and fewer departments are involved. Larger organisations tend to follow a more formal process in which several departments, such as fleet management, operations, finance, procurement, and sustainability, are involved. As a result, the speed of decision-making, the order in which decisions are logically taken, and the amount of internal alignment required differ from one company to another. This organisational context is illustrated in Boxes 5.1 and 5.2.

Box 5.1 : Smaller and family-owned operators: direct decision-making

"There are now three owners: my uncle, my father and another uncle. Big investments we discuss together. Every investment is a small strategic choice."

(Respondent 5)

"It lies with us, with our whole family. […] At the kitchen table we discuss these things, and that is where the decision is made."

(Respondent 8)

Box 5.2: Larger organisations: formal, multi-department process

"If you draw the picture, there is really no department that it does not affect."

(Respondent 6)

> *"The core decision was with fleet and sustainability. […] Ultimately such a strategy must be presented to the management board and approved."*
>
> (Respondent 3)

5.4. Empirical insights on transport profile heterogeneity

The previous section discussed the interview findings on BET procurement decisions. This section shifts the focus to how respondents described differences between transport operations when assessing the suitability of BETs. In Chapter 3, five preliminary operational dimensions were identified from the literature and used as initial sub-codes during the interview coding process: route predictability, return-to-base frequency, fuelling/charging control, daily distance, and payload sensitivity. During the coding process, two additional dimensions were identified from the interviews: planning flexibility and utilisation intensity. Together, these seven dimensions provide a more empirically grounded understanding of transport profile heterogeneity in the context of BET adoption.

These seven dimensions should be interpreted as operational input variables that shape the conditions under which BET adoption becomes more or less feasible. Rather than representing decisions, the dimensions function as variables that differ across transport scenarios. For example, one transport operation may combine high route predictability, frequent return-to-base, and strong fuelling/charging control, while another operation may involve longer daily distances, low fuelling/charging control, and high payload sensitivity. It is the specific combination of these dimensions that defines the boundary conditions and adoption potential for BETs in a given transport context.

This also means that the dimensions should not be treated as static transport characteristics that apply in the same way to diesel-truck operations. In diesel transport, many of these variables are less restrictive because refuelling infrastructure, refuelling time, and operational routines are already well established. In BET transport, however, these same variables become more critical for feasibility because they influence whether charging can be integrated into the operation, whether the vehicle can complete the route, and whether the business case remains viable. As Respondent 1 explained, diesel operations often allow operators to *"pump the diesel, and then you go on and on", whereas electric operations require operators to consider "when to charge, where to charge, how much to charge ... how long can I drive, how much can I carry?"*. Therefore, the seven dimensions together do not describe a decision outcome, but the operational context that shapes the potential for BET adoption and informs the subsequent decision-making process. Table 5.7 provides an overview of the transport dimensions observed in the interview material.

Route predictability refers to the extent to which routes, schedules, and customer flows are recurring and known in advance. The interviews confirm that predictable operations are easier to electrify as the energy demand, charging moments, and vehicle deployment can be taken into consideration before the route is executed. Respondent 11 explained that electric trucks are deployed on *"fixed routes where we are reasonably sure that we will arrive at a charging location where we can recharge"*. This shows that route predictability is not only about whether the distance is short or long, but about whether the operator knows in advance where the vehicle will be, when it returns, and where charging can take place. Respondent 2 similarly indicated that fixed shuttle operations are favourable because *"if you have fixed shuttles, you can have your charging infrastructure on your own site, you are not dependent on public charging, and you can make many kilometres"*. Route predictability, therefore, acts as a key input variable: when predictability is high, the operational uncertainty of BET deployment decreases. When predictability is low, the same vehicle technology becomes more difficult to integrate.

Return-to-base frequency describes how often a vehicle returns to a depot, terminal, or another location where the operator can arrange charging. The interviews show that a high return-to-base frequency improves BET adoption potential because charging can be connected to existing depot operations. Respondent 2 stated that *"routes where you return, or at least can charge at your own locations, are faster to electrify and economically more attractive than routes where you have to charge on the road"*. Respondent 6 provided a similar example by explaining that their distribution vehicles *"return every day to our sites"*, allowing the company to organise charging at its own locations. This dimension, therefore, functions as an important boundary condition. A transport operation with frequent depot

Table 5.7: Empirical overview of transport heterogeneity dimensions based on interview findings and literature

Transport dimension	Meaning of the dimension	Derived from	Academic sources
Route predictability	Degree to which routes, customer flows, and schedules are predictable and repetitive.	Literature and interviews	Amiri et al., 2023
Return-to-base frequency	Degree to which vehicles return to a depot, terminal, or other controlled charging location.	Literature and interviews	Speth and Plötz, 2024
Fuelling/charging control	Degree to which the operator can control the location, timing, availability, and cost of fuelling/charging.	Literature and interviews	Karam and Rich, 2025
Daily distance	Degree to which the daily distance fits within vehicle range, charging windows, and operational time constraints.	Literature and interviews	Zgonc et al., 2019; Cheng and Lin, 2024
Payload sensitivity	Degree to which battery weight and payload requirements affect operational feasibility.	Literature and interviews	Amiri et al., 2023
Planning flexibility	Degree to which planning routines can be adapted to BET-specific constraints.	Interviews	–
Utilisation intensity	Degree to which the vehicle must be used to make the business case viable.	Interviews	–

Note. ”Derived from”: ”Literature and interviews” = literature-based (found in the literature, refined in the interviews); ”Interviews” = emerged from the interviews only (planning flexibility and utilisation intensity)

returns creates more opportunities for private charging, lower charging costs, and controlled planning. A transport operation with limited return-to-base frequency becomes more dependent on public or third-party charging, which increases uncertainty.

Fuelling/charging control concerns the degree to which fleet operators can control where, when, and under which conditions the truck is charged. Overall, respondents preferred private or customer site charging over public charging, as these provide more certainty about availability, costs, and operational integration. Respondent 6 explained: *”we try to charge as much as possible on our own site. If a route cannot be completed, we also have the possibility to charge with third parties, but as little as possible, because that does not help the business case”*. Respondent 11 similarly mentioned that *”everything is charged at home, so on our own location”* and explained that the company originally calculated with *”92 to 95% charging on own locations and only 5% on the road”*. These examples show that fuelling/charging control is one of the most critical dimensions for BET feasibility. When charging is controlled by the operator, it can be planned as part of the transport operation. When charging depends on public infrastructure, the operation becomes more vulnerable to uncertainty, higher costs, and possible waiting times.

Daily distance was confirmed as an important dimension, but the interviews show that it should not be interpreted as a simple distance condition. Distance becomes constraining in combination with vehicle range, charging opportunities, time windows, and the predictability of the route. Respondent 5 gave a clear example from an early BET assessment: *”we drove about 220 kilometres per day for that contract. That electric truck could only drive 110 kilometres per day”*. The same respondent explained that this was problematic because the truck was *”roughly twice as expensive in cost price, while it only did half the work”*. However, the same interview also shows that this dimension changes over time as vehicle range improves. For a newer vehicle, Respondent 5 assessed routes that should reach *”about 500 kilometres per day”*. Daily distance should therefore be understood as a dynamic input variable rather than a fixed condition. Its effect depends on the combination of route predictability, fuelling/charging control, number of stops, and available charging time.

Payload sensitivity refines the preliminary literature-based dimension of payload sensitivity. The interviews show that the relevance of payload depends strongly on the weight characteristics of the transported goods. In weight-sensitive transport, the battery weight of BETs can directly reduce operational feasibility. Respondent 8 explained that with a normal trailer, the company could load *”about three to four tonnes less than with a normal truck”*. Respondent 6 described a similar challenge for transport with heavy goods: *”if we do that electrically, where we have to add a large battery capacity, it simply means that we can carry less freight. Then the business case collapses, and we also do not consider that a sustainable solution”*. At the same time, payload was not equally restrictive for all respondents. Respondent 5 indicated that weight required attention, but *”did not limit us to such an extent”* because their freight was relatively light. This shows that payload sensitivity is not a universal dimension but a scenario-dependent one. The same electric truck can be feasible in volume-based transport but much more difficult in weight-sensitive operations.

Planning flexibility was one of the two additional dimensions identified inductively from the interviews. This dimension refers to the ability of an organisation to adapt planning routines, operational assumptions, and daily coordination to the requirements of electric transport. Respondent 7 explained that the organisation hired a dedicated planner for electric trucks as *”with a diesel truck, if the tank is empty, it takes 3.5 to 5 minutes to fill it up. With an electric truck, that is not possible”*. The same respondent explained that this planner works with *”simulations of what the route will look like, when the battery is empty, and when you have to recharge”*. Respondent 13 also emphasised this shift by stating that operators will have to *”plan charging into the route and therefore plan differently than diesel”*. These examples show that planning flexibility is not a transport decision in itself, but a condition that determines whether the organisation can work with BET-specific constraints. When planning flexibility is high, charging, range, and time windows can be integrated into the operation. When planning flexibility is low, even technically feasible routes may become difficult to execute.

Utilisation intensity was the second dimension identified inductively from the interviews. This dimension describes the degree to which a vehicle must be used to make the business case viable. High utilisation can improve the financial attractiveness of BETs because the higher investment cost is spread over more kilometres. However, high utilisation also creates operational challenges as there is limited time available for charging. Respondent 11 explained that once such an expensive truck enters the fleet, the transport manager starts thinking about how to use it *”7 days a week, day and night, as efficiently as possible”*. Respondent 5 similarly assessed future BET deployment by looking at *”how many kilometres per day we can put into it”*, aiming for routes of *”about 500 kilometres per day”* to improve the business case compared with diesel. Utilisation intensity, therefore, can strengthen the economic potential of BET adoption.

6

From Empirical Insights to Multi-Level Decision-Support Framework

This chapter translates the literature- and empirically based findings into the final multi-level decision-support framework and, therefore, answers the third sub-question: *Which strategic, tactical, and operational fleet operator BET procurement decisions are affected by adoption barriers and drivers?* Besides, this chapter translates the synthesis into a Multi-Level Decision-Support Framework and addresses the fourth sub-question: *How can fleet operators structure BET procurement decision-making across strategic, tactical, and operational levels to overcome adoption barriers and respond to adoption drivers?*

In Section 6.1 the insights from Chapters 3 and 4 are compared to the empirical findings from Chapter 5. The comparison focuses on adoption barriers & drivers, BET procurement decision, and transport dimensions. Section 6.2 synthesises the insights by linking the barrier and driver clusters to the strategic, tactical, and operational decisions within BET procurement. Section 6.3 then maps the interdependencies between these decisions, showing which decisions influence one another and where the key connections lie. Finally, Section 6.4 contains the Multi-Level Decision-Support framework and explains how fleet operators can use this framework to structure BET procurement.

6.1. Comparing literature- and empirically based insights

The empirical results largely confirm the literature-based findings, but also refine them in several important ways. The literature provides the conceptual structure by identifying the main decision levels, the relevant adoption barriers and drivers, and the importance of transport dimensions. It also recognises that these decisions are interdependent rather than isolated (Langevin and Riopel, 2005; Bakker et al., 2025). What the literature does not specify, however, is which BET procurement decisions influence one another, in which direction, and how strongly. The interviews address this gap. They show that fleet operators experience BET adoption as a connected decision-making process, in which specific decisions, barriers, drivers, and transport dimensions influence one another, and they make the concrete interdependencies between decisions explicit. The directed relationship matrix in Section 6.3 captures these specific links, which the literature recognised only in general terms.

Three refinements are especially important for the development of the framework (Table 6.1). First, barriers and drivers should not be treated as separate factors, but as clusters that affect specific decisions. Second, BET procurement is confirmed as a multi-level process, but the interviews add three decisions that were less explicit in the literature and that span all three levels: 1) transport & charging network configuration at the strategic level, 2) energy & peak-load management at the tactical level, and 3) workforce training & routine adaptation at the operational level. Third, the interviews refine how transport context should be assessed. Broad transport profiles such as short-haul, line-haul, and long-haul are confirmed as useful categories, but the interviews show that they are too general to explain feasibility on their own. Instead, feasibility is better assessed through the underlying transport dimensions introduced in Chapter 3. The interviews confirmed the relevance of these dimensions in practice and added two that were not part of the preliminary set: planning flexibility and utilisation intensity. Therefore, the framework should assess specific transport cases through these seven dimensions rather than the five preliminary dimensions alone.

Table 6.1: Comparison between literature- and empirically based insights

Element	Literature-based insight	Empirical refinement
Barriers and drivers	BET adoption is shaped by economic, technological, infrastructural, operational, organisational, and institutional factors.	Fleet operators experience these barriers and drivers as clusters that either constrain or enable specific decisions.
BET procurement decisions	BET procurement extends diesel-truck procurement with decisions on charging, infrastructure, routing, planning, and organisational capabilities.	Interviews confirm the multi-level structure and add practical decisions: 1) transport & charging network configuration, 2) energy & peak-load management, and 3) workforce training & routine adaptation.
Transport dimensions	Route predictability, return-to-base frequency, fuelling/charging control, daily distance, and payload sensitivity are identified as key dimensions for assessing BET feasibility across transport profiles.	Interviews confirm these dimensions and add planning flexibility and utilisation intensity as additional dimensions.

Barriers & drivers

The literature review identified a broad set of adoption barriers and drivers for HDV electrification. Chapter 4 grouped these barriers and drivers into six themes: 1) economic, 2) technological, 3) infrastructural, 4) operational, 5) organisational & behavioural, and 6) institutional & policy-related barriers and drivers (Table 4.1). This thematic structure shows that BET adoption is not shaped by one dominant barrier or driver, but by a combination of barriers and drivers that interact across financial, technical, infrastructural, operational, organisational, and policy-related domains. The empirical findings largely confirm this broad understanding, but also show how these barriers and drivers are experienced by fleet operators in relation to concrete BET procurement decisions.

Building on this literature-based thematic structure, the empirical findings confirm the relevance of the identified barriers and drivers, but also refine how they should be interpreted. The interviews show that barriers and drivers are not experienced by fleet operators as separate issues, but as interconnected barriers and drivers that influence concrete BET procurement decisions. For example, charging infrastructure, costs, operational planning, customer demand, and organisational capabilities are discussed in relation to one another rather than in isolation. This means that the empirical findings shift the interpretation from a thematic overview of barriers and drivers towards decision-oriented clusters that shape the feasibility, timing, and sequencing of electrification decisions.

For example, charging infrastructure is not only an infrastructural barrier. This barrier affects route selection, charging strategy, scheduling, depot charging infrastructure design, and the reliability of daily operations. Similarly, customer demand is not only a general market driver. It can influence the business model, support contract redesign, and help identify which routes should be electrified first.

This means that barriers and drivers should be interpreted through their effect on decision-making. Barriers can act as constraints or gatekeepers when they prevent fleet operators from moving to the next decision stage. Drivers can act as triggers or enablers when they create urgency, improve feasibility, or reduce uncertainty. This interpretation is important because it shifts the focus from identifying barriers and drivers towards understanding where they influence the BET procurement process.

BET procurement decisions

The literature review showed that BET procurement differs from diesel-truck procurement because it is not limited to selecting and purchasing a vehicle. In diesel-truck procurement, the surrounding system of fuel infrastructure, maintenance routines, operational planning, and vehicle deployment is relatively stable. BET procurement changes this situation. Fleet operators must also make decisions about 1) charging strategy, 2) depot infrastructure design, 3) energy & peak-load management, 4) route suitability, 5) daily charging schedules, 6) payload & load allocation, and 7) capability sourcing & partnership.

The interviews confirm this broader interpretation of BET procurement decision-making. Respondents described BET adoption as a process in which strategic choices, tactical deployment decisions, and operational execution are closely connected. At the strategic level, fleet operators need to define the broader conditions for adoption, including the business model, contracts, charging strategy, depot infrastructure, partnerships, and implementation pathway. These choices are then translated at the tactical level into decisions about route selection, customer-route allocation, fleet transition and integration, and energy and peak-load management. At the operational level, BET deployment becomes visible in daily BET routing and scheduling, daily charging scheduling, payload and load allocation, and workforce training and routine adaptation.

The empirical findings also refine the conceptual model. 1) Transport & charging network configuration, 2) energy & peak-load management, and 3) workforce training & routine adaptation emerged as important additional decisions. Transport & charging network configuration is relevant because BET adoption may require fleet operators to rethink how transport flows, depots, charging locations, and customer routes are organised. Energy & peak-load management is relevant because electricity use, peak loads, charging timing, and grid constraints become part of fleet operations. Workforce training & routine adaptation is relevant because planners and drivers need to understand how BETs affect routing, charging, driving behaviour, and daily routines.

These findings confirm that BET procurement should be seen as a decision-making process across organisational levels, rather than an isolated replacement decision. The feasibility of BET adoption depends on whether the organisation can align the vehicle, charging system, transport operation, customer requirements, and internal capabilities.

Transport dimensions

The literature review distinguished between short-haul, line-haul, and long-haul transport to explain why BET feasibility differs across transport contexts. These profiles provide a useful starting point: short-haul transport is generally more favourable because routes are more predictable, vehicles return to base more often, and charging can be organised at the depot, while long-haul transport is more challenging due to longer distances, lower fuelling/charging control, and greater operational uncertainty. However, the empirical findings show that these broad transport profiles are not precise enough for decision support.

Respondents did not assess BET feasibility only by classifying an operation as short-haul, line-haul, or long-haul. Instead, they focused on the underlying characteristics of specific routes, customers, depots, and planning routines. This confirms the relevance of the transport dimensions identified in Chapter 3, such as route predictability, return-to-base frequency, fuelling/charging control, daily distance, and payload sensitivity. At the same time, the interviews refined this perspective by identifying planning flexibility and utilisation intensity as additional dimensions. Planning flexibility determines whether transport planning can be adapted to BET-specific constraints, such as charging windows, range limitations, and delays. Utilisation intensity has a more ambiguous effect: high utilisation can improve the business case, but it can also reduce charging time and increase pressure on operational reliability.

This means that the transport dimensions should be used in the framework as a first feasibility check. Before assessing the procurement decisions, fleet operators use these dimensions to screen whether the specific operational conditions of a route or transport flow make it a realistic candidate for BET deployment. Rather than asking whether a general transport profile is suitable for BETs, they assess whether a concrete route or flow provides a feasible starting point. This screening step helps identify where BET deployment is most realistic, which barriers are most critical, and which drivers can support implementation. Section 6.3 builds on this insight by linking these dimensions to the decisions that fleet operators need to make.

6.2. Synthesising barriers and drivers with BET decisions

Section 6.1 showed that the empirical findings confirm and refine the literature insights of this thesis. The next step is to integrate these insights into one decision-making context. This section, therefore, links the barrier and driver clusters from Section 5.2 to the BET procurement decisions from Section 5.3, while accounting for the transport dimensions discussed in Section 5.4. This thesis answers the third sub-question of this thesis: *Which strategic, tactical, and operational fleet operator BET procurement decisions are affected by adoption barriers and drivers?*

The synthesis is based on the idea that barriers and drivers influence BET adoption through specific decisions. Barriers mainly indicate where fleet operators face constraints, risks, or uncertainty. Drivers indicate where there is pressure, support, or opportunity to move the decision-making process forward. Table 6.2 presents this relationship by mapping the barrier and driver clusters identified in the interviews into the strategic, tactical, and operational decisions involved in BET procurement. This mapping is derived from the coded interview material: a barrier or driver cluster is linked to a decision when respondents discussed that cluster in direct relation to that decision. The relationships are therefore grounded in how respondents connected constraints and pressures to specific procurement decisions, rather than assigned on theoretical grounds alone.

Barriers in synthesis

Table 6.2 shows that barriers do not affect all decisions in the same way. Some barriers mainly constrain specific decisions, while others function as gatekeepers that must be addressed before the decision-making process can continue. Financial constraints and charging & energy constraints are especially important at the strategic level. They affect whether BET adoption can be justified commercially and whether the required charging conditions can be organised. If these conditions are not sufficiently addressed, fleet operators are unlikely to move beyond pilots or limited deployment.

At the tactical level, barriers become more connected to the characteristics of specific transport flows. Fleet transition & integration, route selection, energy & peak-load management, and customer-route allocation depend on the fit between the BET, the charging system, and the transport operation. Technological and operational mismatch is especially relevant at this level as range limitations, payload restrictions, and planning constraints determine whether a specific route can realistically be electrified.

At the operational level, barriers influence daily operations. Daily BET routing & scheduling, daily charging scheduling, and payload & load allocation are constrained by the same issues, but in a more nuanced way. Operational problems can therefore also function as feedback signals. When a selected route is difficult to execute in practice, this may reveal that earlier assumptions about charging availability, vehicle range, planning flexibility, or utilisation were too optimistic.

Drivers in synthesis

Drivers play a different role in the synthesis. They do not remove barriers automatically, but they can make specific decisions more attractive or urgent. Customer market pull is mainly relevant when it can be connected to concrete deployment decisions, such as route selection, contract & risk-sharing, or customer-route assignment. In this way, customer demand can turn electrification from a general ambition into a specific business case.

Strategic and business motivation mainly supports early action and organisational preparation. It can justify pilots, capability development, partnerships, and initial fleet deployment, even when the financial case is not yet feasible. Fiscal and regulatory incentives influence the timing and attractiveness of adoption by improving the business case or increasing pressure to electrify specific routes or markets. Growing transition readiness supports the process more broadly, as improvements in knowledge, technology, charging availability, and operational experience reduce uncertainty across strategic, tactical, and operational decisions.

Table 6.2: Influence of barrier and driver clusters on BET procurement decisions

Decision	Level	Barrier clusters	Driver clusters
Business model adaptation	Strategic	B1 Financial constraints B4 Organisational readiness gaps	D1 Customer market pull D2 Strategic & business motivation D3 Fiscal & regulatory incentives D4 Growing transition readiness
Contract & risk-sharing	Strategic	B1 Financial constraints	D1 Customer market pull
BET implementation pathway	Strategic	B1 Financial constraints B4 Organisational readiness gaps B5 Transition management uncertainty	D2 Strategic & business motivation D3 Fiscal & regulatory incentives D4 Growing transition readiness
Transport & charging network configuration	Strategic	B2 Charging & energy constraints B5 Transition management uncertainty	D4 Growing transition readiness
Charging strategy	Strategic	B1 Financial constraints B2 Charging & energy constraints	D4 Growing transition readiness
Depot charging infrastructure design	Strategic	B2 Charging & energy constraints	D3 Fiscal & regulatory incentives
Capability sourcing & partnership	Strategic	B4 Organisational readiness gaps B5 Transition management uncertainty	D2 Strategic & business motivation D4 Growing transition readiness
Fleet transition & integration	Tactical	B1 Financial constraints B2 Charging & energy constraints B3 Technological & operational mismatch B5 Transition management uncertainty	D1 Customer market pull D2 Strategic & business motivation D3 Fiscal & regulatory incentives D4 Growing transition readiness
Route selection for BET deployment	Tactical	B3 Technological & operational mismatch	D1 Customer market pull D4 Growing transition readiness
Energy & peak-load management	Tactical	B2 Charging & energy constraints	D4 Growing transition readiness
Customer-route allocation	Tactical	B2 Charging & energy constraints B3 Technological & operational mismatch	D1 Customer market pull
Daily BET routing & scheduling	Operational	B3 Technological & operational mismatch	D4 Growing transition readiness
Payload & load allocation	Operational	B3 Technological & operational mismatch	None
Daily charging scheduling	Operational	B2 Charging & energy constraints B3 Technological & operational mismatch	D4 Growing transition readiness
Workforce training & routine adaptation	Operational	B4 Organisational readiness gaps	D4 Growing transition readiness

Transport dimensions in synthesis

Transport dimensions provide the contextual layer for this synthesis. They do not add separate decisions to Table 6.2, but help explain why the same barrier or driver can affect fleet operators differently across transport contexts. For example, charging and energy constraints are less restrictive for predictable depot-based operations with frequent return-to-base, but become more critical when operations depend on public or corridor charging. Similarly, technological and operational mismatch becomes more critical when daily distances are high, payload sensitivity is strong, or planning flexibility is limited. This means that the relationships in Table 6.2 should not be interpreted as fixed or equally important for every fleet operator. Instead, the relevance of each barrier-driver-decision relationship depends on the operational characteristics of the specific transport flow.

Overall, the synthesis shows how the different empirical findings are connected. Barriers and drivers shape specific BET procurement decisions, while transport dimensions determine the relevance and strength of their influence. Strategic decisions define whether adoption is commercially, infrastructurally, and organisationally feasible. Tactical decisions translate this into deployment choices for routes, vehicles, customers, and energy use. Operational decisions then test whether these choices can be executed reliably in daily practice.

6.3. Mapping interdependencies between BET decision-making

Section 6.2 linked the barrier and driver clusters to the individual BET procurement decisions from Section 5.3. That synthesis explained where fleet operators face constraints and pressure, but it treated the decisions largely one by one. The interviews showed, however, that these decisions are not made in isolation: a choice on one decision frequently constrains or enables another. Before the decisions can be organised into the Multi-Level Decision-Support Framework, this section therefore makes the interdependencies between them explicit. In doing so, it provides the empirical basis for the links and the ordering used in the framework.

Table 6.3 presents these interdependencies as a directed relationship matrix. Each row is a source decision and each column is a target decision, so a filled cell indicates that the source decision was found to influence the target decision. The value in each cell is the number of distinct interviews (out of 14) in which that directed influence was evidenced, which keeps the matrix consistent with the breadth measure used in Chapter 5. The black diagonal marks the same decision, an empty cell means no relationship was observed, and a red border marks a connection that was identified in the interviews but was not part of the framework derived from the literature in Section 6.1. The two margins summarise each decision's role: the out-degree counts how many other decisions it influences, and the in-degree counts how many decisions influence it.

Table 6.3: Directed relationship matrix between BET procurement decisions

From \ To	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Out
1. Business model adaptation	X										5					3
2. Charging strategy		X														4
3. Contract and risk-sharing			X													1
4. BET implementation pathway				X	6		6									3
5. Capability sourcing & partnership			5		X						5					3
6. Depot charging infrastructure design					6	X		6								3
7. Transport & charging configuration		6					X									1
8. Route selection for BET deployment		6			5			X								2
9. Customer-route allocation									X			5		6		2
10. Fleet transition & integration									5	X	6			5		3
11. Energy & peak-load management			4						6		X					3
12. Payload & load allocation												X	4	5		2
13. Daily charging scheduling											5		X			1
14. Daily BET routing & scheduling											5		6	X		2
15. Workforce training & routine adaptation					4										X	1
In	**0**	**2**	**3**	**2**	**5**	**1**	**1**	**2**	**2**	**1**	**7**	**1**	**2**	**3**	**2**	

The matrix shows that the interdependencies are concentrated rather than evenly spread. Charging strategy has the highest out-degree, meaning that it shapes the largest number of other decisions, while energy & peak-load management has the highest in-degree, meaning that it depends on the most other decisions. More generally, the charging, energy, and depot-related decisions are strongly linked to each other and to the strategic decisions, which confirms that charging conditions are a central organising factor in BET procurement rather than a separate operational concern. The connections marked with a red border extend the literature-based framework with interdependencies that only became visible through the empirical material.

These mapped relationships form the bridge to the Multi-Level Decision-Support Framework in Section 6.4. Where Chapter 5 identified which decisions exist and Section 6.2 explained which barriers and drivers affect them, this section establishes how the decisions connect to one another. The directed relationships are precisely the arrows in Figure 6.1: they justify which decisions are linked and support the ordering of decisions across the strategic, tactical, and operational levels. In this way, the matrix turns the separate empirical findings into a connected decision structure that the framework then organises into a usable, stepwise process for fleet operators.

6.4. Multi-Level Decision-Support Framework

The synthesis in the previous section provides the basis for the Multi-Level Decision-Support Framework (Figure 6.1). It answers the fourth sub-question: *How can fleet operators structure BET procurement decision-making across strategic, tactical, and operational levels to overcome adoption barriers and respond to adoption drivers?* The framework translates the empirical insights into a structured decision-support logic for fleet operators. Its purpose is not to predict whether a BET should be purchased in every situation, but to make the procurement decision-making process explicit. In this way, the framework supports fleet operators in moving from a general electrification ambition towards a concrete and context-specific deployment pathway.

Figure 6.1 should be read from top to bottom. The framework starts with the transport dimensions because these determine the operational context in which BET deployment is assessed. These dimensions function as the first feasibility layer before procurement decisions are made. After this initial assessment, the framework moves through three decision levels: strategic, tactical, and operational. Each level contains decisions that need to be addressed before BET deployment can be implemented reliably in practice. The arrows between the decisions show that the process is not linear. Decisions at one level influence decisions at other levels, while operational experience can create feedback to earlier strategic or tactical choices.

At the strategic level, the framework supports fleet operators with decisions that shape the boundary conditions that are required for BET adoption. These decisions concern the commercial, infrastructural, organisational, and implementation conditions under which BET deployment could become feasible. The following decisions have been structured in the framework at this level: 1) business model adaptation, 2) contract & risk-sharing, 3) charging strategy, 4) depot charging infrastructure design, 5) transport & charging network configuration, 6) capability sourcing & partnership, and 7) BET implementation pathway.

The tactical level translates these strategic conditions into deployment decisions. This level is important because it prevents BET adoption from becoming either too abstract or too broad, as strategic decisions are translated into operational implementation. Therefore, operational feasibility, customer demand, charging options, and vehicle availability need to be aligned. The following decisions have to be made at this level: 1) route selection for BET deployment, 2) energy & peak-load management, 3) fleet transition & integration, and 4) customer-route allocation.

The operational level focuses on the daily execution of BET deployment. At this level, tactical deployment choices are translated into concrete routines for drivers, planners, and operational staff. The relevant decisions are 1) workforce training & routine adaptation, 2) daily BET routing & scheduling, 3) daily charging scheduling, and 4) payload & load allocation. These decisions determine whether the selected BET deployment can function reliably in practice. If operational problems occur repeatedly, they should not only be interpreted as daily planning issues. They may also indicate that earlier decisions need to be reconsidered.

The barrier and driver clusters are not shown in Figure 6.1 as separate decisions, because they are not decisions that fleet operators make. Instead, they influence the feasibility, urgency, and sequencing of the decisions in the framework. Table 6.2 therefore complements Figure 6.1 by showing where specific barrier and driver clusters affect the decision-making process. Together, the table and figure show both the structure of the process and the barrier and driver clusters that shape the decision-making structure.

The framework was discussed in three refinement interviews with industry experts. These interviews

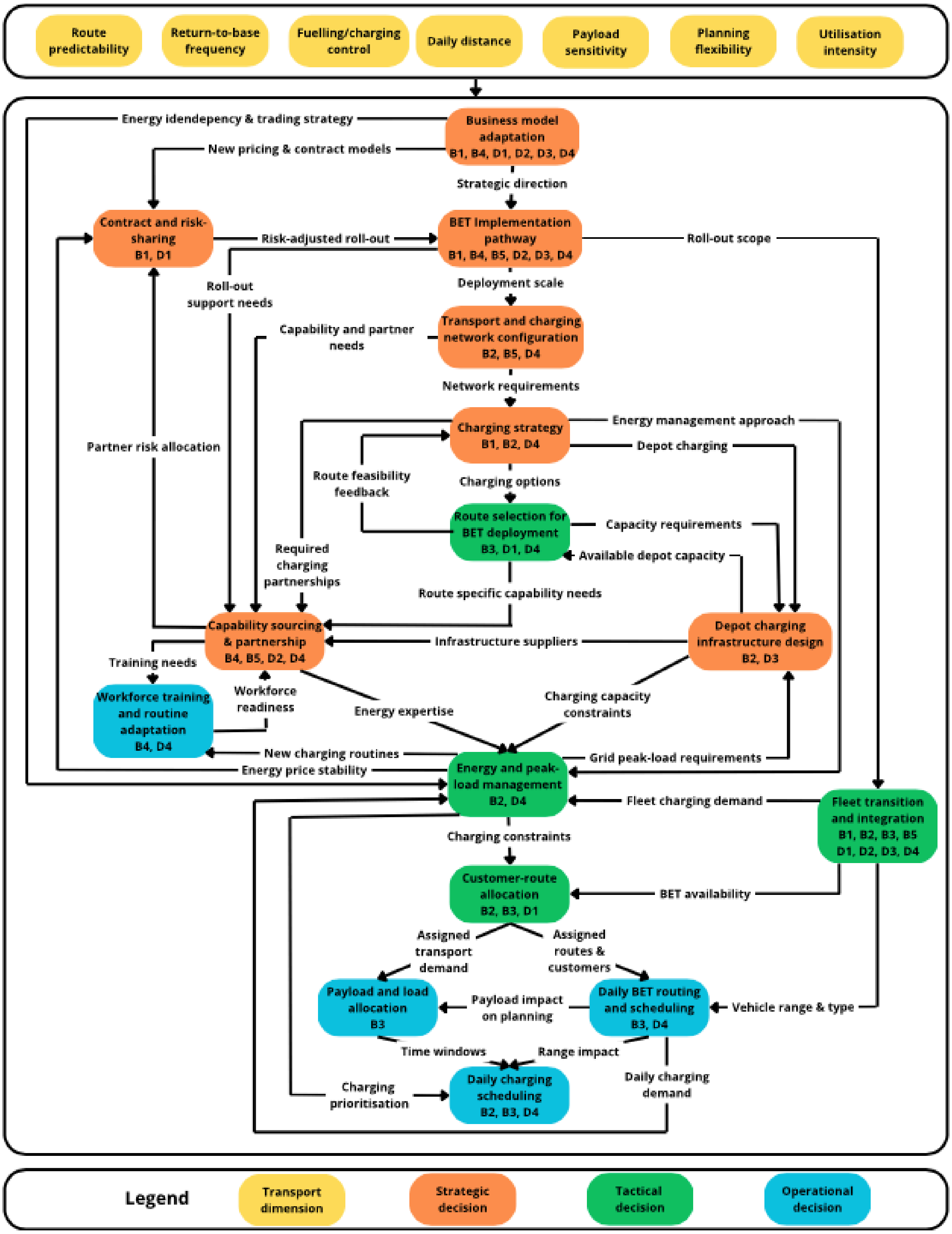

Figure 6.1: Visualisation of multi-level decision-support framework

did not lead to major changes in the overall structure of the framework. Respondents recognised the multi-level structure and confirmed that the framework provides a useful way to organise BET procurement decisions. The main refinement from the interviews concerns the link between energy & peak-load management and daily charging scheduling. Respondents indicated that energy & peak-load management influences not only charging infrastructure and electricity use at a tactical level, but also affects operational charging prioritisation. In practice, decisions about when to charge and which vehicle to charge depend on available grid capacity, electricity costs, route planning, and vehicle availability. Therefore, Figure 6.1 includes a connection between energy & peak-load management and daily charging scheduling to reflect this relationship.

The practical value of the framework is that it helps fleet operators structure BET procurement in a stepwise way. First, a specific transport case is assessed through the transport dimensions. Second, the strategic conditions for adoption are defined. Third, these conditions are translated into tactical deployment choices. Fourth, operational execution is tested and used as feedback for further refinement. This makes the framework especially useful for phased implementation. Fleet operators use the transport dimensions to identify which transport cases offer the most feasible starting point, deploy BETs there first, learn from operational experience, and scale to more demanding cases only when the relevant conditions become more mature. Box 6.1 illustrates this stepwise application for a concrete transport case, showing where a fleet operator starts and how the levels and the barrier & driver clusters come together.

Box 6.1: Illustrative application of the framework

A fleet operator considers electrifying a regional distribution route.
Step 1 (transport dimensions). The route is assessed through the seven dimensions: high route predictability, daily return-to-base, a moderate daily distance of around 250 km, low payload sensitivity, charging under the operator's own control at the depot, sufficient planning flexibility, and high utilisation. This profile offers a feasible starting point, so the operator continues.
Step 2 (strategic). The operator defines the conditions for adoption: securing a customer contract to cover the price premium (business model adaptation, contract & risk-sharing), arranging overnight depot charging (charging strategy, depot charging infrastructure design), and choosing an implementation pathway. Financial constraints (B1) and charging & energy constraints (B2) are most critical here, while customer market pull (D1) and fiscal incentives (D3) support the case.
Step 3 (tactical). These conditions are translated into route selection, customer-route allocation, fleet transition & integration, and energy & peak-load management.
Step 4 (operational). The route is executed through daily routing & scheduling, daily charging scheduling, and workforce training. Recurring operational problems feed back to the tactical and strategic choices. The operator starts with this feasible case, learns from it, and only scales to more demanding routes, such as long-haul flows, once the relevant conditions mature.

Overall, Figure 6.1 and Table 6.2 answer the fourth sub-question by showing how fleet operators can structure BET procurement decision-making across strategic, tactical, and operational levels while accounting for the barriers and drivers that shape this process. The framework integrates the main findings of this thesis without reducing BET adoption to a single go/no-go decision. Instead, it presents BET procurement as a structured, multi-level decision-making process in which transport dimensions, strategic choices, tactical deployment decisions, operational experience, and barrier & driver clusters are connected. In this way, the framework helps fleet operators identify where barriers need to be addressed, where drivers can support implementation, and how deployment can be scaled through a phased and context-specific approach.

7 Discussion

This chapter reflects on the findings of this thesis by discussing the contribution to existing literature, the main limitations and assumptions, and the implications for future research and practice.

Discussion of contributions

The main contribution of this thesis is that it makes the complexity of BET procurement decision-making explicit and structures it into a multi-level decision-support framework from the perspective of fleet operators. Existing logistics literature shows that logistics decision-making consists of interrelated decisions across strategic, tactical, and operational levels (Langevin and Riopel, 2005), and transport decision-making is described as a multi-criteria process in which costs, reliability, flexibility, service quality, and operational requirements are considered simultaneously (Meixell and Norbis, 2008). These studies, however, mainly describe conventional diesel-truck transport, in which the fuelling infrastructure, operational routines, and vehicle deployment assumptions are stable. They therefore do not capture how electrification changes the decision-making context itself.

The central argument of this thesis is that BET procurement is far more complex than the current literature represents. Within the literature, this complexity is fragmented across separate studies. Some studies treat BET adoption mainly as a vehicle replacement or Total Cost of Ownership problem, while others examine isolated parts of the system, such as charging infrastructure, route planning, charging scheduling, or grid capacity (Amiri et al., 2023; Bakker et al., 2025; Cheng and Lin, 2024; Karam and Rich, 2025). Each of these studies addresses a relevant part of the problem, but none of them shows how these parts come together in the actual decision-making process of a fleet operator. As a result, the literature under-represents the organisational reality that fleet operators describe, in which a single truck purchase is connected to charging strategy, grid capacity, energy management, customer contracts, business model changes, workforce routines, and network design.

This thesis adds to the literature by treating this complexity as the object of study rather than as a background condition. The empirical findings show that BET procurement should not be understood as a single go/no-go vehicle replacement decision, but as a broader organisational decision-making process in which decisions, barriers, drivers, and transport characteristics influence one another. This complexity is demonstrated in three concrete ways. First, the interviews revealed fifteen interrelated decisions spread across the strategic, tactical, and operational levels, three of which (transport and charging network configuration, energy and peak-load management, and workforce training and routine adaptation) were not explicit in the reviewed literature but emerged as relevant in practice. Second, the directed relationship matrix shows that these decisions are interdependent rather than separate, and that some decisions, such as charging strategy, shape many others. Third, the synthesis shows that adoption barriers and drivers do not act as stand-alone obstacles or incentives, but operate through specific decisions, which is why simply listing barriers and drivers provides limited guidance for fleet operators.

A further contribution concerns transport heterogeneity. The results confirm that short-haul, line-haul, and long-haul transport are useful categories for understanding BET feasibility, but that they are too broad to support decision-making on their own. In practice, fleet operators assess the underlying operational dimensions of a specific route or flow. This shows that BET feasibility is not determined by vehicle performance or cost-competitiveness alone, but by the fit between the truck, the charging system, and the specific transport operation.

Taken together, the contribution of this thesis is not only the framework as an artefact, but the underlying insight that BET procurement is a complex, multi-level, and interdependent organisational decision-making process. By combining logistics decision-making, adoption barriers and drivers, and transport heterogeneity into one structure, the thesis makes visible a complexity that the existing literature describes only in fragments.

Limitations and assumptions

This thesis contains several limitations and assumptions that should be taken into account when interpreting its conclusions. These limitations also qualify how strongly the framework and the findings can be presented.

First, the research is qualitative and exploratory. The findings are based on a limited number of interviews and are not statistically representative of the road freight sector. Tables 5.1, 5.2, 5.3 & 5.4 indicate how widely a theme was shared across respondents, but do not provide statistical evidence of the importance, weight, or ranking of a specific barrier, driver, or decision. The framework should therefore be read as an analytical and structuring tool, not as a statistically validated model of fleet operator behaviour.

Second, the framework reflects analytical choices made by the researcher. The identification of the decisions, the assignment of each decision to the strategic, tactical, or operational level, and the judgement that certain decisions, such as fleet transition and integration, customer-route allocation, daily BET routing and scheduling, and payload and load allocation, are highly relevant and shaped by BET characteristics, are based on the researcher's interpretation of the interview material rather than on an objective measurement. A different researcher could have grouped, labelled, or prioritised these decisions differently. The framework is therefore one defensible structuring of the decision-making process, not the only possible one.

Third, the construction of the directed relationship matrix in Section 6.3 made use of AI tools, which has implications for transparency and reproducibility. The systematic coding of the interviews was carried out in ATLAS.ti, which provides a traceable coding structure. AI tools were used only to support the construction of the directed relationship matrix, by interpreting the coded interview material into directed links between decisions. The full procedure by which this matrix was derived is documented in Appendix B for transparency. This use of AI affects reproducibility, because AI-assisted interpretation is not fully deterministic, and a different run or a different prompt may produce slightly different results. This is especially relevant here, because both the existence and the direction of a link between two decisions depend on interpretation of the interview material. To mitigate this, the AI-assisted results were cross-checked against the ATLAS.ti coding and the underlying transcripts. Future work could further improve reproducibility by deriving the relationship matrix directly from a fixed analysis.

Fourth, and most importantly, the framework has not been tested in practice. It was discussed in three refinement interviews with industry experts. These interviews provided feedback on the structure and recognisability of the framework but did not provide evidence for practical effectiveness. The framework was not applied to a real BET procurement process and the proposed sequencing of decisions is not observed in an actual organisation over time. As a result, it remains unknown whether the framework improves decision-making outcomes, whether it is complete, and whether the proposed ordering holds in practice. The practical value of the framework is therefore proposed on the basis of the empirical findings, but not yet demonstrated. This is an important limitation, because it means the framework should be presented as a conceptual decision-support structure that still requires empirical testing, rather than as a tool that has been shown to work.

Fifth, the interview sample did not represent all transport profiles, firm sizes, and national contexts equally. This matters because BET feasibility is strongly context-dependent. A large fleet operator with its own depot, long-term customer contracts, and internal sustainability targets faces a different decision-making context than a smaller carrier with limited charging control, shorter contracts, and lower investment capacity. The interviews also showed that the type of organisation influences how the decision-making process unfolds, which means that the relevance and ordering of the decisions in the framework may differ between operators.

Finally, the context of BET adoption is developing quickly. Vehicle range, battery costs, charging speeds, electricity prices, grid capacity, subsidies, environmental zones, and public charging infrastructure may all change over time. The added value of the framework therefore lies mainly in the structure of the decision-making process, rather than in the current relevance of each individual barrier or driver.

Taken together, these limitations mean that the conclusions of this thesis should be read as analytically grounded and empirically informed, but not as statistically generalisable or practically validated. The framework structures and clarifies a complex decision-making process, but its effectiveness in practice remains an open question for further research.

Implications for research and practice

The limitations above point directly to several implications for future research. First, the framework should be empirically tested rather than only reviewed. This could be done through case studies in which fleet operators are followed throughout the full BET procurement and implementation process, which would show whether the sequencing of decisions in the framework corresponds with actual organisational decision-making over time, and whether following the framework leads to better-informed decisions. Second, future research could examine the direction and mutual influence of the relationships between decisions in more detail, for example through a larger sample or a dedicated method for mapping decision dependencies, to test whether the directions proposed in this thesis hold. Third, the framework could be tested across different transport profiles, firm sizes, and organisational contexts, especially among smaller fleet operators and in less predictable line-haul and long-haul operations. Fourth, future research could combine the framework with quantitative decision-support models, such as TCO analysis, route optimisation, charging infrastructure planning, and grid capacity assessment.

For practice, the framework offers fleet operators a way to structure BET procurement before committing to large investments, while keeping in mind that it has not yet been validated in practice. The main practical implication is that fleet operators should not start with the vehicle purchase itself. Instead, they should first assess the operational dimensions of specific transport flows. Routes with predictable schedules, frequent depot returns, high charging control, manageable daily distances, and sufficient planning flexibility provide more feasible starting points for BET deployment. Once these transport flows have been identified, fleet operators should align the business model, customer agreements, charging strategy, infrastructure investments, grid capacity, and organisational capabilities.

This research also suggests that pilots should not only be used to test the vehicle, but also to learn about the wider decision-making system around the vehicle. A pilot can reveal whether planners understand charging constraints, whether drivers can adapt their routines, whether charging windows are sufficient, and whether customer requirements are compatible with BET deployment. In this way, operational experience becomes a feedback mechanism for strategic and tactical decisions. Because fleet operators cannot overcome all adoption barriers independently, the transition to BETs also requires coordination with policymakers, OEMs, charging infrastructure providers, grid operators, and customers.

8
Conclusion

“Buying the truck is the easy part. Aligning the strategy, the charging, and the daily operations around it is not.”

The central finding of this thesis is that the hardest part of truck electrification is not buying a BET, but managing the web of decisions that the purchase sets in motion. Where diesel trucks fall into a stable system of fuelling, maintenance, and routines, a BET pulls charging infrastructure, grid capacity, energy management, customer contracts, business models, workforce routines, and network design into a single, connected decision-making process. This thesis is among the first to bring these aspects together from the fleet operator’s perspective and to show that BET adoption is, at its core, an organisational decision-making problem rather than a vehicle-buying problem.

This reframing answers the main research question: *How can a multi-level decision-support framework guide fleet operators in structuring the interdependent strategic, tactical, and operational decisions of BET implementation across transport profiles, while accounting for adoption barriers and drivers?* The answer is a framework built from three elements that emerged from the literature and the interviews: the transport dimensions that determine feasibility, the strategic, tactical, and operational decisions that procurement involves, and the adoption barriers and drivers that shape those decisions. The framework does not tell operators whether to buy a truck. It does something more useful: it makes the full decision-making process visible, shows how its parts connect, and turns a vague electrification ambition into a structured and phased process.

Three empirical insights give the framework its power. First, BET procurement is a transformative decision-making process, not a truck replacement decision. The interviews show that operators face an entirely new set of decisions, from charging strategy and depot charging infrastructure to contracts, business models, and network configuration, while familiar decisions such as routing, fuelling scheduling, and load allocation change because they now depend on range, charging time, and charging access. The directed relationship matrix in Chapter 6 makes this concrete by showing that these decisions are not separate but feed into one another, with charging-related decisions shaping many of the others.

Second, feasibility is decided below the level of transport profiles. Short-haul, line-haul, and long-haul are too broad to act on. What determines whether a truck fits is the combination of seven operational dimensions, from route predictability and return-to-base frequency to fuelling/charging control and utilisation intensity. The same truck can be a clear win on one route and unworkable on the next. This is why the framework begins with the transport context rather than the vehicle, and why it treats that context as the first feasibility check before any procurement decision is made.

Third, the impact of barriers and drivers only becomes visible once they are connected to specific decisions. Listing them, as much of the literature does, explains little. Connecting grid capacity to depot design and charging scheduling, or customer demand to the business model and route selection, is what turns them into guidance. The synthesis in Chapter 6 shows where each barrier and driver cluster enters the decision-making process, so that operators know not only what stands in the way, but where it stands in the way during their decision-making.

Taken together, these insights reveal a complexity that existing research has only described in fragments. As discussed in Chapter 7, the literature has studied charging, routing, grid capacity, and total cost of ownership in isolation, and has treated adoption largely as a cost or technology question. The main contribution of this thesis is to show why that fragmentation falls short in practice and to replace it with a single, multi-level structure in which transport context, strategic conditions, tactical deployment, and operational feedback are connected, and in which operational experiences feeds back to sharpen earlier choices. This is the connected organisational reality that fleet operators describe but that the literature has not captured.

The framework also carries a clear message for practice, set out in more detail in Chapter 7. Fleet operators should not start with the vehicle. They should start by assessing the operational dimensions of a specific transport flow, identifying where conditions are already favourable, deploying there first, and scaling to harder routes only as charging, grid capacity, and experience mature. Pilots, in this view, are not only a test of the truck but also a test of the system around it: whether planners can handle charging constraints, whether drivers adapt their routines, and whether customer requirements fit BET deployment. Because no operator can remove every barrier alone, the framework also makes clear where progress depends on policymakers, OEMs, charging and grid providers, and customers acting together.

These contributions should be read together with the limitations in Chapter 7. The framework is based on the researcher's own choices in how the decisions were identified, grouped, and linked, and it was discussed in three expert refinement interviews instead of being tested in a real procurement process. The contribution of the framework is therefore mainly conceptual. It gives structure to a decision-making process that fleet operators currently go through without a clear structure, and it provides a basis for further research. Whether the framework also leads to better decisions in practice still needs to be tested. Chapter 7 explains how future research could do this, for example through case studies that follow fleet operators over time and by combining the framework with quantitative tools such as TCO and route analysis.

The wider message is straightforward. Truck electrification will not be won or lost at the dealership. It will be won by fleet operators who treat the truck as the starting point of a connected set of decisions, and who match the right operation to the right truck before they commit. By making that complexity explicit and giving it structure, this thesis offers fleet operators, researchers, and policymakers a shared way to move truck electrification from ambition to a realistic, phased reality.

References

ACEA. (2025). *Decarbonising heavy-duty road transport: State of the enabling conditions*. Retrieved March 3, 2026, from https://www.acea.auto/publication/decarbonising-heavy-duty-road-transport-state-of-the-enabling-conditions

Ahmed, U., & Roorda, M. J. (2022). Modelling carrier type and vehicle type choice of small and medium size firms. *Transportation Research Part E: Logistics and Transportation Review*, *165*, 102909. https://doi.org/10.1016/j.tre.2022.102909

AllChiefs. (2025). *Accelerating road transport electrification*.

Amiri, A., Zolfagharinia, H., & Amin, S. H. (2023). A robust multi-objective routing problem for heavy-duty electric trucks with uncertain energy consumption. *Computers & Industrial Engineering*, *178*, 109108. https://doi.org/10.1016/j.cie.2023.109108

Axsen, J., & Pickrell-Barr, J. (2024). What drives fleets? organizations' perceived barriers and motivators for alternative-fuel vehicles. *Transportation Research Part D: Transport and Environment*, *132*, 104220. https://doi.org/10.1016/j.trd.2024.104220

Bae, Y., Mitra, S. K., Rindt, C. R., & Ritchie, S. G. (2022). Factors influencing alternative fuel adoption decisions in heavy-duty vehicle fleets. *Transportation Research Part D: Transport and Environment*, *102*, 103150. https://doi.org/10.1016/j.trd.2021.103150

Bakker, J., Alvarez, J. A. L., Veldman, J., & Buijs, P. (2025). Strategic fleet replacement for the electrification of heavy-duty road freight transportation. *Applied Energy*, *391*, 125935. https://doi.org/10.1016/j.apenergy.2025.125935

Basma, H., Beys, Y., & Rodríguez, F. (2021). *Battery electric tractor-trailers in the european union: A vehicle technology analysis*. Retrieved March 4, 2026, from https://theicct.org/wp-content/uploads/2021/12/eu-tractor-trailers-analysis-aug21-2.pdf

Basma, H., & Rodriguez, F. (2022). *Long-haul battery-electric trucks in europe*. Retrieved March 3, 2026, from https://theicct.org/wp-content/uploads/2022/01/Long-haul-be-trucks-EU-slides-02072022.pdf

Basma, H., & Rodríguez, F. (2023, November). *A total cost of ownership comparison of truck decarbonization pathways in europe*. International Council on Clean Transportation. https://theicct.org/publication/total-cost-ownership-trucks-europe-nov23/

Bernard, M. R., Tankou, A., Cui, H., & Ragon, P.-L. (2022). *Charging solutions for battery-electric trucks*. Retrieved March 4, 2026, from https://theicct.org/wp-content/uploads/2022/12/charging-infrastructure-trucks-zeva-dec22.pdf

Brito, J. (2022). *No fleet left behind: Barriers and opportunities for small fleet zero-emission trucking*. Retrieved March 4, 2026, from https://theicct.org/wp-content/uploads/2022/10/small-fleet-ze-trucking-oct22.pdf

Cheng, X., & Lin, J. (2024). Is electric truck a viable alternative to diesel truck in long-haul operation? *Transportation Research Part D: Transport and Environment*, *129*, 104119. https://doi.org/10.1016/j.trd.2024.104119

Corguillé, J. L., Hacker, F., & Dolinga, T. (2025). *Real-world data analysis of battery electric trucks operating in germany*. Retrieved March 4, 2026, from https://www.oeko.de/fileadmin/oekodoc/Real-world-data-analysis-of-battery-electric-trucks.pdf

Danielis, R., Niazi, A. M. K., Scorrano, M., Masutti, M., & Awan, A. M. (2025). The economic feasibility of battery electric trucks: A review of the total cost of ownership estimates. *Energies*, *18*(2), 429. https://doi.org/10.3390/en18020429

Engelhardt, J., Andersen, P. B., & Teoh, T. (2023). *Guidelines – charging infrastructure for truck depots*. Retrieved March 4, 2026, from https://smart-freight-centre-media.s3.amazonaws.com/documents/Guidelines-Charging-Infrastructure-for-Truck-Depots.pdf

European Automobile Manufacturers' Association. (2024, February). *Report – vehicles on european roads*. https://www.acea.auto/publication/report-vehicles-on-european-roads/

European Commission. (2024, May). *Co□ emission standards for heavy-duty vehicles: Council gives final green light to stronger emission reduction targets for new trucks and buses*. https://ec.europa.eu/commission/presscorner/detail/en/ip_24_287

European Commission. (2026). *Weights and dimensions*. Retrieved March 3, 2026, from https://transport.ec.europa.eu/transport-modes/road/weights-and-dimensions_en

European Environment Agency. (2023). *Freight transport activity (sustainability of europe's mobility systems)*. https://www.eea.europa.eu/en/analysis/publications/sustainability-of-europes-mobility-systems/freight-transport-activity

European Environment Agency. (2024). *Reducing greenhouse gas emissions from heavy-duty vehicles in europe*. https://www.eea.europa.eu/en/analysis/publications/reducing-greenhouse-gas-emissions-from-heavy-duty-vehicles-in-europe

European Union. (2021). Regulation (eu) 2021/1119 establishing the framework for achieving climate neutrality (european climate law). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32021R1119

European Union. (2024). *Regulation (eu) 2024/1610 amending regulation (eu) 2019/1242 as regards strengthening the co2 emission performance standards for new heavy-duty vehicles*. https://eur-lex.europa.eu/eli/reg/2024/1610/oj

Eurostat. (n.d.-a). *Road freight transport by vehicle characteristics*. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Road_freight_transport_by_vehicle_characteristics

Eurostat. (n.d.-b). *Road freight transport statistics*. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Road_freight_transport_statistics

Foda, A., & Mohamed, M. (2026). Zero-emission medium- and heavy-duty fleet operation: The perspectives of stakeholders. *Transportation Research Part D: Transport and Environment*, *150*, 105127. https://doi.org/10.1016/j.trd.2025.105127

Gatta, V., Marcucci, E., & Pira, M. L. (2017). Smart urban freight planning process: Integrating desk, living lab and modelling approaches in decision-making. *European Transport Research Review*, *9*, 32. https://doi.org/10.1007/s12544-017-0245-9

Gillström, H., Björklund, M., Stahre, F., & Abrahamsson, M. (2024). Wired for change: Sustainable business models in the transition towards electrified road freight transport. *Cleaner Logistics and Supply Chain*, *13*, 100185. https://doi.org/10.1016/j.clscn.2024.100185

Hacker, F., Gnann, T., Corguillé, J. L., Stephan, A., Kappler, L., Mottschall, M., & Plötz, P. (2023). *Truck depot charging: Analysis from a logistics company and energy perspective*. Retrieved March 4, 2026, from https://www.transportenvironment.org/uploads/files/TE_truck-depot-charging_final-report.pdf

Hrabec, D., Hvattum, L. M., & Hoff, A. (2022). The value of integrated planning for production, inventory, and routing decisions: A systematic review and meta-analysis. *International Journal of Production Economics*, *248*, 108468. https://doi.org/10.1016/j.ijpe.2022.108468

İmre, Ş., Çelebi, D., & Koca, F. (2021). Understanding barriers and enablers of electric vehicles in urban freight transport: Addressing stakeholder needs in turkey. *Sustainable Cities and Society*, *68*, 102794. https://doi.org/10.1016/j.scs.2021.102794

International Energy Agency. (2025). *Regulation (eu) 2023/1804: Alternative fuels infrastructure regulation*. https://www.iea.org/policies/27375-regulation-eu-20231804-alternative-fuels-infrastructure-regulation

Karam, A., & Rich, J. (2025). Planning the transition to electric trucks: An optimization framework for line-haul logistics. *Research in Transportation Business and Management*, *61*, 101413. https://doi.org/10.1016/j.rtbm.2025.101413

Karsten, B., Kühnel, S., & Günther, M. (2023). *Grid readiness for hdv charging*. Retrieved March 4, 2026, from https://www.transportenvironment.org/uploads/files/2023_07_TE_AFIR_grid_readiness_final.pdf

Khani, A., & Emami, B. D. (2022). *Benefits and barriers to electrification of the freight system in minnesota: White paper*. Retrieved March 3, 2026, from https://www.dot.state.mn.us/ofrw/mfac/pdf/white-paper-electrification-of-freight.pdf

Kin, B., Hopman, M., & Quak, H. (2021). Different charging strategies for electric vehicle fleets in urban freight transport. *Sustainability*, *13*, 13080. https://doi.org/10.3390/su132313080

Konstantinou, T., & Gkritza, K. (2023a). Are we getting close to truck electrification? u.s. truck fleet managers' stated intentions to electrify their fleets. *Transportation Research Part A: Policy and Practice*, *173*, 103697. https://doi.org/10.1016/j.tra.2023.103697

Konstantinou, T., & Gkritza, K. (2023b). Examining the barriers to electric truck adoption as a system: A grey-dematel approach. *Transportation Research Interdisciplinary Perspectives*, *17*, 100746. https://doi.org/10.1016/j.trip.2022.100746

Langevin, A., & Riopel, D. (Eds.). (2005). *Logistics systems: Design and optimization*. Springer Science+Business Media.

Leung, J., & Peace, J. (2020). *Insights on electric trucks for retailers and trucking companies*. Retrieved March 4, 2026, from https://www.c2es.org/wp-content/uploads/2020/02/Insights-On-Electric-Trucks-For-Retailers-And-Trucking-Companies.pdf

Link, S., & Plötz, P. (2022). Technical feasibility of heavy-duty battery-electric trucks for urban and regional delivery in germany — a real-world case study. *World Electric Vehicle Journal*, *13*(9), 161. https://doi.org/10.3390/wevj13090161

Luman, R. (2026, January). *Europe's e-truck market gains speed – but the road is uneven*. ING THINK. https://think.ing.com/articles/europes-e-truck-market-speeds-up/

Mareev, I., Becker, J., & Sauer, D. U. (2018). Battery dimensioning and life cycle costs analysis for a heavy-duty truck considering the requirements of long-haul transportation. *Energies*, *11*(1), 55. https://doi.org/10.3390/en11010055

Meixell, M. J., & Norbis, M. (2008). A review of the transportation mode choice and carrier selection literature. *The International Journal of Logistics Management*, *19*(2), 183–211. https://doi.org/10.1108/09574090810895951

Melander, L., Nyquist-Magnusson, C., & Wallström, H. (2022). Drivers for and barriers to electric freight vehicle adoption in stockholm. *Transportation Research Part D: Transport and Environment*, *108*. https://doi.org/https://doi.org/10.1016/j.trd.2022.103317

Mercedes-Benz Trucks. (2026). *Eactros*. Retrieved March 3, 2026, from https://www.mercedes-benz-trucks.com/int/en/trucks/eactros.html

Ministerie van Infrastructuur en Waterstaat. (2026). *Programma vrachtwagenheffing*. Retrieved March 16, 2026, from https://www.vrachtwagenheffingsbeleid.nl/

Mirhedayatian, S. M., & Yan, S. (2018). A framework to evaluate policy options for supporting electric vehicles in urban freight transport. *Transportation Research Part D: Transport and Environment*, *58*, 22–38. https://doi.org/10.1016/j.trd.2017.11.007

Moons, S., Ramaekers, K., Caris, A., & Arda, Y. (2017). Integrating production scheduling and vehicle routing decisions at the operational decision level: A review and discussion. *Computers & Industrial Engineering*, *104*, 224–245. https://doi.org/10.1016/j.cie.2016.12.010

Müller, C. (2024). Transition to battery-electric and fuel cell heavy-duty trucks: A multi-level, multi-dimensional approach. *Transportation Research Part D: Transport and Environment*, *127*, 104052. https://doi.org/10.1016/j.trd.2024.104052

Nykvist, B., & Olsson, O. (2021). The feasibility of heavy battery electric trucks. *Joule*, *5*(4), 901–913. https://doi.org/10.1016/j.joule.2021.03.007

Otero-Palencia, C., Jaller, M., Amaya-Mier, R., & Meza, J. (2026). Battery electric truck deployment, collaborative routing, and charging infrastructure: Towards a sustainable freight movement system. *Transportation Research Part A: Policy and Practice*, *203*, 104712. https://doi.org/10.1016/j.tra.2025.104712

Özlü, L., & Çelebi, D. (2024). Electrifying freight: Modeling the decision-making process for battery electric truck procurement. *Sustainability*, *16*(9). https://doi.org/https://doi.org/10.3390/su16093801

Petroni, M., & Getachew, H. (2025). *Road to real zero freight trucking in europe*. Retrieved March 4, 2026, from https://ca1-clm.edcdn.com/publications/Road-to-real-zero-freight-trucking-in-Europe.pdf

Raoofi, Z., Mahmoudi, M., & Pernestål, A. (2025). Electric truck adoption and charging development: Policy insights from a dynamic model. *Transportation Research Part D: Transport and Environment*, 104515. https://doi.org/10.1016/j.trd.2024.104515

Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). Free Press.

Roman, G., & Zadek, H. (2024). Zero-emission heavy-duty trucks in logistics: A systematic review and analysis of relevant adoption parameters. In F. Concli, L. Maccioni, R. Vidoni, & D. T. Matt

(Eds.), *Latest advancements in mechanical engineering: Proceedings of the 3rd international symposium on industrial engineering and automation (isiea 2024), volume 2* (pp. 101–115, Vol. 1125). Springer. https://doi.org/10.1007/978-3-031-70465-9

Rubal, D., & Almutairi, S. (2025). A perspective on emerging policy and economics research priorities for enabling low-carbon trucking. *Energy Research & Social Science*, *124*, 104025. https://doi.org/10.1016/j.erss.2025.104025

Sader, K. M., Biswas, S., Jones, R., Mennig, M., Rezaei, R., & Green, W. H. (2025). Battery electric long-haul trucking with overnight charging in the united states: A comprehensive costing and emissions analysis. *Applied Energy*, *384*, 125443. https://doi.org/10.1016/j.apenergy.2025.125443

Scherrer, A., Ziemsky, V., & Ertelt, S.-M. (2026). From early adopters to early majority: Barriers and policy support needs for battery-electric truck adoption in germany and sweden. *Transport Policy*, *181*. https://doi.org/https://doi.org/10.1016/j.tranpol.2026.104076

Shoman, W., Yeh, S., Sprei, F., Plötz, P., & Speth, D. (2023a). Battery electric long-haul trucks in europe: Public charging, energy, and power requirements. *Transportation Research Part D: Transport and Environment*, *121*, 103825. https://doi.org/10.1016/j.trd.2023.103825

Shoman, W., Yeh, S., Sprei, F., Plötz, P., & Speth, D. (2023b). Public charging requirements for battery electric long-haul trucks in europe: A trip chain approach [Fraunhofer Institute for Systems and Innovation Research (ISI), DOI: 10.24406/publica-694]. *Working Papers "Sustainability and Innovation" S01/2023*.

Smit, R., Helmers, E., Schwingshackl, M., Opetnik, M., & Kennedy, D. (2024). Greenhouse gas emissions performance of electric, hydrogen and fossil-fuelled freight trucks with uncertainty estimates using a probabilistic life-cycle assessment (plca). *Sustainability*, *16*(2), 762. https://doi.org/10.3390/su16020762

Speth, D., & Plötz, P. (2024). Depot slow charging is sufficient for most electric trucks in germany. *Transportation Research Part D: Transport and Environment*, *128*, 104078. https://doi.org/10.1016/j.trd.2024.104078

Speth, D., Plötz, P., & Wietschel, M. (2025). An optimal capacity-constrained fast charging network for battery electric trucks in germany. *Transportation Research Part A: Policy and Practice*, *193*, 104383. https://doi.org/10.1016/j.tra.2025.104383

Sugihara, C., Hardman, S., & Kurani, K. (2023). Social, technological, and economic barriers to heavy-duty truck electrification [https://doi.org/10.1016/j.rtbm.2023.101064]. *Research in Transportation Business & Management*, *51*.

Sugihara, C., Hardman, S., & Kurani, K. (2024). Who decides which trucks to buy? implications for electrifying freight fleets. *Transportation Research Part D: Transport and Environment*, *126*, 104015. https://doi.org/10.1016/j.trd.2023.104015

Suneson, A., Kässer, M., Schneiderbauer, T., Blos, A., & Becker, H. (2025, November). *Europe's ze truck transition: Key for decarbonization—and competitiveness*. McKinsey & Company.

Then, J., Agalgaonkar, A. P., & Muttaqi, K. M. (2025). Planning for medium- and heavy-duty electric vehicle charging infrastructure in distribution networks to support long-range electric trucks. *Energies*, *18*(4), 785. https://doi.org/10.3390/en18040785

Wexler, M. N. (2001). The who, what and why of knowledge mapping. *Journal of Knowledge Management*, *5*(3), 249–264. https://doi.org/10.1108/EUM0000000005868

Zgonc, B., Tekavčič, M., & Jakšič, M. (2019). The impact of distance on mode choice in freight transport. *European Transport Research Review*, *11*(10). https://doi.org/10.1186/s12544-019-0346-8

A

Interview questions

General:

1. Could you briefly describe your role and how you are involved in electric truck adoption or procurement decisions?
2. What do you see as the main reasons why some companies move earlier than others toward electric trucks?
3. What triggered the organisation to start exploring electric trucks in the first place?
4. For which transport profile does your organization currently use electric trucks or is considering their use?

Decision-making:

1. Which decisions need to be made before a company can move toward procuring electric trucks?
2. Can you walk me through how electric truck adoption or procurement decisions are made in your organisation?
3. Who is involved in these decisions, and how are the responsibilities divided?
4. How do you balance financial considerations, operational feasibility, and sustainability goals when deciding whether to invest?
5. How does the decision-making process differ across transport profiles, such as short-haul, medium-haul, and long-haul, within your organisation? (in case of multiple transport profiles)
6. Which external actors influence the decision-making process, such as OEMs, energy providers, grid operators, policymakers, leasing companies, or customers?
7. Which criteria are the most important in the final procurement decision?

Barriers and drivers:

1. What are the main drivers for considering or adopting electric heavy-duty trucks?
2. What are the main barriers that make adoption or procurement difficult?
3. How do these drivers and barriers influence the actual decision-making process?
4. How does your organisation deal with these drivers and barriers in practice?
5. To what extent do you expect barriers and drivers for truck electrification to change in the future?

Additional questions:

1. How do you determine whether a specific transport operation or route is suitable for an electric heavy-duty truck?
2. Transport margins are often tight. How does your organisation balance those margins with the relatively high costs and risks associated with BETs?

3. What is your organisation's charging strategy, and how was this strategy decided upon?
4. How are decisions regarding charging infrastructure made, and how do these relate to vehicle procurement decisions?
5. Has your organisation used pilots or small-scale trials before making broader procurement decisions? If so, what was learned from them?

B

Use of AI in constructing the directed relationship matrix

Purpose and role: I used a generative AI model as a structured tool for one labour-intensive coding step: scanning all interview transcripts for directed relationships between the fifteen procurement decisions. The AI did not replace the analysis. Interpretation and final responsibility for the results remain mine.

Tool and input: The work was carried out on Thursday 18 June 2026 using Claude Opus 4.8. I supplied three inputs: the full list of fifteen decisions (grouped strategic, tactical, operational), a document containing all fourteen interview transcripts, and the visual of my decision-making structure.

Task: The prompt I gave (originally in Dutch, translated here) was: ”Could you create a directed relationship matrix with frequencies for me. Make sure the directed relationship matrix contains all decisions on both axes. The relationships between the same decisions you may mark as a black box. If there is no relationship, leave it empty. Where there are links between decisions, you may indicate with a frequency how often this came up in the interview transcripts. Make sure all arrows from my visual are argued for in your matrix. If you have suggestions for new arrows/adjustments, let me know.”

Output: The model produced a 15x15 directed matrix (rows = source, columns = target), with frequency defined as the number of interviews showing each link, a written justification per arrow with supporting interviews and short quotes, and five suggested additions.

How I checked and validated the output: I treated the AI output as a first draft that I had to verify myself. I first went through my own visual and confirmed that every arrow in it also showed up in the matrix, so nothing was lost. For the frequencies, I checked that each one was linked to specific interviews (I1 to I14) and I went back to a number of those transcripts to read the relevant passages and confirm the link was really there. I also did some basic sanity checks on the structure, such as the black diagonal, the empty cells, and whether the number of incoming and outgoing relations per decision made sense. On top of that, I looked critically at the five suggestions the model made for new arrows, of which I kept four and left one out because it did not fit the scope of my model. Finally, I compared the conclusions from the matrix with a separate structural reading of it to verify the outcomes.

Reproducibility: Generative AI is not fully deterministic, so an identical prompt may yield slightly different wording or counts on a rerun. The frequencies are a form of analyst coding of qualitative material and represent relative weight, not exact measurements. For this reason the output is documented transparently (model, date, prompt, inputs, supporting interviews per link) and was manually verified, so that the reasoning rather than the exact run can be reproduced and checked.

Alternative considered: Another option would have been AI-assisted coding within ATLAS.ti, the qualitative analysis software. I assessed its AI coding features as not yet developed enough for this task: the relationship matrix required reasoning across multiple long transcripts at once and mapping inferred links onto a predefined decision structure, which goes beyond the segment-level auto-coding that ATLAS.ti currently offers. Claude Opus 4.8 handled this cross-document relational reasoning more effectively, while I retained the same researcher-led verification I would have applied to any tool.