

Exploring Data Sharing through the Lens of Open Data Ecosystems in Public- Private Freight Logistics



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ABSTRACT

Background: The freight transport sector is expected to grow, and with sustainability challenges, there is a need for more efficient solutions. Data sharing has been identified as one approach to increase efficiency in the domain of freight logistics by sharing transport-related information within an Open Data Ecosystem (ODE). This enables involved actors to collaborate towards a common goal, supported by a technological platform.

Objective: This thesis aims to develop a conceptual, empirical, and design-oriented understanding of data sharing through the lens of ODEs. Within the context of municipal and regional freight logistics, the thesis investigates how data sharing is organized in practice and explores design insights that may support the development of more efficient and sustainable freight logistics through data sharing solutions.

Methodology: The research follows a design science research approach consisting of three interconnected studies. The first paper employs a literature review to develop a conceptual understanding of data sharing in ODEs in relation to logistics. The second paper builds on this understanding through a longitudinal multiple-case study of three cases, involving prolonged participation with stakeholders and validation through a workshop. Drawing on the findings from the first two studies, the third study takes initial steps towards the solution domain by exploring design insights and mechanisms from cross-sector domains.

Results: The results show that data sharing emerges as a central mechanism within ODEs, but it takes different forms depending on elements such as technical maturity, organizational structure, and governance arrangements. A conceptual model was developed to illustrate platforms, stakeholders, relationships, and roles. The findings identify recurring socio-technical challenges related to interoperability, data quality, governance, procurement, and sensitive data. Building on these findings, we identified design insights and supporting mechanisms that may contribute to the development of more flexible and interoperable data sharing platforms.

Conclusion: The thesis contributes a conceptual understanding of data sharing in ODEs, an empirical understanding of data sharing in municipal and regional freight logistics, and initial design-oriented knowledge in the form of design insights and mechanisms. The research progresses from the problem domain towards the solution domain, where the identified design insights provide a foundation for future research concerning the development and evaluation of TMS platforms.

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John Larsson

Lund, 2026

“Flour + Water + Salt + Yeast + Time”

LIST OF PUBLICATIONS

This thesis consists of an introduction section and the three papers listed below. The introductory section provides an overview of the research presented in the thesis of the included papers. Throughout the introduction section, the papers are referred to by Roman numerals (Papers I–III).

Included Publications

I Enabling Data-sharing in Logistics through Open Data Ecosystems – A Literature Review

John Larsson, Johan Linåker, Per Runeson.

Proceedings EGOV-CeDEM-ePart conference, September 1-5, 2024. Ghent University and KU Leuven, Ghent/Leuven, Belgium.

URL: <https://ceur-ws.org/Vol-3737/paper4.pdf>

II Exploring public-private data sharing practices through the lens of Open Data Ecosystems: A multiple case study on municipal and regional freight logistics

John Larsson, Johan Linåker, Per Runeson.

Submitted to a journal, under revision

III Design insights for a flexible and interoperable data sharing platform for last-mile logistics

John Larsson, Johan Linåker, Per Runeson.

Unsubmitted manuscript

Contribution statement

All papers included in this thesis have been co-authored with other researchers. John Larsson, the first author of the three included papers, had the main responsibility for all stages of the research process and conducted the majority of the writing. The specific contributions to Papers I–III are outlined below.

Paper I

John Larsson initiated and conducted the study with the assistance of Johan Linåker and Per Runeson. John Larsson conducted the data collection, analysis, and the majority of the writing. The co-authors contributed through scientific discussions, feedback, and revisions of the manuscript.

Paper II

John Larsson initiated and conducted the study with the assistance of Johan Linåker and Per Runeson. John Larsson, Johan Linåker, and Per Runeson conducted the data collection through interviews. John Larsson conducted the analysis and the majority of the writing. The co-authors also contributed through scientific discussions, feedback, and revisions of the manuscript.

Paper III

John Larsson, together with Johan Linåker and Per Runeson, designed the study. John Larsson was responsible for data collection, analysis, and most of the writing. Johan Linåker and Per Runeson contributed through scientific discussions, feedback, and manuscript revisions.

Use of AI tools

AI tools were used in this thesis to support grammar checking, language refinement, and text editing. The suggestions provided by these tools were critically evaluated and revised when considered relevant.

Contents

Introduction	1
1 Introduction	1
2 Background	2
2.1 Open data ecosystems	2
2.2 Elements of data sharing in open data ecosystems	3
2.3 Data sharing platforms and boundary resources	4
3 Research methodology	5
3.1 Paper contributions	7
3.2 Research methods in Papers I-III	8
3.2.1 Literature review	8
3.2.2 Multiple case study	8
3.2.3 Exploration of design insights	9
4 Results	10
4.1 Paper I	10
4.2 Paper II	10
4.3 Paper III	12
5 Synthesis	13
5.1 From conceptual understanding to empirical insights (RQ1–RQ2)	13
5.2 From challenges to design insights: Towards flexible and interoperable data sharing platforms (RQ2–RQ3)	15
6 Threats to validity	16
7 Future work	18
7.1 Paper IV: Validation of design insights	19
7.2 Paper V: Architectural development of TMS platforms	19
7.3 Paper VI: Validation and evaluation	20
8 Conclusion	21

Included Papers 23

I	Enabling Data-sharing in Logistics through Open Data Ecosystems	
	– A Literature Review	25
1	Introduction	26
2	Research Design	26
3	Results	28
3.1	Open Data Ecosystems	28
3.2	Open data ecosystems in logistics	30
3.3	Horizontal Collaboration in freight logistics	31
4	Discussion	32
4.1	ODEs in logistics	32
4.2	Threats to validity	34
5	Conclusions	34
II	Exploring public-private data sharing practices through the lens of Open Data Ecosystems: A multiple case study on municipal and regional freight logistics	37
1	Introduction	38
2	Background & related work	39
2.1	Glossary	39
2.2	Open data ecosystems	40
2.3	Activities, elements, and roles within ODEs	41
2.4	Governance structure of ODEs	41
2.5	Quality of data in ODEs	42
2.6	Legal aspects of ODEs	42
2.7	Data sharing platform	43
3	Research design	43
3.1	Unit of analysis	44
3.2	Data collection	44
3.3	Thematic analysis	46
3.4	Cross case analysis	47
3.5	Ethical considerations	47
3.6	Threats to validity	47
3.6.1	Internal validity	47
3.6.2	External validity	48
3.6.3	Reliability	48
3.6.4	Construct validity	48
3.7	Case descriptions	48
3.7.1	Helsingborg Municipality	49
3.7.2	Södertörn Municipalities	49
3.7.3	Predictive Movement	50
4	Results	50

4.1	Data sharing models in the three cases	54
4.1.1	Technical and organizational challenges	55
4.2	Logistics data sharing platforms and operational challenges	56
4.3	Roles and Governance Approaches	58
4.4	Sensitive data	60
4.5	Data quality	61
4.6	Procurement	62
4.7	Sustainability aspects	63
4.8	Summary proposition	64
5	Discussion	65
5.1	Platform configuration and design to enable data sharing in municipal and regional last-mile freight logistics	65
5.2	Enabling factors for data sharing	66
5.3	Sustainable freight transport	68
6	Conclusion	69
III Design insights for a flexible and interoperable data sharing plat-		
form for last-mile logistics		71
1	Introduction	72
2	Background and related work	73
2.1	Open data ecosystem	73
2.2	Platform	73
2.3	Governance	74
3	Design science research approach	74
3.1	Data collection	75
3.2	Data analysis	75
3.3	Problem domain and design baseline	76
3.4	Solution domain	77
3.5	Technological Rules	77
3.6	Threats to validity	78
4	Results	78
4.1	Boundary resources	79
4.2	Governance structure	80
4.3	Certified platforms and decentralized orchestration	80
5	Discussion	81
5.1	Standardized data sharing	82
5.2	Platform interoperability	82
5.3	Governance and orchestration of certified data sharing plat- forms	83
6	Conclusion	83
Bibliography		85

INTRODUCTION

1 Introduction

Air pollution is a major sustainability challenge [26], and the growing freight transport sector contributes substantially to this [84]. Therefore, more efficient freight logistics solutions are needed to achieve national [81, 63] as well as global [86] sustainability goals. One approach to improving the sustainability of freight logistics is data sharing of transport-related information, such as shipment information and transport demand. This enables strategic planning for more efficient co-loading, which, in this context, refers to consolidating goods in municipal and regional last-mile logistics, thereby reducing the number of transport operations and the associated environmental impact.

In municipal and regional last-mile freight logistics, data sharing among stakeholders can occur at varying levels of openness [14]. These variations in openness can be analyzed through the lens of an *open data ecosystem* (ODE), defined as a setting in which actors share data and collaborate toward a common goal, typically underpinned by a technological platform [70].

While prior research highlights the potential of data sharing and ODEs [41, 70, 39], there remains limited understanding of how ODEs function in practice within public-private partnerships in regional and municipal freight logistics. Furthermore, data sharing is not only a technical challenge but also involves socio-technical aspects such as data quality [6, 36], legal frameworks [70], roles [91, 53, 29], and governance structures [70], and is closely related to research on data sharing platforms and freight logistics [52, 48]. In this context, data sharing platforms can be understood as technical infrastructures that enable actors to interact and share data, where platform openness enables actors to use artifacts and reach beyond the local boundaries of the platform [52].

This thesis investigates key aspects of ODEs in public-private partnerships in regional and municipal freight logistics. It derives design insights and mechanisms aiming to support more efficient and sustainable municipal and regional freight logistics. Public-private partnerships refer to business relationships between public and private actors engaged in data sharing and how these shape the functioning of ecosystems.

This licentiate thesis primarily addresses the early stages of the design science process [19], focusing on problem identification and conceptual understanding in practice. In this thesis, we also take initial steps towards the solution domain, where potential solution concepts are explored. The research questions reflect this progression, moving from conceptual understanding based on the literature (RQ1), through empirical investigations (RQ2), to exploring design insights and design-oriented knowledge (RQ3). Accordingly, we address the following research questions:

- **RQ1:** What characteristics and challenges of public-private data sharing in open data ecosystems are identified in the literature in relation to logistics?
- **RQ2:** How do these challenges emerge in the context of regional and municipal last-mile freight logistics?
- **RQ3:** What design insights and mechanisms can be derived to address these challenges and support interoperable and flexible data sharing platforms within open data ecosystems?

2 Background

This section provides an overview of the theoretical foundations relevant to data sharing in ODEs. The background begins with the concept of ODEs, followed by a brief overview of elements influencing data sharing, and describes data sharing platforms and boundary resources.

2.1 Open data ecosystems

The literature does not provide a universal definition of an open data ecosystem (ODE) [53, 70]. Zuiderwijk et al. [91] define an ODE as a set of organizations and individuals that collaborate within a network, where their common interest lays the groundwork for the relationships among the actors. The collaboration is supported by a technological platform [31], creating an environment that allows actors to process and consume data [53]. These elements further contribute to innovation, business, and value creation.

Actors in the ecosystem can also collaborate on the data and related resources, such as standards and software, by exchanging information, resources, and artifacts across the network [31]. Drawing on the description of ODEs, Jussen et al. [33] conclude that data sharing in ecosystems has complex socio-technical challenges involving multiple aspects. These challenges include data quality, governance, roles, and contractual agreements. To address these aspects, there is a need to coordinate multiple actors, combine roles and responsibilities, and establish a shared standard among the involved actors. Together, these observations highlight the importance of the socio-technical aspects in relation to public-private

freight logistics, where involved stakeholders have different responsibilities, technical maturity, and capabilities to collaborate on data.

The ODE perspective is therefore particularly relevant for this thesis, which investigates how data sharing can support more efficient and sustainable municipal and regional freight logistics. How sharing of data supports organizations can also be seen in the literature by Melville et al. [46], indicating that data and information systems have an important role in reducing environmental impact by enabling more low-carbon operations and informed decision-making. We therefore consider data sharing as a critical component of supporting efficient and sustainable municipal and regional freight logistics, involving public and private actors to work on aspects such as orchestrating governance, sharing data, and enabling high-quality data. Building on this, it is also important to consider aspects such as *elements of data sharing in ODEs*, and *data sharing platforms and boundary resources*, which are further described below.

2.2 Elements of data sharing in open data ecosystems

The literature on ODEs highlights several key elements that shape how data sharing is organized and established. These elements include activities, roles, governance structures, data quality, and legal and regulatory aspects.

From an activity perspective, data sharing in ODEs involves processes such as publishing, analyzing, combining data, and providing feedback to data producers [91]. These activities are complemented by additional elements, including meta-data, quality management systems, and user pathways, which together support interoperability within the ecosystem. Data sharing also involves multiple roles, such as data providers, intermediaries, and data users [53, 91]. In this context, actors may assume one or more roles depending on the context, and different roles may overlap in terms of responsibilities [29, 53].

Governance structures also play a central role in shaping data sharing within ODEs by orchestrating actors. Bartolomucci et al. [7] further describe that governance between actors and data governance should be viewed together. The governance dimensions in the ecosystem should be considered from a socio-technical perspective, as the dimensions also influence how value and effectiveness are derived from the data.

Different governance configurations have been identified in the literature, as proposed by Dal Bianco et al. [10], ranging from *organization-centric*, to *consortium*, and *community-based*. Organization-centric governance is based on a single actor, and consortium-based governance circulates among actors or organizations, which may also be co-owned by the ecosystem actors. Community-based ecosystems have a different setup, where governance may be structured around the actors who are members of the ecosystem.

In some cases, a keystone actor may be established in the ecosystem and assume a central coordinating role, influencing the overall functioning and health of

the ecosystem [32, 27]. This can also be seen in keystone-centric governance structures [54], where a keystone actor can be a private organization, a public actor, or shared between involved stakeholders.

We consider the governance perspective as important for municipal and regional last-mile freight logistics, where the municipalities can assume the role of ecosystem orchestrators. This arrangement may position municipalities as coordinators between public and private stakeholders, providing responsibilities and control over the ecosystem. Municipalities may therefore influence coordination and data sharing between involved stakeholders. This also includes governance related to data quality and legal aspects, which are described further below.

Data quality is a critical component of data sharing, affecting both the efficiency and usability of the ecosystem. This includes several aspects and guidelines, such as usability, understandability, accuracy, timeliness, completeness, openness, transparency, consistency, and compliance, which have been identified as important dimensions of data quality [6, 36].

The legal aspects have an important role in data sharing practices. This includes issues related to data protection and licensing [70], where there is uncertainty around legal compliance [62]. To address these challenges, solutions for the legal uncertainties are also highlighted in the literature, where clearer guidelines and frameworks [17, 43], and agreements may be alternatives.

2.3 Data sharing platforms and boundary resources

A data sharing platform can be conceptualized as a technical infrastructure that enables data sharing between actors within an ecosystem. The platform serves as a central infrastructure by supporting functionalities such as technical architecture, governance, and interfaces [66]. In an ecosystem, the platform enables actors to process data, promote innovation, and create value. The platform can also exhibit variation in its technical and organizational structures, shaping how data is shared within the ecosystem [41].

A data sharing platform can be extended through complementary third-party software modules, for example through application programming interfaces (APIs) [47], enabling access to exchange data on common standards [67] and shared platform infrastructure. APIs may also support interoperability and facilitate collaboration among actors within ODEs [39].

Regarding the data sharing platform and its technical aspects, it can also be understood as a socio-technical system, encompassing organizational arrangements and standards that influence both the system and the actors involved [47].

Boundary resources constitute an integral component of ODEs [70]. Within data ecosystems, boundary resources are defined as the software tools and regulations that serve as interfaces between the platform owner and external stakeholders [25]. The interface also depends on the platform owner to provide ecosystem participants with appropriate boundary resources [41].

Boundary resources can be categorized into technical and social components. Technical boundary resources include elements such as software development kits and APIs, which extend the technical architecture among stakeholders, giving them access to the platform [25, 10]. APIs are among the most widely used boundary resources [10], facilitating data exchange within ecosystems. In addition, social boundary resources support knowledge transfer between actors. These include platform guidelines, documentation, incentives, and intellectual property rights [10].

APIs, as a technical boundary resource, enable actors within an ecosystem to communicate through a standardized interface, which in turn facilitates the exchange of key variables and data. This can include both static and real-time data [41]. Standardized data formats can also be considered a complementary mechanism. One approach could be to employ data models in the form of standardized data formats [41], ensuring that stakeholders within the ecosystem share a common understanding of the structure.

3 Research methodology

This thesis follows a design science research methodology inspired by Engström et al. [19], Runeson et al. [68], and Wieringa [88]. Design science aims to address real-world problems by developing generalizable design knowledge and artifacts within a specific domain, ultimately contributing to improvements in both practice and theory [19, 68]. The ultimate goal of practicing design science is also to develop an improvement expressed as a technological rule that provides a foundation for achieving a specific effect in a specific situation by applying a specific intervention [19]. In this context, an intervention can be understood as a treatment where an artifact is introduced into a problem context to achieve improvement [88].

This thesis adopts a pragmatic epistemological stance, where knowledge is viewed as useful for action to create intervention and change [45]. From this perspective, we develop knowledge using a design science research methodology by using multiple methods to create an understanding [61] of the domain. We develop this understanding by following Van Aken [3], where we have the ambition to develop knowledge that is grounded and linked to a real-world setting of the problem and solution domain.

In this thesis, the three papers included are studies of a longitudinal design science research process. Through prolonged participation with stakeholders over a period of approximately two and a half years, insights and findings were continuously revisited with respondents, grounding the knowledge within the empirical domain.

During this period, the research process is primarily in the early stages of the design science process. A significant part of the work has been conducted in the problem domain, focusing on problem identification and conceptual understanding

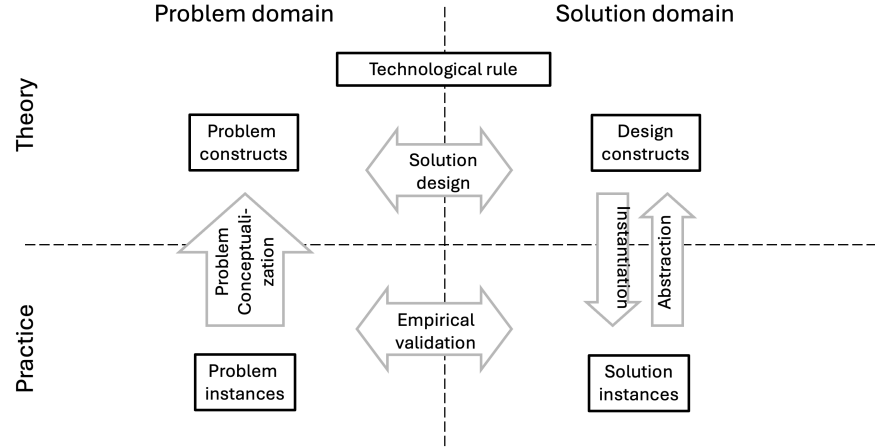


Figure 1: Illustration by Engström et al. [19], visualizing the activities and relationships in the design science process. This includes the problem domain, solution domain, and technological rules.

in practice, while initial steps have been taken toward the solution domain, where potential solution concepts and design knowledge are explored [19]. Figure 1 illustrates how the progression of the thesis follows a design science process, where it can be interpreted that each paper represents a step in the research process, moving from the problem understanding within the problem domain toward the solution domain. The first two studies are situated within the problem domain, contributing to conceptual and empirical understanding, while the third study moves toward the solution domain by exploring design insights relevant for the design constructs.

The progression of the papers included in this thesis can also be explained through Wieringa’s design science perspective, in which the research evolves through iterative cycles of problem investigation, treatment design, and treatment validation [88].

To interpret this progression, we adopt Wieringa’s distinction between knowledge questions and design problems. We use this perspective to complement Engström et al. [19] by explaining how the three included papers progress from the problem domain towards the solution domain. Figure 2 visualizes this progression. Knowledge questions concern understanding the area of exploration, while design problems involve designing artifacts for stakeholders to achieve their goals.

Conceptualizing Papers I-III in relation to Wieringa, we argue that Paper I focuses on knowledge questions by exploring the problem domain, and Paper II provides empirical insights into how the identified concepts and challenges are evident in practice. Together, these studies help answer knowledge questions about data

Activity:	Paper I	Paper II	Paper III
RQ	RQ1	RQ2	RQ3
Method	Literature study	Multiple case study	Design-oriented study
DSR activity (Engström et al.)	Problem conceptualization	Problem conceptualization + stakeholder validation	Towards solution design
Research focus (Wieringa)	Knowledge questions	Knowledge questions + emerging design problems	Design problems

Timeline: 

Figure 2: Research progression across the three papers from a design science perspective, progressing from problem conceptualization (problem domain) towards solution design (solution domain).

sharing in regional and municipal last-mile freight logistics. Building on this conceptual understanding, Paper III focuses on design problems by exploring design insights and mechanisms that may inform interventions in the solution domain. Accordingly, the research progresses from conceptual and empirical understanding in the problem domain to solution-oriented knowledge in the solution domain.

3.1 Paper contributions

Paper I establishes a conceptual understanding of enabling data sharing in logistics through ODEs. Through a literature review, it identifies key concepts, challenges, and characteristics, providing a theoretical foundation for the subsequent studies.

Building on this foundation, Paper II explores the problem domain empirically through a longitudinal, multiple-case study comprising three cases in municipal and regional freight logistics contexts. Through prolonged participation with stakeholders in the three cases, including recurring interviews and a validating workshop, the study provides insights into how data sharing functions in practice. The study identifies key challenges related to governance, platform interoperability, data quality, actor roles, and legal constraints. These empirical insights deepen understanding of how the problem manifests in real-world settings. Paper III builds further on the findings from the previous studies and moves toward the solution domain by adopting an approach that explores design insights. Based on the identified challenges, the study explores cross-sector approaches to derive design insights and mechanisms that can support the development of more flexible and interoperable data sharing platforms.

3.2 Research methods in Papers I-III

This section provides an overview of the research methods used in this thesis. The choice of methods reflects the different stages of the design science process, ranging from conceptual understanding to empirical investigation and a design exploration towards the solution domain.

3.2.1 Literature review

In Paper I, we employed a literature review to establish a conceptual understanding of data sharing in ODEs within the logistics domain. The review is inspired by an integrative approach proposed by Snyder [75], which enables the inclusion and synthesis of research across multiple domains.

To identify relevant literature, we applied a combination of search strategies. Following the guidelines by Wohlin [89], snowball sampling was conducted, with a starting set of two articles. This approach helped identify key studies and related work. Because the initial search indicated limited research in the freight logistics domain, we explored additional sources, including government literature.

To complement the snowball sampling, we conducted database searches using keywords related to data sharing and logistics. We screened the identified studies against predefined inclusion and exclusion criteria. Papers meeting the criteria were further reviewed and analyzed.

The analysis used thematic analysis, inspired by Braun and Clarke [12], in which the data were systematically analyzed and categorized into themes. These themes form the basis for our understanding of key aspects of data sharing in ODEs, including governance, data quality, legal frameworks, actor roles, and platform-related perspectives.

3.2.2 Multiple case study

In the second study, we adopted a qualitative multiple case study approach, inspired by Runeson et al. [60]. We used this method to explore data sharing practices in the context of municipal and regional freight logistics. Three cases were purposively selected, all of which share a common characteristic: they are public entities engaged in data sharing. This enabled us to investigate key aspects, including data sharing practices, data quality, legal frameworks, governance structures, and platform maturity.

The unit of analysis for the case study focuses on how public and private actors share and receive data in freight logistics to improve the efficiency of regional and municipal last-mile logistics. We explore the roles of actors and how they address aspects such as data quality, legal constraints, and governance. The selection of the unit of analysis was informed by the conceptual understanding developed in the preceding literature study.

Data collection was primarily interview-based, with interactions with respondents taking place over time. Prolonged participation [60] formed the basis for our interaction with actors within the cases. This approach enabled us to develop a deeper understanding of the complexity of the cases and provided opportunities to access the knowledge and perspectives of the involved actors through multiple interactions.

For data analysis, we conducted a thematic analysis inspired by Braun and Clarke [12]. The analysis followed a deductive approach, in which we derived themes from the research questions and insights from the literature review. To complement the thematic analysis, we also conducted a cross-case analysis, inspired by Yin [90]. This enabled us to compare and identify patterns across the cases, which were then synthesized into a higher-level conceptual structure that formed the foundation for a general conceptual model. To validate the findings, we conducted a workshop with respondents from the three cases. The workshop contributed to validating the analysis and supported further development of the higher-level conceptual model.

3.2.3 Exploration of design insights

In the third study, we adopt a problem-solution approach that focuses on developing design knowledge to address context-specific real-world problems [19]. This involves activities related to problem conceptualization, solution design, and validation [68].

The study builds on insights from the previous studies, including the literature review and the multiple-case study, which together provide an initial understanding of the problem domain. These prior studies also serve as the foundation for an abstracted understanding through problem conceptualization [68], further refining the problem domain.

Building on the problem domain, the study moves toward the solution domain, aiming to develop design insights that may contribute to future solution design. To identify relevant cross-sector domains, we conducted exploratory discussions with domain experts. This led us to investigate more mature approaches to data sharing, including the public transport sector and emerging regulatory frameworks in the logistics domain.

To gather relevant data from these domains, we reviewed existing publications in academic databases, as well as publicly available documentation and grey literature. Based on these data sources, we conducted a qualitative synthesis that enabled us to identify and abstract design insights and supporting mechanisms. These insights revealed promising patterns for addressing the problem conceptualization at a higher level of abstraction.

While the study is positioned as an analytical design study moving from the problem domain toward the solution domain, the identified design insights do not constitute fully developed or validated design knowledge. However, the identified

insights provide initial design contributions, which can be interpreted as a first step towards the development of design knowledge.

4 Results

This section presents an overview of the results from the included papers in this thesis. It begins with a literature review (Paper I), followed by a multiple-case study (Paper II) and a design-oriented study (Paper III). Each paper is presented as a subsection in this thesis.

4.1 Paper I

The literature review provides a conceptual understanding of data sharing in logistics through the lens of ODEs. The results indicate that, although there is no universally agreed definition of ODEs, they are consistently described as socio-technical systems in which organizations and individuals collaborate within a network based on a shared interest. This collaboration is supported by a technological platform that enables actors to process, share, and reuse data, facilitating value creation and innovation.

Across the reviewed studies, we identified several key components as central to the functioning of ODEs. These include governance structures, activities and roles, data quality, and legal aspects. Together, these components shape how data sharing is conducted, how collaboration is enabled, and how value is generated among involved actors within the ecosystem.

The study also reveals a gap in the literature regarding the application of ODEs in logistics. To address this gap, knowledge is drawn from cross-sector domains, such as public transport and horizontal collaboration in freight logistics. While horizontal collaboration highlights the importance of data sharing among actors, it is typically limited to actors at the same organizational level. In contrast, an ODE enables broader collaboration across multiple actors and organizational levels, including public and private stakeholders. Taken together, the findings highlight both the potential of data sharing in logistics and the lack of domain-specific knowledge on ODEs in freight logistics.

4.2 Paper II

The multiple case study provides an empirical understanding of how data sharing for municipal and regional freight logistics is conducted in practice. Across the three cases, data sharing emerged as a central mechanism, but it takes different forms depending on technical maturity, organizational structure, and governance arrangements.

The findings highlight the importance of interoperable platforms as central infrastructure for supporting more efficient data sharing and logistical coordination.

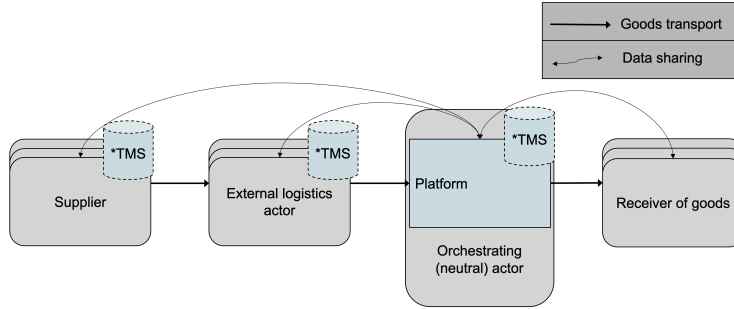


Figure 3: General conceptual model of data sharing and exchange of goods between actors from a holistic perspective. The thinner arrows represent data sharing between involved actors, while the wider arrows highlight the flow of goods between the supplier, external logistics actor, and goods receivers. The existing system and Transport Management System (TMS) can operate as integrated or standalone systems that support logistics services.

However, the practical use of the examined platforms reveals several challenges, including limited interoperability between systems, reliance on manual processes, varying levels of technical capability, and system lock-ins. As a result, these challenges constrain the efficiency of data sharing among municipal and regional actors.

To synthesize the findings across the three cases, we developed a conceptual model, as presented in Figure 3. From a holistic perspective, the model visualizes a central data sharing platform together with involved stakeholders, systems including transport management systems (TMS), relationships, and roles. The TMS is positioned as a supporting system for logistics operations and may either be integrated with existing systems or positioned as a standalone system. The model captures relationships between the involved actors, highlighting the exchange of data and physical goods within the ecosystem. Another important aspect highlighted by the model is how data sharing is enabled through a combination of platform coordination and system integration, creating interoperability between actors. However, data sharing within the ODE does not depend on a single system or actor. Instead, it emerges through the orchestration of multiple actors and systems and can be interpreted as a socio-technical system.

Another central finding concerns the variation of roles and governance approaches among the cases. In one case, the municipality acts as a neutral facilitator, assuming the role of a central actor, fostering engagement and reducing competition among involved actors. In contrast, another case is characterized by a governance structure where an externally procured actor undertakes the role of a central actor. These approaches shape how collaboration and control are distributed within the ecosystem, thereby influencing the coordination of data sharing and logistics

operations.

Furthermore, the study identifies recurring challenges in handling data across cases. This includes aspects related to data quality, sensitive data, and procurement. Data quality varies across the cases in terms of accuracy, completeness, compliance, and timeliness, which in turn affects the efficiency and integration of the ecosystem.

The handling of sensitive data highlights the balance between transparency requirements and the need for confidentiality, as well as compliance with regulations such as the GDPR. In addition, public procurement is found to have a dual role, as it can act as an enabler for requirements on data sharing, but also as a constraint by limiting flexibility among actors.

Finally, the findings indicate that data sharing may support more sustainable freight logistics practices by enabling the integration and monitoring of key sustainability aspects. However, these opportunities are often limited in practice due to operational and organizational constraints.

4.3 Paper III

The third study builds further on the empirical findings from the multiple-case study (Paper II) by exploring data sharing solutions in cross-sector domains. We aim to identify design insights, illustrated in Figure 4, that might support the development of more flexible and interoperable data sharing platforms.

Through a design-focused analysis, several key insights are identified based on the public transport sector and emerging regulatory frameworks in freight logistics. The insights are synthesized into a set of design mechanisms illustrating how components can be integrated into a data sharing platform.

The key design insights include boundary resources, governance structures, and certified platforms within the eFTI framework [23]. Rather than developing new concepts, these insights were identified from more mature data sharing domains and a regulatory framework, and analyzed as relevant design insights for addressing the challenges identified in Paper II. Regarding boundary resources visualized in Figure 4, these can support flexibility and interoperability between actors through mechanisms such as APIs and standardized data formats.

These insights are underpinned by mechanisms such as application programming interfaces (APIs) and standardized data formats, which enable platforms and systems to communicate.

The study also identified an alternative design approach based on the emerging regulatory framework, eFTI [23]. In this framework, rather than relying on a single platform, interoperability is achieved by standardized data formats and certified platforms, supported by mechanisms such as reference architecture and decentralized governance.

The identified design insights collectively indicate different approaches to achieving interoperability and flexibility in data sharing platforms. While centralized

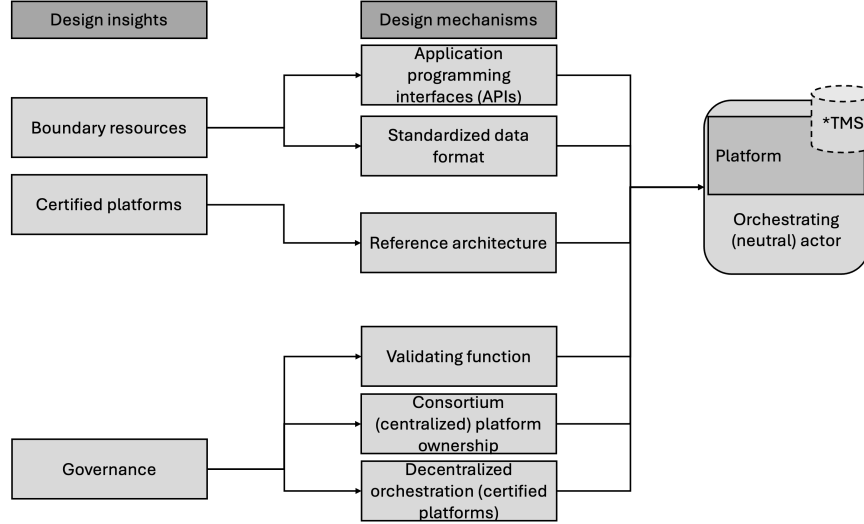


Figure 4: The figure illustrates the design insights (left side of the figure) and associated design mechanisms (middle), and how these elements influence the orchestration of data sharing platforms (right side). This includes elements such as governance structure, boundary resources, and reference architecture.

governance relies on a neutral actor and a shared platform, decentralized governance instead relies on certified platforms that adhere to common formats, thereby fostering collaboration across independent systems.

5 Synthesis

This section synthesizes the findings of the thesis by integrating insights from the three included papers. The synthesis follows a progression from conceptual understanding to empirical insights and, further, to design insights. The section presents how the research moves from the problem domain towards the solution domain, addressing RQ1–RQ3.

5.1 From conceptual understanding to empirical insights (RQ1–RQ2)

The literature review (Paper I) and empirical findings (Paper II) establish a conceptual understanding of data sharing, which constitutes the primary collaboration activity within the ODE. Previous research described ODEs as socio-technical

systems in which actors collaborate around data through relationships supported by technological platforms, resources [53, 70, 91], and governance structures [7]. From this perspective, data sharing can enable actors to create value and coordinate logistics operations, facilitating stronger relationships and value creation across organizational boundaries. Data sharing in the ecosystem can therefore be viewed as a central mechanism that creates value among involved public and private actors, not limited to those within a common organizational hierarchy.

However, the empirical findings from the multiple case study (Paper II) demonstrate that while data sharing is essential for value creation, it is also associated with challenges. This is also consistent with previous research, which highlights that data sharing in ecosystems presents complex socio-technical challenges related to data quality, governance, roles, and contractual agreements [33]. Similar to the literature, our empirical study shows that the functioning of ODEs is not only a technical configuration but also depends on several interrelated socio-technical factors. Also, while many of the identified elements are evident across the investigated cases, their implementation varies depending on technical maturity, governance arrangements, and organizational structures.

In particular, we could see that data sharing is highly dependent on the underlying technical platform infrastructure, serving as a backbone for the ecosystem and creating an environment for efficient data sharing. This observation supports previous research describing technical platforms serving as central infrastructure [66], enabling actors to process data, promote innovation, and create value [41]. Also, previous research highlights the importance of platforms to support collaboration and relationships among actors in ODEs [53, 70]. Although platforms enable stronger collaborations and relationships, the analysis revealed several operational challenges, including limited interoperability between internal systems, manual processes, a lack of automation, varying levels of technical capability, and system lock-in. This highlights that the conceptualization of data sharing requires further insights to account for the complexity encountered in practice.

Furthermore, empirical findings show that enabling factors such as data quality, legal aspects, public procurement, and governance structures play a significant role in shaping the ecosystem's performance in practice. These findings also strengthen the previous literature, which highlights data quality, legal aspects, and governance as playing a central role in shaping the ODE [7, 6, 70]. However, as the ODE represents a socio-technical system, the empirical findings also illustrate that its components are interconnected and require continuous balancing in practice. These elements introduce important trade-offs, for example, between data quality and data volume, or transparency and confidentiality. Another key trade-off is observed in the context of public procurement, which can serve as a central governance mechanism and a constraint, as the requirements must align with the capabilities of the market.

5.2 From challenges to design insights: Towards flexible and interoperable data sharing platforms (RQ2–RQ3)

The findings from Paper I and Paper II provide a conceptual and empirical understanding of the identified challenges within the domain, particularly related to interoperability, governance structure, data quality, legal aspects, and procurement practices. These challenges can be considered interrelated and reflect a balance between technical and organizational considerations that influence the data sharing practices. While Paper I and Paper II provided this understanding, they also revealed a gap between the problem domain and the solution domain. To address this gap, Paper III adopts an exploration of design insights approach, moving from the problem domain towards the solution domain by exploring design-oriented knowledge to support the configuration of data sharing platforms.

Through this exploration of design insights approach, Paper III identifies a collection of design insights and associated mechanisms that aim to address the challenges observed in the empirical cases. The insights cover boundary resources, governance structures, and certified platforms.

For boundary resources, these include standardized APIs and data formats, providing structured interfaces for data exchange and fostering interoperability across stakeholders and systems. The relevance of boundary resources became evident through the fragmentation and interoperability challenges identified in Paper II. Across the cases, data sharing was constrained by varying levels of technical maturity, manual processes, and limited interoperability among existing systems. Previous research has shown that boundary resources constitute an important mechanism for enabling interaction between the platforms and involved stakeholders in the ecosystems [25, 10]. However, the empirical findings underscore the importance of these mechanisms for municipal and regional last-mile logistics. From this perspective, boundary resources in the form of standardized APIs and data formats can be viewed not only as a technical solution but also as a mechanism to reduce fragmentation and increase collaboration among stakeholders with varying technical maturity, organizational structures, and governance arrangements.

The design insight related to governance emphasizes the importance of a central or neutral orchestrating actor, combined with mechanisms of validation functions and platform ownership structure. This follows previous research, highlighting that governance structures and orchestrating actors have an important role [7] in coordinating the ecosystem and facilitating collaboration through data sharing among the stakeholders involved in the ecosystem [32, 27]. However, the empirical findings in Paper II emphasized challenges related to municipal and regional freight logistics. In the examined cases, there is often a mismatch between responsibility and control in the municipalities, constraining data sharing practices. Even though municipalities believe that data sharing is an area they have under control, governance is often limited by other factors, such as procurement, capacity, and technical constraints. A central or neutral orchestrating actor with a valida-

tion function can therefore be seen as a mechanism for mitigating the mismatch observed in Paper II, while facilitating coordination and collaboration among involved stakeholders.

The design insight of certified platforms and the connected mechanism of reference infrastructure enable decentralized but standardized data sharing. While previous literature highlights interoperability as an important aspect in terms of technical platforms [70, 25, 10], the empirical findings show challenges related to interoperability, technical capabilities, and system lock-ins. From this perspective, certified platforms and reference architectures can be interpreted as insights that enable interoperability without relying on a central platform orchestrated by one actor. This design approach may therefore support interoperability across the data sharing platforms, while reducing the risk of system lock-ins, thereby addressing challenges related to flexibility and variations in technical capabilities among actors.

When synthesizing the findings across the three papers, the papers demonstrate a progression of the research. Paper I provides a conceptual foundation by identifying key components in the literature on data sharing in the ODE. Paper II extends this with a deductive approach by conducting a multiple-case study demonstrating how these components are shaped by socio-technical complexity in practice, revealing interrelated constraints. Extending these insights and perspectives, Paper III builds on these identified challenges and explores design-oriented knowledge, identifying design insights and mechanisms that can support the development of more flexible and interoperable data sharing platforms in the context of municipal and regional last-mile logistics.

6 Threats to validity

This thesis builds on three individual studies, each with its own methodological approach and associated threats to validity. Instead of repeating the validity assessment of the individual research papers, we use this section to reflect on the threats to validity at the meta-level, following Runeson et al. [68] and Engström et al. [19]. Following the design science research approach, Runeson [68] describes the framework of problem conceptualization, solution design, and validation. If there is interest in learning more about the threats to validity in our research, we refer readers to the individual papers.

Problem conceptualization. Threats related to the problem conceptualization, which is a key part of the research process, concern how the problem domain is interpreted and understood [68]. In this thesis, the problem conceptualization is derived from Paper I, presenting the conceptual understanding of data sharing in ODEs. This is then elevated into Paper II, where construct validity constitutes a threat to validity since we define the different concepts. These threats are reflected in Paper I, highlighting the risk that researcher bias may influence whether the se-

lected research is deemed suitable for the study. However, studies were selected from multiple databases using snowball sampling and included both academic and governmental literature, which might mitigate selection bias. Paper II builds further on this problem conceptualization, as it is an empirical study in which we aimed to ensure that the interview questions were closely aligned with the theoretical constructs being investigated.

Building on the problem conceptualization, external validity represents an additional potential threat in this thesis, especially in Paper I and II, as they are based on a limited set of contextual factors. Consequently, the conceptualized problems are expected to be applicable in contexts similar to those investigated in this thesis. Therefore, we acknowledge limitations regarding the transferability of our findings to other contexts.

Solution design. Solution design refers to the activity of relating the problem domain to the solution domain [68], where the focus is on developing concrete solution approaches [19]. This is the focus of Papers II and III, which relate to internal validity. In Paper II, for example, there is a risk that the thematic analysis might introduce researcher bias, as the data may be interpreted through the lens of previous research, influencing the selected themes. To mitigate these threats, we attempt to analyze from an abstract perspective, focusing on patterns and overarching themes. Also, multiple researchers conducted the coding process, strengthening the coding framework. Similar threats to internal validity are also evident in Paper III, where prior knowledge and experience may influence the identification of insights. This risk comes from both empirical knowledge and secondary data.

Validation. Threats related to empirical validation concern the grounding and transferability of the findings, particularly regarding the approach's applicability in other contexts [68]. In this thesis, we discuss validation in relation to internal and external validity. In Paper II, to strengthen the study's external validity, multiple cases from different areas were included. However, the limited sample size may restrict transferability to other contexts.

To mitigate threats to validity in Paper II, we used a variety of approaches, including multiple coders, workshop validation, and revised case interpretations. By using multiple coders in the thematic analysis, we reduced the risk of researcher bias: the first author conducted the initial coding, followed by the second and third authors, who coded independently. In addition, a validation workshop was held with interview respondents, during which the findings were discussed. This enabled us to receive feedback on the interpretations, and this process supported the credibility of the results by allowing respondents to validate them, ensuring that the findings reflected their experiences. Furthermore, the prolonged participation with the three cases allowed for repeated interactions with the respondents over time, including follow-up interviews. This facilitated iterative refinement of the case understanding, allowing interpretations to be revisited and validated in subsequent interviews with the cases.

In Paper III, threats to validity primarily relate to the generalization of the

findings. To address this, we applied analytical generalization by conceptualizing the empirical data and design insights to a higher level of abstraction. However, as the study represents an early design step moving towards the solution domain, we do not claim that the findings of the study can be universally generalized. Instead, they should be interpreted as initial design knowledge that may support initiatives in similar contexts. We emphasize that further evaluation and validation of the proposed design insights are important directions for future work.

7 Future work

Several directions for future research can be identified based on the findings of this thesis. We structure these directions into three future studies (Papers IV–VI), extending the progression illustrated in Figure 2, where we now progress from the problem domain toward the solution domain, illustrated in Figure 5.

The future Papers IV–VI share a common focus on the development and evaluation of the conceptual architecture of a flexible and interoperable TMS platform for efficient co-loading in municipal and regional last-mile logistics. This aims to support regional and municipal actors through a more integrated system for procured logistics solutions. Drawing on the findings from Papers I–III, the future work is structured around the aspects and mechanisms identified in this thesis, including quality, legal, public procurement, boundary resources, and governance structures.

Activity:	Paper I	Paper II	Paper III	Paper IV	Paper V	Paper VI
RQ	RQ1	RQ2	RQ3	RQ4-RQ5	RQ6	RQ7-RQ8
Method	Literature study	Multiple-case study+workshop	Design-oriented study	Multiple-case study+Delphi-inspired workshop	Design-oriented study	Multiple-case study+workshop
DSR activity (Engström et al.)	Problem conceptualization	Problem conceptualization+stakeholder validation	Towards solution design	Towards solution domain	Solution domain	Solution domain+stakeholder validation
Research focus (Wieringa)	Knowledge questions	Knowledge questions+emerging design problems	Design problems	Design problems	Design Problems	Design problems+Knowledge questions

Timeline: 

Figure 5: Research progression across the three included papers (Papers I–III) and the three future papers (Papers IV–VI) from a design science perspective, progressing from problem conceptualization (problem domain) to solution design (solution domain).

7.1 Paper IV: Validation of design insights

From a design science perspective, one primary direction concerns the initial validation of the design insights identified in Paper III, with a focus on the future architectural development of a TMS. The study could be conducted using the cases from Paper II and extended to include additional cases involving external logistics actors and platform providers, thereby contributing to deeper design knowledge. By examining the design insights from Paper III, we could also validate how the proposed design insights can support scaling up municipal and regional data sharing and improved co-loading practices through the use of a TMS, particularly regarding public procurement, governance structures, data quality, and legal aspects. This may contribute to a TMS that could support more effective data sharing practices among involved actors. Corresponding research questions are:

- **RQ4:** To what extent are the identified design insights applicable for supporting interoperable data sharing within municipal and regional last-mile freight logistics?
- **RQ5:** How do external logistics actors and platform providers view the relevance of the identified design insights for future architectural development of a TMS?

Methodological approach:

To conduct this study, a qualitative multiple-case study is considered an appropriate methodological framework. Relevant activities may include validation-oriented, semi-structured interviews and a Delphi-inspired workshop involving stakeholders from the cases explored in Paper II and from additional cases. Conducting the study using these approaches would facilitate an understanding of the research questions (RQ4–RQ5). The combination of semi-structured interviews and Delphi-inspired workshops would also allow stakeholders to discuss, evaluate, and further develop the design insights and supporting mechanisms.

7.2 Paper V: Architectural development of TMS platforms

Building on the validated design insights in Paper IV, a possible path forward is to focus on the architectural development of TMS platforms. This includes examining how the technical components and underlying data infrastructures can be designed to support interoperable data sharing and more efficient co-loading practices among involved actors. This could involve expertise in database technology to support the design and evaluation of technical solutions.

- **RQ6:** How can validated design insights be conceptualized into the architectural design of TMS platforms to support more efficient municipal and regional freight logistics through improved co-loading and data sharing?

Methodological approach:

Following the Design Science Research approach, this study adopts a platform design approach (Design-oriented study) and focuses on the architectural development of TMS platforms. Building on the design insights in Paper IV, we would like to involve expertise in database technology. Through iterative design and evaluation cycles, this study would allow us to develop an architectural conceptualization of key platform components, requirements, standards, and interfaces. From Wieringa's perspective [88], this study can be viewed as a treatment design phase, in which validated insights develop into more concrete design concepts for solution propositions to address the challenges in the problem domain.

7.3 Paper VI: Validation and evaluation

Drawing on the validation and architectural development of TMS platforms in Papers IV-V, future research should evaluate the findings with relevant stakeholders. Such an evaluation could provide insights into how the architectural design, governance structure, and mechanisms can be applied within the examined cases to support data sharing and more efficient co-loading practices. Conducting this study with stakeholders involved in papers IV-V would therefore allow us to validate the findings, following Wieringa [88].

The following research questions are considered relevant for this study:

- **RQ7:** To what extent does the proposed interoperable TMS architecture support data sharing among stakeholders in municipal and regional last-mile logistics?
- **RQ8:** How do involved stakeholders evaluate whether the proposed governance structure and collaboration mechanisms support an interoperable TMS platform?

Methodological approach:

To conduct this study, we consider an evaluation-oriented approach, in line with design science [19], to be relevant. This would allow us to involve logistics companies engaged in data sharing and data platform management. As this is an evaluation study, we consider activities such as semi-structured interviews and workshops. This would allow stakeholders to evaluate and validate the findings from Papers IV-V, regarding the proposed architecture of a TMS platform, the supporting governance structure, and mechanisms. From Wieringa's perspective [88], this study can be interpreted as an initial treatment validation phase, in which we evaluate the proposed solutions with respect to the problem domain.

From a design science perspective, these directions may help strengthen the integration between the problem and solution domains, thereby supporting the development of an interoperable TMS platform, together with governance structures and supporting mechanisms. These studies can therefore contribute to the further

development and validation of insights for designing and developing data-sharing platforms within socio-technical ecosystems.

8 Conclusion

This thesis investigates data sharing in ODEs in the context of municipal and regional freight logistics, developing a conceptual, empirical, and design-oriented understanding. The conceptual understanding is captured through a literature review that identifies a research gap in the application of ODEs to freight logistics. The understanding is further explored in the empirical study, which shows that data sharing serves as a central coordination mechanism, enabling integration and value creation among actors.

However, the findings also demonstrate that ODEs are not only technical configurations but also depend on several interrelated socio-technical aspects, including interoperability, data quality, legal aspects, procurement, and governance structures. Building on these insights, we conducted a design-oriented study in which we identified several design insights and underlying mechanisms that may support the development of flexible and interoperable data sharing platforms for regional and municipal last-mile freight logistics. These include boundary resources, such as APIs and standardized data formats, as well as certified platforms supported by reference architecture and governance structures.

The research is framed using a design science process, where the literature review and multiple-case study contribute to the problem domain, and the design study takes initial steps toward the solution domain. The thesis thus contributes by providing a conceptual understanding, empirical insights, and design-oriented knowledge that may support the development of data sharing platforms. Future research will follow several directions, including validating and further developing the identified insights, exploring the architectural development of TMS platforms, and evaluating the findings with logistics actors.

INCLUDED PAPERS

ENABLING DATA-SHARING IN LOGISTICS THROUGH OPEN DATA ECOSYSTEMS – A LITERATURE REVIEW

John Larsson, Johan Linåker, Per Runeson

Abstract

Background: Road transportation is one of the main sources of CO_2 emissions. Making logistics more efficient, e.g., through co-loading freight transport, would reduce emissions. However, this requires the sharing of freight and routing data between actors in the logistics chain.

Aim: This study aims to explore the literature on how Open Data Ecosystems (ODEs) can be applied to the logistics sector. The study focuses on ODE governance, the actors involved, and legal and quality aspects.

Method: The literature review employed publication database search, snowball sampling, and selected governmental literature. Thematic analysis is carried out on the identified literature.

Results: The results indicate how an ODE can be applied to the logistics sector, although primarily evident in public transport. For freight transport, literature refers to Horizontal Collaboration. The literature is consistent in terms of governance of the ODEs and Horizontal Collaboration where there is typically a need for a neutral actor to take on the role of a platform provider to promote trust and enable collaboration.

Conclusions: We conclude that the two literature streams of ODEs and Horizontal Collaboration could be integrated and foster a more efficient logistics sector where data is shared among the involved actors. Our findings also indicate aspects underpinning the collaboration among actors.

1 Introduction

According to a forecast by the Swedish Transport Administration [84], transport work in Sweden is expected to increase by 47 % by 2040 compared to 2017. This calculation includes several different types of transport modes, such as road transport, railroad, and shipping. For road transport, the forecast indicates that there will be a 57 % increase in transport work between 2017 and 2040. Furthermore, the Government Offices of Sweden [26] describes that the transport sector is responsible for one-third of all greenhouse gas emissions to air, and road transport is a large part of this. Furthermore, it is described that one-fifth of all truck transports in the European Union drive without carrying a load [20].

Horizontal data-sharing and collaboration are reported as one important lever for such efficiency, e.g., by enabling co-loading and route-optimization in freight transport [82]. One means of contextualizing such sharing and collaboration is through the lens of Open Data Ecosystems (ODEs) [70].

In this study, we aim to *explore the literature on how ODEs can be applied to the logistics sector, both for public transport and freight transport. To create a frame of reference for our analysis, the study also focuses on how the ODE may be governed, which actors could be involved, and what aspects exist linked to legal and quality aspects.* Specifically, we define the following research questions:

RQ1 How can ODEs be applied and contextualized in logistics, how are they governed, and what activities and roles occur in the ecosystems?

RQ2 How can quality, legal, and format aspects of the data in these ODEs be characterized?

We conducted an integrative literature review [75] based on snowball search [89], exploration in the archives of the Swedish Transport Administration (Trafikverket), and exploration in the Scopus database. To analyze the results, we conducted a thematic analysis inspired by Braun and Clarke [12]. We limited the scope of the literature review by defining a focus by our research questions.

2 Research Design

In our literature review, we drew inspiration from Snyder’s *integrative* approach [75]. We utilized (1) snowball sampling, starting with an initial set, which yielded findings on what an ODE entails, as well as data sharing within logistics linked to public transport. However, we found no relevant articles on data sharing within freight transport. Therefore, we (2) searched the archives of the Swedish Transport Administration for governmental literature. Here, terms related to data sharing and logistics were identified, which were subsequently used in a (3) database query in Scopus.

Inclusion criteria	Exclusion criteria
Is about open data ecosystem or data ecosystem	Language of academic writings not English
Describes the governance of open data ecosystem	Not relevant for the research questions of the study
Quality /legal aspects of data sharing	Focus on software ecosystem
Open governmental data	
Data sharing in logistics / Horizontal Collaboration	

Table 1: Inclusion and exclusion criteria used in the study selection.

For each of the papers identified, we (4) iteratively performed an analysis process where the paper was first screened and matched against our inclusion and exclusion criteria as defined in Table 1. Papers meeting the criteria were further reviewed, starting with abstract reading. If deemed suitable based on criteria and research questions, entire articles were read. Thematic analysis [12] was conducted on selected scientific texts inspired by the guide of six steps, and the data was analyzed in a spreadsheet¹. Data analysis involved categorizing data into themes. Themes were based on research questions, allowing raw data categorization. Below, we describe in more detail how each of the three search steps was performed.

Snowball sampling was carried out according to Wohlin [89], where a starting set of two articles were chosen [70, 41]. Both forward and backward snowballing were carried out [89]. Linked to the snowball and inclusion/exclusion process, a total of 96 *scientific* texts were relevant, but after further analysis and duplicates removed, 24 *scientific texts* were considered relevant.

Archival analysis of governmental literature was launched in the Swedish Transport Administration's archives of technical reports. The governmental literature found was verified through discussions with experts within the Administration. The researchers explained their understanding of the texts, which was then confirmed. The search queries were: "transport efficiency data sharing" and "open data", which yielded *two relevant reports*. The search specifically highlighted the common use of the term Horizontal Collaboration (HC) to characterize data-sharing and collaboration.

Extended search through Scopus was conducted using the keywords "horizontal logistics collaboration". This search yielded 171 results, of which 38 articles were selected through review. Following this process, we opted to exclude 30 articles, *while eight articles* were deemed relevant for the study.

¹https://portal.research.lu.se/files/188680610/Snowball_and_database_search_spreadsheet.xlsx.ods

3 Results

In our review, we identified literature about ODE in general, applied to logistics, and indirectly through the concept of Horizontal Collaboration (HC) in logistics. In Section 3.1, we introduce ODEs as a background, including activities and roles, governance of the ecosystem, data quality, and legal aspects. In Section 3.2, we summarize the literature on ODEs in the context of logistics focusing on public transport. In Section 3.3, HC is presented, referring to *collaboration between actors in freight logistics regarding data sharing and other aspects*.

3.1 Open Data Ecosystems

This section describes the concept of an ODE, delineating the constituent roles and activities therein, as well as its structural composition. Moreover, it expounds upon the significance of data quality in the context of ODEs. Lastly, the legal aspects of ODEs are explained.

Definitions of ODEs. There is no universally agreed definition of a data ecosystem in the literature [53, 70, 35]. However, Runeson et al. [70] propose the following synthesized definition: ODEs are networked communities of actors (organizations and individuals), that base their relations on a *common interest*, supported by an underpinning *technological platform* that enables actors to process data (e.g., find, archive, publish, consume, or reuse) as well as to foster innovation, create value, or support new businesses. Actors *collaborate on the data and boundary resources* (e.g., software and standards), through the exchange of information, resources, and artifacts.

Activities and roles within ODEs Utilizing ODEs involves multiple activities, as outlined by Zuiderwijk et al. [91]. In addition to publishing, one must explore, evaluate, and consider the different licenses associated with the data, analyze and correct errors in the data, establish data linkages, and devise methods for data visualization, as well as interpret the data and give feedback to the producer of the data. Moreover, the literature highlights additional elements for ensuring interoperability: (1) determining optimal data utilization methods, (2) implementing a management system for data quality, and (3) establishing metadata connections between ecosystem elements.

Roles within a data ecosystem are also identified [29, 53, 35, 42, 91, 28], comprising essential ones, such as *data providers*, *service providers*, and *data users* [91, 53]. *Intermediaries*, act as links facilitating data use for different actors [53]. Additionally, Immonen et al. define a comprehensive set of roles [29]: *data broker*, *data provider*, *service provider*, *application developers*, *infrastructure and tool providers*, and *application users*.

Governance in ODEs The governance of the ecosystem can be described using five different categories: “intermediary-centric, platform-centric, marketplace-oriented, business model, and keystone-centered.” In the latter, actors are gathered around the central keystone actor [53], for example, a government or an authority [54, 27]. In the open government data (OGD) system, the state actor can stand as the central player. This implies according to Harrison et al. that the state actor also takes the lead in pursuing goals that contribute to efficient management and health within the system [27].

Quality of data in ODEs The data quality affects both the usability of the data and how much the ODE is utilized [71, 53, 9]. The ecosystem does not reach its full capacity when data quality is low [71, 6]. Several criteria related to how quality can be ensured in an ODE are also described in the literature [6, 87, 71, 43, 49]. It is also emphasized that there is no general definition of what constitutes data quality [6]. However, some guidelines can be used to influence the quality of shared data [6, 87]:

1. Usability – how easy it is for data consumers to use the shared data. The usability of data can be influenced by the quality of the data and therefore the variables listed below in 2–8 [6].
2. Understandability/Accessibility– how easily data consumers can find, access, and perceive the data and metadata correctly. [6, 87, 74].
3. Accuracy – how accurate the data is and how it is described with metadata [6, 87, 74, 49]. Also, metadata may contribute to interoperability [91].
4. Timeliness – how up-to-date is the shared data, including the up-to-date metadata [6, 87, 74].
5. Completeness – how complete is the shared data, such as the number of fields that are complete in metadata or data records. Missing important values can negatively impact the use of the ecosystem [6, 87, 49].
6. Openness – how open and accessible the data is, which may affect the use and reuse of the data. Both machine-readability and metadata formats influence [6, 74].
7. Transparency – how transparent the data published in the database is. For the actors to be able to trust the data, the data should be transparent [69, 38].
8. Consistency/Compliance – how the data complies with standards. Data and metadata should conform to a consistent format throughout the database [6, 87] and be available in electronic, machine-readable format [6, 9, 35]. Standards may also support interoperability of the data since the actors can work on the same level [41, 29].

Legal aspects of ODEs Fully open data should be licensed free to use [6]. However, there is legal uncertainty about the sharing and reuse of the data [69, 43] which in turn can create barriers to the use of the data. Various approaches are discussed to resolve the legal uncertainty surrounding rules and licenses for ODEs. Some studies mention clearer policies and guides to laws for open data [71, 43]. One study also described that licensing is important because it tells where and who can use the shared data [91]. However, the implementation of laws and regulations within ODEs can also act as a barrier that prevents the use of ODEs [34, 16, 71, 35]. Moreover, the laws can act as a driving wheel but also as a “red tape” where actors instead have more variables to deal with [34].

3.2 Open data ecosystems in logistics

This section explains how ODEs are applied and contextualized in literature, specifically in the area of logistics. Since the identified literature did not mention freight logistics, the section focuses on public transport and details the actors and elements involved in the reported ODEs and their governance. Additionally, the data formats within the reported ODEs are described.

Open data ecosystems in public transport logistics A number of studies [65, 64, 44, 40, 41], describe ODEs in public transport. The quality and standard of the data can have a major impact on the functioning of the ecosystem [64]. It can also be seen that if the system has access to high-quality data, it can provide added value for passengers using public transport, for example, give passengers a notification that they need to change modes of transport to reach their destination within their allocated time [64, 44].

Actors and elements of ODEs in public transport logistics Three studies [65, 40, 41] describe actors that can be included in an ODE connected to logistics. They describe the cases of Trafiklab and Helsinki Regional Transport (HSL), which are platforms with the purpose for actors to share data. Furthermore, Trafiklab can be considered a neutral platform governed by the involved actors as it is created by Samtrafiken, which is an organization owned by Swedish regional transport authorities and several of the regional transport operators [40]. Data shared on the platform can be traffic information, but also APIs. Trafiklab offers four APIs, to supply the users with both real-time and static data related to public transport disruptions. Additionally, not all APIs are managed by Trafiklab but rather by private and governmental organizations [40].

Governance of ODEs in public transport logistics ODEs can be mapped to an organizational structure model, called the “onion model” [51]. In the Trafiklab case, Samtrafiken is in the center, as they are the actors who hold the platform, orchestrating and having an influence on how the platform should be managed. In

the next layer, authorities of public transport are located as they have an ownership role of the system and Trafiklab. Then there are partners, service providers, and finally, end users.

Data formats in logistics ODE Some actors impose requirements on the standard and format of the data [65]. For instance, Google has its standard, “Google transit feed specification” (GTFS). For the data to be published by Google, the data shared by different actors had to meet certain criteria [65]. Samtrafiken has the opportunity to transform the incoming data to meet a certain standard instead [40]. However, there are risks when actors transform the data between different types of standards, and therefore Samtrafiken chose to develop a portal for this purpose.

3.3 Horizontal Collaboration in freight logistics

This section presents data sharing among stakeholders within Horizontal Collaboration related to freight logistics. It delineates what Horizontal Collaboration entails, and how it may be structured, and elucidates how a digital platform can be integrated into Horizontal Collaboration. Also, legal aspects associated with Horizontal Collaboration are explained.

Horizontal Collaboration and data sharing HC is a collaboration between two or more actors at a similar level [4, 8, 50, 85]. In such collaboration, entities can exchange different resources, such as freight flows, traffic flows, or goods flows [85]. Involved actors work together to achieve different goals, such as reducing operational costs, improving service, and minimizing the environmental impact [50]. HC can therefore lead to a more efficient transport sector [85] and a win-win situation, if the involved parties first examine whether they are strategically suited to cooperate with each other [4]. Further, products to be transported must be compatible, for instance, the goods transport environment [50].

Regarding information sharing, it is important to have effective communication between the involved actors [15]. A majority (70%) of HC fail due to factors, such as incompatible partners, information not collected efficiently, poor decision-making, and inadequate communication [50]. Information sharing between actors can be considered the “glue” that enables actors to collaborate and manage the relationships [72].

Governance in Horizontal Collaboration Horizontal Collaboration can be created at several different levels depending on the business model, ranging from less complex collaboration to more advanced [8].

Trust has an important function for HC [13, 72, 8, 1]. Mistrust among actors can hinder collaboration [13] and may stem from fear of sharing information, which competitors could exploit [72]. Furthermore, actors do not want to invest in others’ benefits, hence a neutral publicly funded platform could be a solution to

this [85]. This neutral organizer can also help with the coordination and management of the data being shared [50].

Legal aspects in connection to Horizontal Collaboration Governance can be regulated formally and informally [72]. In the formal case, the actors use contracts, which regulate relations and conditions in case there is any kind of ambiguity or conflict. In the informal case, governance is regulated by trust and communication among the actors within the collaboration.

Legislation, such as GDPR² and the Competition Act, is important to consider for any actors involved in the collaboration [85, 83]. Furthermore, when actors collaborate and share data, it is important that competition is not restricted, as it otherwise can lead to cartel formations [83, 8, 58].

4 Discussion

4.1 ODEs in logistics

The literature review results indicate a lack of a universal definition of what constitutes an *Open Data Ecosystem* [53, 70, 35]. Sharing data within the ecosystem is considered essential for fostering collaboration among the actors, as it serves as a “glue” facilitating relationships, as described in the results where data sharing is highlighted as a facilitator [50, 72].

Regarding the ODEs for logistics, research has focused on ODEs in the public transport context [65, 40, 41], but the connection between ODEs and freight logistics was not explored. However, the concept of *Horizontal Collaboration* was found [85, 4, 8, 50] through our extended and exploratory literature search. This raises the question of how ODEs can be established in the logistics sector, within freight transport. HC refers to when actors at a common organizational level engage in collaboration, sharing data. According to Basso et al. [8], there are different levels of complexity in HC, based on the business model of the actors, ranging from rather simple collaboration to a more complex integration of the actor’s organizations.

HC in freight logistics, as reported in the literature, can be compared to an ODE, but confined to a limited number of actors. In ODEs, data sharing and collaboration commonly occur across multiple levels, including a multitude of actors with different roles. Therefore, it can be argued that ODEs are likely to foster stronger collaboration among actors, including governmental bodies, as data can be shared among all involved parties, not limited to those within a common organizational hierarchy.

Furthermore, as visualized in Figure 1, several factors can influence how effective and interoperable ODEs are. Governance, quality aspects, and legal aspects

²https://commission.europa.eu/law/law-topic/data-protection/eu-data-protection-rules_en

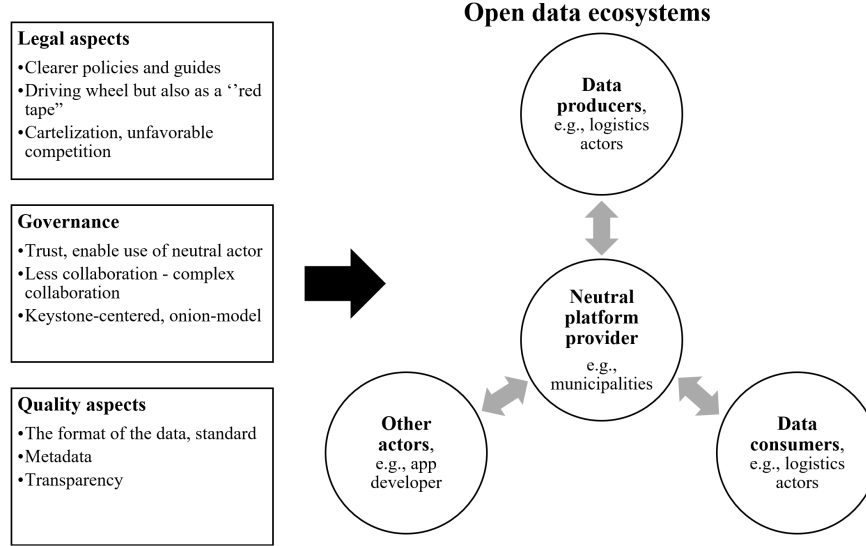


Figure 1: Open data ecosystems and the involved actors and aspects. Actors in the ecosystem can have one or multiple roles, for instance, both producing and consuming data.

have significant impacts. Governance pertains to how the governance of the actors is conducted, such as the so-called keystone-centered model [53], or the “onion model” [41]. These models address governance not only within specific actors, such as “logistic actor 1” in Figure 1 but also within ODEs. By employing one of these models, governance can be facilitated by a neutral platform provider, such as a government entity [27].

Utilizing a neutral platform provider can increase trust among different actors, enabling better collaboration [50, 85, 41], as mistrust may otherwise act as a barrier to collaboration [13]. Moreover, employing a neutral platform provider and having some form of internal governance system, such as the “onion model” may also build trust within the ecosystem. Using the example of Trafiklab, actors occupy different layers, and actors that have more influence in the system could also foster increased trust among the involved actors since they are all involved in the ecosystem.

The quality aspect is also a factor that influences the effectiveness of the ODE and how data sharing among actors functions [71, 53, 9]. As there is no universal definition of data quality [6], but as depicted in Figure 1 and indicated in the results, there are guidelines that can assist users of ODEs [6, 87], with factors such as transparency, metadata, and data formats.

Sharing a common standard to enforce a certain level of quality is exemplified in the context of public transport where the GTFS standard is utilized [65]. Utilizing a standard that meets quality requirements may be a way to achieve a universal definition of what constitutes data quality. This would also promote data sharing, especially if a neutral platform provider is used, allowing all actors to both share data and utilize the shared data without significant modifications.

The final aspect that underpins an ODE, as also visualized in Figure 1, is the legal aspect. There is uncertainty about whether actors legally can use the shared data or not [69, 43]. Moreover, laws and regulations can act as “red tape” and instead harm data sharing [34]. Despite these uncertainties it is evident in practice, for example freight logistics, where unfair collaboration or the risk of cartel formation may imply significant consequences. This might be mitigated by a neutral actor, especially if it is, for example, a government actor. This further emphasizes the importance of a neutral platform provider orchestrating and facilitating data sharing. Combined with high data quality, for example through standards, along with effective legislation, this may imply efficiency, leading to environmental, economic, and service-related benefits [50].

4.2 Threats to validity

We discuss factors affecting the results, with respect to study selection validity, data validity, and research validity [5]. Studies were *selected* from multiple sources, using snowball sampling. There might be a risk of researcher bias influencing whether the articles are considered suitable for the study, in relation to the inclusion and exclusion criteria. Regarding the *data validity*, we conducted thematic analysis and attempted to minimize bias. Still, there may be traces of the researcher in the process. There is also a risk of misinterpretation of the data analyzed, even though experts within the administration were contacted. Threats to *research validity* may have an impact on the study, with respect to generalization; from public transport to goods, from logistics to other sectors, and from the Swedish context to other sectors. We do not make strong claims in this respect and our further research has to assess the matter.

5 Conclusions

Our research reveals a significant gap in the literature on Open Data Ecosystems (ODE) in logistics. We have specifically focused on two segments of logistics: public transport logistics and freight logistics. While we found some literature on the integration of ODEs in public transport logistics, our snowball sampling did not uncover any such literature for freight logistics. However, we did identify a related phenomenon, Horizontal Collaboration (HC), which reported the context of freight logistics. This concept explores how actors on a similar hierarchical level share and collaborate on data, a more limited practice than the broad data sharing

and collaboration within an ODE. Our findings (RQ1) suggest that ODEs have the potential to foster stronger collaboration among actors, including governmental bodies, as data can be shared among all involved parties, not limited to those within a common organizational hierarchy. Our findings (RQ2) also indicate multiple quality, legal, and format aspects that underpin the collaboration among actors involved in ODEs, highlighting the importance of these aspects.

Our future research aims to bridge the gap between the two streams of research, ODEs and HC, and explore their integration in further detail. We believe that this integration could lead to significant benefits for practitioners, extending data-sharing activities and collaboration to an ecosystem level. A widened collaboration beyond the same organizational levels could result in more data being shared of higher quality and further innovation output in services and applications. We are particularly interested in investigating how such collaboration may be applied in the context of municipal ODEs, focusing on promoting increased co-loading among logistic operators. With the shared vision of reducing the climate footprint, this collaborative approach has the potential to prompt significant change in the logistics industry and inspire new ways of thinking about data sharing and collaboration.

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EXPLORING PUBLIC-PRIVATE DATA SHARING PRACTICES THROUGH THE LENS OF OPEN DATA ECOSYSTEMS: A MULTIPLE CASE STUDY ON MUNICIPAL AND REGIONAL FREIGHT LOGISTICS

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Abstract

Background: Freight transport is expected to increase in the upcoming years, contributing to air pollution. There is, therefore, a critical need for increased efficiency that can reduce emissions. Data sharing is one approach, where actors within Open Data Ecosystems (ODEs) collaborate and share data to plan and operate more efficient and sustainable freight transport. **Aim:** In this study, we explore how data sharing practices within ODEs in the context of municipal and regional last-mile logistics in Sweden can enhance the efficiency of freight transport. **Method:** Following a prolonged participation process, we conducted a multiple-case study involving three different cases, built upon initial meetings, semi-structured interviews, supported by a thematic analysis, and validated through a follow-up workshop. **Results:** The findings show that data sharing in ODEs is shaped by interrelated socio-technical aspects, including platform design, roles of actors, handling of sensitive data, data quality, and procurement processes. We further synthesize

our findings in a conceptual model, highlighting key actors and their relations. **Conclusion:** Data sharing is a central mechanism enabling integration and value creation in last-mile logistics, but it depends on the interaction between technical and organizational aspects. Public actors can undertake a key role as a neutral key-stone actor by orchestrating the ecosystem and facilitating data sharing through governance practices such as procurement.

1 Introduction

In light of the growing freight transport [84], air pollution is an increasing challenge [26], and therefore, finding more efficient freight transport solutions is crucial to achieve national [81, 63] and global [86] environmental sustainability targets. One promising approach to addressing these challenges is data sharing between stakeholders, which enables analysis and planning for more efficient co-loading, which in this context refers to consolidating goods from different logistics actors into a single vehicle and thereby reduces the driven distance and consequently, air pollution.

The data sharing can occur at varying levels of openness between involved actors [14]. The dynamics between actors can be further analyzed through the lens of an *open data ecosystem* (ODE), defined as actors sharing data and collaborating toward a common goal, typically underpinned by a technological platform [70]. While this perspective emphasizes collaboration and coordination among actors, our prior research suggests that realizing such ecosystems in practice remains challenging. This means that data sharing between stakeholders and organizations is not merely a technical challenge, but a complex socio-technical one that covers aspects such as governance, privacy, and legal agreements, and affects multiple business decisions [33].

Despite its potential, there are challenges involved in facilitating and implementing this type of data sharing. These challenges highlight the need to further explore and deepen the understanding of how data sharing is conceptualized, and to what extent perspectives, such as ODEs, capture these issues in practice. Previous research on open data in relation to public actors has focused on *open government data*, where public actors share data [6, 71], while other studies have explored ODE in different contexts [70, 35]. However, to our knowledge, similar attention has not been paid to the data sharing practices in the context of public-private partnership in the municipal and regional last-mile freight logistics, constituting the final stage of the delivery process.

Building on prior research on open data ecosystems [91, 53], related research on data platforms and logistics [52, 48], as well as our previous literature study [36], we explore ODEs in public-private partnerships in practice, through three Swedish cases. In this context, public-private partnerships refer to business relationships between public and private actors engaged in data sharing, and to how

these shape the functioning of the ecosystem. We also investigate and build upon aspects related to the operations of an ODE, including quality [6], legal frameworks [24], roles [91, 53, 29], and governance structures [10].

This study is a qualitative, multiple-case study where findings are synthesized through a thematic analysis. The study follows a prolonged participation process, starting with initial meetings, followed by two iterations of semi-structured interviews. The study includes three cases: Helsingborg Municipality, Södertörn Municipalities, and Predictive Movement. To validate the findings, a follow-up workshop was conducted with the case participants. Based on this methodological approach, the study addresses the following research questions:

- RQ1 What are the conceptual relations and data sharing practices between actors in the last-mile freight transport of goods on behalf of public actors?
- RQ2 How do actors address quality control, legal compliance, sustainability, governance, and other aspects that they consider important?
- RQ3 What roles do public actors assume in open data ecosystems?

Based on these research questions, this study contributes to conceptual understanding of ODEs in the specific domain of municipal and regional freight logistics, by identifying key components that shape inter-organizational data sharing in public-private contexts. Furthermore, it provides insights into the relationships between stakeholders involved in data sharing practices, and how these relationships are orchestrated within ecosystems. In addition, the study highlights how key components interact in ecosystems, and illustrates the role of platform configurations in structuring and implementing data sharing in public-private freight ecosystems. These findings provide a foundation for generalization across the freight domain, contributing to an emerging theoretical understanding of how platform configurations, roles, and governance structures shape data sharing practices in freight ecosystems.

The paper is structured as follows: Section 2 presents terms, background, and related work. Section 3 describes the research design, followed by a general case description in Section 3.7. Section 4 presents the findings, where an analytical model and a conceptual model are used to communicate the findings of the study. In Section 5, we discuss the findings, and Section 6 concludes the paper.

2 Background & related work

2.1 Glossary

Table 1 provides definitions of the conceptual actors that appear in the analysis as well as in the figures. These terms are used to ensure consistency and clarity throughout the study.

Table 1: Definition of conceptual actors recurring in the analysis and related figures.

Conceptual actors	Description
Public authorities	Actors such as municipalities, governmental authorities.
External consolidation terminal	Operates as a separate unit and is an external component procured by one or more municipalities.
External logistics actor	Actors who provide the logistical services, such as carriers.
Supplier of goods	Supplies different actors, such as municipalities with goods.
Goods receiver/recipients	The actor who receives the goods from the supplier.
Neutral actor/ Non-profit actor	An actor who is considered neutral, and might foster collaboration.

2.2 Open data ecosystems

The definition of an open data ecosystem (ODE) is not universally agreed [53]. However, as described by Zuiderwijk et al. [91], an ODE can be explained as organizations and individuals that collaborate within a network where their common interest forms the ground for the relationships between the actors. Such ecosystems are supported by a technological platform [31], which enables stakeholders in the ODE to process data [53]. These capabilities further contribute to innovation, new businesses, and the creation of value. Within ODEs, actors collaborate on the data and other resources associated with it, for example, standards or software. The collaboration is facilitated through the exchange of information, resources, and artifacts between different actors across the network [31]. While embraced in the above definition, Jussen et al. [33] highlight that data-sharing in ecosystems has complex socio-technical challenges, including issues related to governance, contractual agreements, and data quality. These challenges are evident from the need to coordinate multiple actors, combining roles and responsibilities, and establish common standards between data providers and consumers sharing data on a platform.

In relation to the overall aim of this study to reduce air pollution in freight logistics, Melville et al. [46] indicate that data and information systems play a significant role in enabling reduced environmental impact by supporting more informed decision-making and low-carbon operations. The study also emphasizes that system, data accuracy, and completeness are critical for enabling efficient decision-making aimed at reducing emissions and achieving low-carbon opera-

tions [46]. In data ecosystems, this is further emphasized by Bozkurt et al. [11], highlighting the dependency on data sharing across different systems, domains, and networks. Cross-organization sustainability-related data is therefore needed to reduce inefficiencies and excessive emissions by enabling transparency and coordination among actors in the ecosystem.

2.3 Activities, elements, and roles within ODEs

Zuiderwijk et al. [91] describe the establishment of an ODE, which involves different levels (e.g., user and producer of data), which in turn also includes different types of activities depending on the level. They explain the following activities applied to data: *searching, cleansing, viewing, requesting, analyzing, and combining data*. Furthermore, they describe that previous research had a primary focus on fewer activities, and not on the larger picture of ODEs, and Zuiderwijk et al. [91] therefore have chosen to highlight several interlinked key elements that an ODE should address. The key elements are: *publish data, explore data and their related licenses, analysis of data, interpret the data, as well as giving feedback to the producer*. Several other elements are also described as essential for ODEs, *user pathways for the data, quality management system, and metadata for connection between the elements*. These last elements should then act as an enabler for interoperability between the elements of the ecosystem.

Multiple roles within ODEs are also found in the literature, where Oliveira et al. [53] and Zuiderwijk et al. [91] highlight the roles of the data provider, intermediaries, and data user. Furthermore, Oliveira et al. and Immonen et al. [29], emphasize that there are multiple other roles connected to ecosystems, while Oliveira et al. also describe that some roles can represent the same duty. An example is when data providers and intermediaries produce data. It can be noted that data providers are not required to have the role of data producer, but can be an area carried out by a data producer who generates data for the ecosystem.

In ecosystem research, Jacobides et al. [30] further describe ecosystems as sets of interacting actors linked through complementarities, where complementary products and services jointly contribute to value creation in the ecosystem. These complementarities exist at the level of roles, linking different types of actors, such as complementors and suppliers. Furthermore, as Adner [2] highlights, ecosystems consist of multiple stakeholders that need to coordinate to create value propositions to materialize.

2.4 Governance structure of ODEs

Data sharing ecosystem may be structured in different ways, as proposed by Dal Bianco et al. [10], ranging from *organization-centric*, to *consortium-based*, and *community-based*. We consider these structures to have different meanings for the ecosystem: organization-centric governance is based on a single actor, and

consortium-based governance circulates among actors or organizations, which may also be co-owned by the ecosystem actors. Community-based ecosystems have a different type of setup, where the governance might be structured around the actors who are members of the ecosystem.

Governance has a central role in data-sharing ecosystems, Bartolomucci et al. [7] highlight, including dependency on both collaborative and data governance dimensions. The governance dimensions should be viewed together from a holistic socio-technical perspective, and their integration also influences how value between these socio-technical aspects is derived from data. The relationship between these dimensions further builds the foundation for effectiveness, regulating how data sharing is enabled and maintained.

A keystone actor might also be found in the ecosystem, as described by Oliveira et al. [53]. Jansen [32], and Harrison et al. [27] further describe the keystone actor, where this actor can have an impact on the health of the ecosystem. Regarding the structure of the ecosystem, Oliveira et al. [53] describe this in terms of five structures: *keystone-centric*, *business model-oriented*, *marketplace-based*, *platform-centric*, and *intermediary-based*. As shown in the study by Oliveira, keystone-centric can be described as a structure where actors in the ecosystem are organized around the keystone. It is also explained by Oliveira and Lóscio [54], that a keystone-centric structure can be a government administration or agency, responsible for providing a greater amount of data within the ecosystem, but with limited control over other actors, following the structure of the governance model by Nakakoji et al. [51].

2.5 Quality of data in ODEs

Attard et al. [6] define what is characterized as good data quality. However, some aspects and guidelines can impact data quality, for instance, Strong et al. [77] describe quality dimensions as accuracy, accessibility, relevance, completeness, and interpretability. Building further on these dimensions [6, 87, 74, 49], data quality in ODEs can be understood through several key dimensions, including usability, understandability, accuracy, timeliness, completeness, openness, consistency, and compliance. Multiple studies also highlight that data quality has a large impact on data sharing [7], where the ecosystem is at risk of not reaching its full potential.

2.6 Legal aspects of ODEs

There are several legal aspects to consider related to data sharing, such as the General Data Protection Regulation (GDPR) [24], but also licensing. Connected to data sharing, there is an uncertainty around legal complications where Soosaar and Nikiforova [62], describe how municipalities can feel fearful of not complying with data protection regulations. However, they also describe that an alternative to

avoid this can be to implement guidelines and processes to comply with the laws that exist, such as GDPR.

Regarding licensing, there is an additional complexity when data is shared. If an organization chooses to share data, liability may remain with the original data-providing organization, what then governs is the type of user agreement and license chosen to use. Solutions for the legal uncertainties are also discussed in the literature, where clearer guidelines and frameworks [17, 43], and agreements may be alternatives.

2.7 Data sharing platform

Data platforms enable actors to interact and share data, where openness as interoperability has important roles in reducing restrictions and allowing stakeholders to access the platform. Platform openness is also considered a key aspect, allowing actors to use artifacts and reach beyond the local boundaries of the platform [52]. In the context of logistics, Möller et al. [48], highlight how digital platforms are related to data-driven business models and services, viewing data as a key resource. The data plays an important role in visibility and optimization services, which support transparency and data-driven decision-making, including logistics planning. Pan et al. [59] describe the importance of digital interoperability between systems and involved actors. They also put forward four major challenges related to digital interoperability: *Data sharing formats, communication, security, and type of data needed*. Furthermore, there are various proposed solutions to these key challenges, with *smart infrastructure and communities* being one solution. This solution highlights how data sharing and interoperability are central not only to effective logistics solutions but also to activities such as efficient planning and communication between actors.

3 Research design

To conduct this study, we utilized a multiple case study methodology approach inspired by Runeson et al. [60]. We designed a qualitative multiple-case study to facilitate a deeper understanding of data sharing in practice within specific contexts. The cases were strategically selected to capture variation in public-private data sharing initiatives within municipal last-mile freight logistics. Three cases were included: Helsingborg Municipality, Södertörn Municipalities, and Predictive Movement, which is orchestrated by Luleå University of Technology. These cases represent different configurations of data sharing initiatives, enabling analytical comparison across governance structures, levels of maturity, and platform configurations. A brief overview of the flow of research activities is provided in Figure 1.

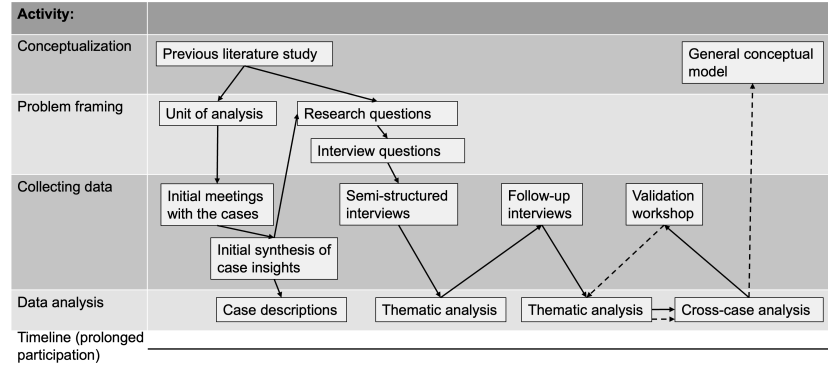


Figure 1: Overview of the methodological approach, describing the different activities involved in the prolonged participation. White boxes represent activities, and gray lanes represent different types of research activity. The timeline begins with our previous literature study [36] and concludes with the development of a general conceptual model, capturing the core of our findings. The solid arrows indicate how the activities are connected over time, and the dashed arrows indicate the progress of data collection and analysis from the validation workshop.

3.1 Unit of analysis

The unit of analysis for this study is the participation of municipal and public actors, in sharing and receiving open data within freight transport on behalf of public actors, with the aim of increasing the efficiency of municipal last-mile logistics. The study explores various roles, such as data consumers, producers, and platform providers. The study also explores how these actors address quality, legal, and governance aspects. The selection of the unit of analysis is inspired by the findings of our previous literature study [36], which is illustrated in Figure 1, acting as a starting point for the study.

3.2 Data collection

The primary empirical data collection is interview-based, with interactions with interviewees taking different forms over time. Prolonged participation [60] serves as the basis for the interaction between researchers and actors within the cases. This is illustrated in the data collection lane in Figure 1, where the exploration of the cases began with initial meetings with respondents from each case. The initial meetings allowed the researchers to take field notes, which were subsequently used to develop initial syntheses. These syntheses were updated after each meeting, allowing for knowledge development, and served as the foundation for the case descriptions in Section 3.7. In the case of Helsingborg Municipality, five respondents participated, in Södertörn, two, and in the case of Predictive Movement,

three respondents, as reported in Table 2. After initial meetings with each case, the researchers conducted two rounds of semi-structured interviews with respondents from the cases. The semi-structured interviews involved nine respondents, five of whom had also participated in the initial meetings, while four additional respondents were considered relevant for the interview phase based on snowball sampling [89] within the cases.

The nine respondents participating in the first interview rounds possess backgrounds in both public and private sector organizations, as well as in academia. An overview of the respondents' roles, years of professional experience, and participation across interview rounds and the validating workshop is presented in Table 2. The table shows the participants' professional roles, their years of experience in the field, and their respondent codes: HBG1–HBG4 refer to Helsingborg Municipality, and PF1 refers to a private company connected to one of the cases. ST1–ST2 refer to Södertörn, and PM1–PM2 refer to the respondents from Predictive Movement. These acronyms are used throughout the results to support the transparency and traceability of the findings. Furthermore, HBG5–HBG7 and PM3–PM4 refer to the additional respondents from the initial interviews.

The respondents comprise a combination of technical and domain expertise. Some participants had strong technical backgrounds and were involved in the design and development process of data sharing platforms and Transport Management Systems (TMS). Other respondents held organizational roles related to procurement and logistics planning, contributing with operational insights into data sharing practices. Together, this ensured that both technical and organizational perspectives were captured.

The first round of semi-structured interviews closely followed the interview questions (see Appendix), and included participants illustrated in Table 2. The interview questions were sent to the respondents well in advance, allowing them to prepare their answers. As illustrated in Figure 1, the research questions that formed the basis for the interview questions were derived from our previous study [36], which examined the theoretical foundations. Following the prolonged participation, a second round of follow-up interviews was conducted with Helsingborg Municipality and Södertörn Municipalities to further enhance the understanding. As shown in Table 2, one respondent from each of these cases was included in the follow-up interview and was chosen for their relevance and participation in the study.

After conducting the interviews, the recorded voices were transcribed using the open source tool WhisperX¹. The raw text data generated by WhisperX was thoroughly reviewed by the researchers to ensure its accuracy. During the coding and thematic analysis process, a spreadsheet was used to record the process. Also, a codebook was created in the spreadsheet (presented in Section 4, Table 3) defining the codes and themes used to describe the data. To validate the findings, a workshop was held with respondents from the different cases, as illustrated in Fig-

¹<https://github.com/m-bain/whisperX>

Table 2: Overview of respondents, their roles, professional experience, and participation across data collection activities, Interview (I) round 1-3, and validating Workshop (W).

ID	Role	Years	I1	I2	I3	W
HBG1	Traffic Planner	14	X	X	X	X
HBG2	Solutions Architect	4		X		
HBG3	User Experience Designer	6	X	X		X
HBG4	Sustainability Strategist	9		X		
HBG5	Procurement Manager	5	X			
HBG6	Innovation Lead	5	X			
HBG7	Innovation Catalyst	3	X			
PF1	Transport Manager	6		X		
ST1	Procurement Logistics Specialist	8	X	X	X	X
ST2	Coordinator Goods Distribution	5	X	X		
PM1	University Lecturer	13	X	X		X
PM2	Postdoctoral Researcher	5		X		
PM3	Project Manager	6	X			
PM4	Associate Professor	2	X			

ure 1. As shown in Table 2, two respondents from Helsingborg Municipality, one from Södertörn Municipalities, and one from Predictive Movement participated in the workshop. The workshop was recorded and transcribed, and as the figure shows, the collected data were also analyzed and used in the thematic analysis, before contributing to the development of the General conceptual model (Section 4, Figure 6).

3.3 Thematic analysis

For the analysis of data, we conducted a thematic analysis inspired by Braun and Clarke [12]. The thematic analysis followed a deductive thematic approach, guided by concepts derived from our prior research on data sharing in public-sector logistics [36]. More specifically, the analysis focused on concepts related to data sharing practices, governance structures, data quality, sensitive data, and sustainability aspects. The analysis followed Braun and Clarke’s six-step guide [12], including familiarization with the data, initial coding, theme identification, and evaluating and refining the themes. For the analysis, the raw data were categorized into themes using codes based on the study’s research questions. To conduct this analysis, a structured coding spreadsheet was used, where the raw data were both color-coded and labeled with text-based codes. The codes were then organized into themes based on the study’s research questions and unit of analysis.

The codes applied and generated through the deductive approach resulted in seven distinct themes, which are defined in Table 3, illustrating the codebook. These themes also served as the basis for the study's subthemes, which are visualized in an analysis model (Section 4, Figure 5). In this model, it can be traced how each theme from Table 3 leads to its corresponding subthemes. Each theme is aligned to one or more research questions. To enhance analytical rigor, the coding process included discussion and comparison among the authors, allowing for evaluation and refinement of the themes across the cases.

3.4 Cross case analysis

A cross-case analysis was conducted, inspired by Yin [90], as a complement to the thematic analysis. Several steps were used in the cross-case analysis. Using the spreadsheet from the thematic analysis, this created the basis for a comparison and analysis of various case patterns. This comparison was then synthesized into a higher conceptual structure, which formed the foundation for the general conceptual model, presented in Section 4, Figure 6. In addition, we deducted proposition sketches as a first step towards theorization, following the principles of Sjøberg et al. [73].

3.5 Ethical considerations

Several ethical aspects have been considered when conducting this study, inspired by Strandberg [76]. These include informed consent, confidentiality, and secure storage of data. Before conducting interviews with the selected respondents, they were asked for permission to participate in the study, consent to the recording of the interview, and agreement for the researcher to transcribe and store the data on a secure server. The transcribed raw data from the interviews were also returned to each respondent, allowing them to review the material and make changes or removals. Furthermore, to safeguard respondent confidentiality, each respondent was assigned an anonymity code. These codes are presented in Section 3.2, Table 2.

3.6 Threats to validity

This section outlines threats to validity related to the study and focuses on internal validity, external validity, reliability, and construct validity [60]. In addition, we present approaches employed to mitigate the identified threats.

3.6.1 Internal validity

A thematic analysis with deductive coding formed the basis for structuring and analyzing the raw data collected from the respondents. This, in turn, can contribute to researcher bias as there is a risk that the data are interpreted based on previous research, which can influence the themes selected. To minimize the impact of this,

the researchers have employed several strategies to strengthen internal validity: The initial coding of the data was performed by the first author. The second and third authors then independently coded a subset of the data to validate the coding framework. The results were then compared and discussed to align interpretations and strengthen the robustness of the thematic analysis. A validation workshop was held with the respondents, in which findings were presented. Participants were invited to provide feedback on the collected data, and this process supported internal validity by allowing respondents to validate the interpretations and ensure that the findings reflected their experiences.

3.6.2 External validity

To strengthen the external validity of the study, the three cases included in the study are from different geographical areas of Sweden. However, the limited sample size might restrict transferability to other contexts. Though some results might be transferable within Sweden, this limitation should be taken into consideration when evaluating the findings.

3.6.3 Reliability

Several technical tools were used to transcribe, code, and conduct a thematic analysis in order to strengthen the reliability. However, there is still a risk of misinterpretation in the creation of a thematic analysis, and this should therefore be taken into consideration.

3.6.4 Construct validity

To strengthen construct validity in this study, the researchers aimed to ensure that the interview questions were closely aligned with the theoretical constructs being investigated. This alignment was intended to ensure that the collected data directly reflects constructs such as data sharing, data quality, legal aspects, and governance structures. Additionally, the validation of the coding process by the second and third authors was established to ensure that the themes identified in the analysis accurately represented the intended constructs, rather than individual researcher bias.

3.7 Case descriptions

This section describes the three explored cases. The descriptions of each case are derived from the initial meetings, explained in Section 3.2, and illustrated in Figure 1. Each subsection outlines key characteristics of the cases considered relevant for the following analysis and presents a conceptual model for each case.

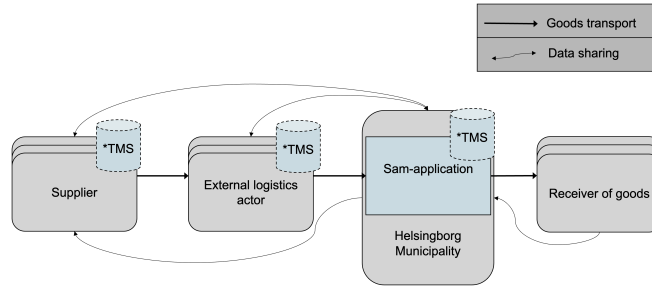


Figure 2: Conceptual model of Helsingborg Municipality, illustrating different actors, systems, and a platform. The Sam-application, acting as a platform, is orchestrated by Helsingborg Municipality, and enables data sharing, supporting more efficient freight transport between involved actors.

3.7.1 Helsingborg Municipality

Helsingborg Municipality, with approximately 150,000 inhabitants, has implemented a digital system for monitoring freight transport connected to the municipality's organizations, such as schools and public institutions. The digital system, the moderately mature Sam-application, is a mobile platform that utilizes ge-fencing technology and enables data sharing between involved actors. The Sam-application is illustrated in the case-specific conceptual model (Figure 2), where some involved actors, such as external logistics actors and suppliers, defined in Table 1, utilize the Sam-application to share and access logistical data. The sharing of data is enabled through registration of vehicle movements in different zones, thus facilitating the collection of real-time delivery data. This data allows for more efficient last-mile transportation by co-loading between logistical actors and informed decisions when planning the transports. As also illustrated in the figure, a TMS can also be connected to involved stakeholders, supporting logistics operations. Furthermore, as the municipality has an annual procurement volume of approximately SEK 4 billion for goods and services, the municipality operates within a context where transport efficiency plays a key role in supporting efficient and accountable public spending.

3.7.2 Södertörn Municipalities

The Södertörn Municipalities, comprising eight local municipalities in the Stockholm region, utilize an external consolidation terminal to manage their contracted municipal transport operations. As illustrated in the case-specific conceptual model (Figure 3), this consolidation terminal serves as a central component in the logistics flow, acting as a platform where goods from various suppliers are received and redistributed to actors such as schools and public institutions. The

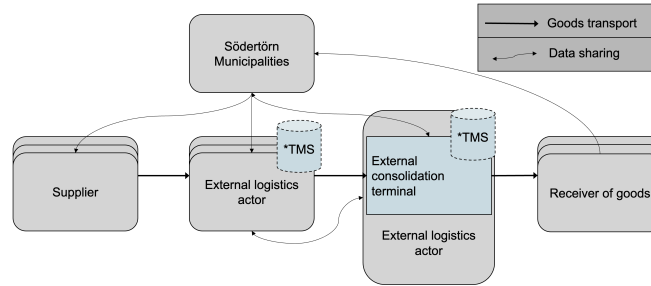


Figure 3: Conceptual model of involved actors, platform, goods, and data sharing involved in the case of Södertörn Municipalities. The external consolidation terminal, acting as a platform, is orchestrated by an external logistics actor.

external consolidation terminal, supported by a connected TMS, enables vehicles to be optimized in their fill rate, thus contributing to the efficiency of municipal last-mile logistics.

3.7.3 Predictive Movement

Predictive Movement is an open-source platform aimed at improving logistics efficiency through data sharing. Compared to the Sam-application, the platform can be considered less mature since it is still under development. However, it has been tested in several pilot projects, with actors such as transport operators and municipalities. The platform primarily focuses on rural areas and explores how logistics operations can be optimized in these contexts. The platform supports three main application areas: freight transport, public transit, and on-demand mobility services. As illustrated in the case-specific conceptual model of Predictive Movement (Figure 4), the platform enables stakeholders, such as external logistics actors or suppliers, to share information on availability and demand for freight transport. This collaborative exchange of data results in a more efficient flow of goods. Furthermore, the platform supports dynamic coordination between actors to improve service levels without increasing the number of transport operations. The platform is also designed to be interoperable with existing systems, such as TMS, and can be adapted or extended by stakeholders with sufficient technical capabilities.

4 Results

From the three cases, we identify patterns in how data sharing is organized and enabled within public-private ODEs. These patterns are derived from a deductive thematic analysis, structured according to the analysis model (Figure 5), which illustrates how themes and sub-themes are connected to the aspects in the findings. From the cross-case analysis, we also identified three overarching elements: data

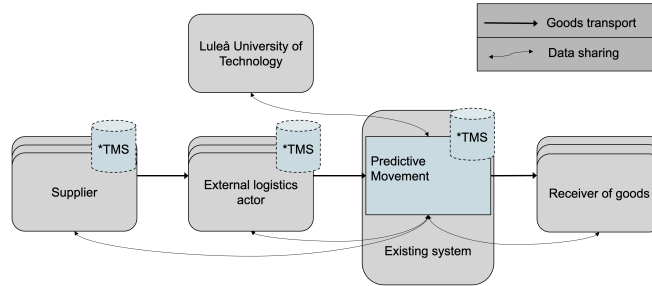


Figure 4: Conceptual model of the initiative Predictive Movement supported by Luleå University of Technology, illustrating different actors, systems, and a platform. Predictive Movement acts as a platform and enables data sharing between involved actors, supporting more efficient logistics operations.

sharing structures, governance and roles, together with enabling factors supporting data sharing. Data sharing structures differ across the cases and are shaped by variations in platform maturity and associated technical and organizational challenges. Governance structures and roles influence how coordination is distributed within the ecosystem, thereby shaping the orchestration of data sharing. Supporting factors, including data quality, procurement, and handling of sensitive data, influence the effectiveness of data sharing in practice.

The cross-case analysis also contributed to the development of the general conceptual model, derived from the case-specific conceptual models presented in Section 3.7. This model illustrates the interplay between actors, defined in Table 1, and includes involved systems and relations in the ODEs identified in three case studies. The themes presented in Table 3 show recurring activities and patterns related to how public and private actors interact with data sharing in the context of freight transport, and are conceptualized as the underpinning elements of the ecosystem. The table also illustrates how each theme is related to the research questions by providing a structure of theme, description, and research question.

The general conceptual model in Figure 6 visualizes a central data sharing platform and a set of actors and roles from a holistic perspective and not one specific case. This includes an orchestrating (neutral) actor, supplier, external logistics actor, and receiver of goods. The model captures the relationships between these actors, highlighting the exchange of both data and physical goods within the ecosystem. The model highlights how data sharing is enabled through a combination of platform coordination and system integration. For instance, data may be shared from the supplier or an external logistics actor to the platform. Through the platform, the orchestrating (neutral) actor and the recipient of the goods can access relevant data. Furthermore, a TMS may either be an integrated component of the data sharing system or a parallel system that supports logistics interoperabil-

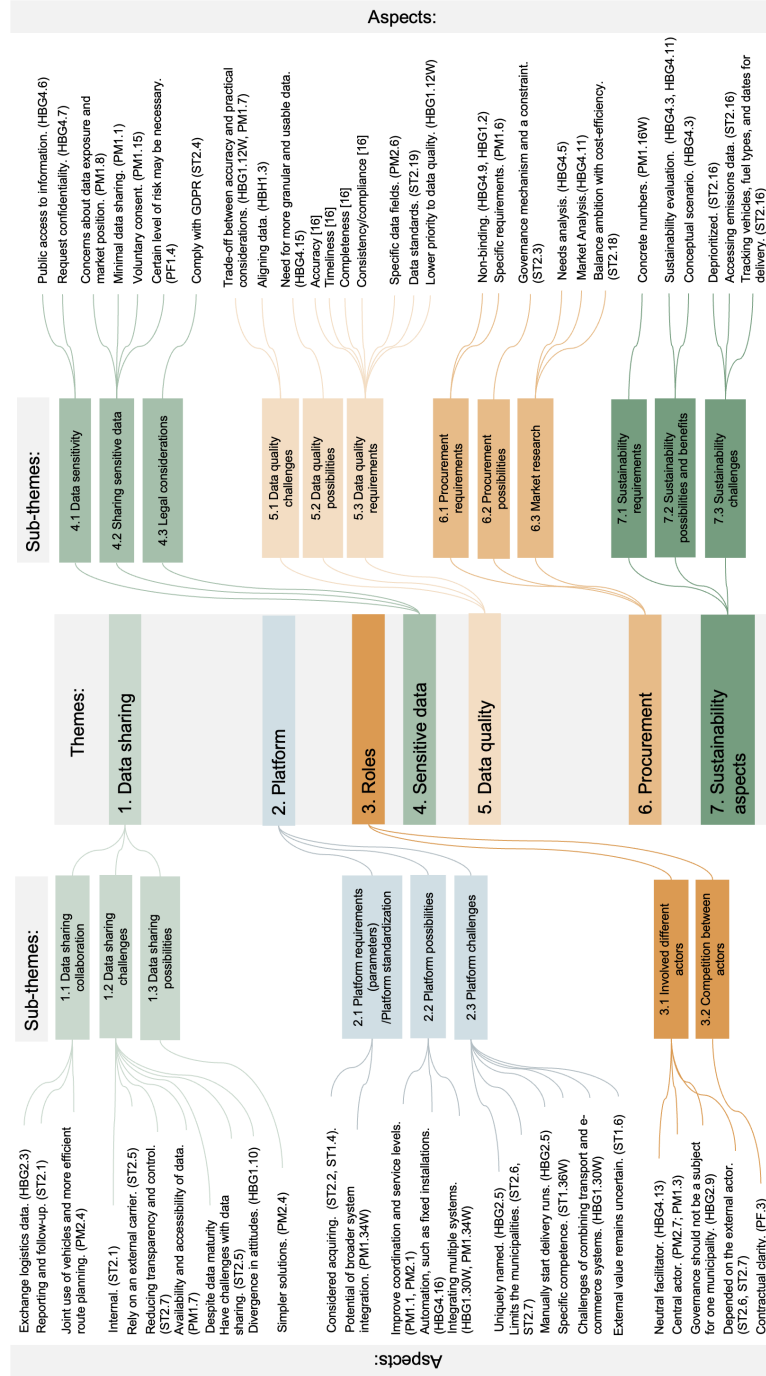


Figure 5: Analysis model, illustrating how themes (1-7), sub-themes (1.1-7.3), and analytical aspects are connected. The themes are located in the center of the figure, which is then followed by sub-themes. The themes are also defined in Table 3, illustrating the study's code book. The analytical aspects are located based on the origin of each sub-theme, highlighting the connection to the findings of the study.

Table 3: Recurring themes identified in the interviews, representing the codebook used in the thematic analysis, along with research questions related to each theme.

Theme	Description	Research question
1. Data Sharing	Exchange of data between actors such as municipalities, suppliers, and carriers, covering data sharing models in the three cases, as well as technical and organizational challenges.	RQ1
2. Platforms	Digital platforms to facilitate and offer structured solutions for data sharing, with focus on existing solutions and operational challenges, together with proposed approaches and system interoperability.	RQ1
3. Roles	Responsibilities and governance approaches of involved actors.	RQ2, RQ3
4. Sensitive Data	Aspects and challenges related to transparency, confidentiality, and legal compliance with data protection regulations.	RQ2
5. Data Quality	Quality aspects related to accuracy, completeness, consistency/compliance, and timeliness.	RQ2
6. Procurement	How public procurement influences data sharing as an enabler and a constraint.	RQ3
7. Sustainability Aspects	Regarding the use of data sharing to integrate sustainability aspects into municipal freight logistics.	RQ2

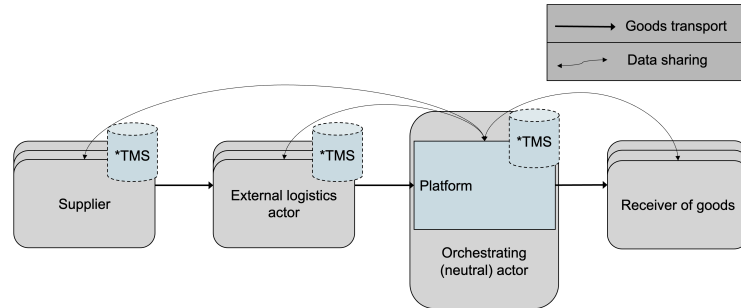


Figure 6: General conceptual model of data sharing and exchange of goods between actors from a holistic perspective. The thinner arrows represent data sharing between involved actors. The darker lines between the supplier, the external logistics actor, and the receiver of goods illustrate the flow of goods between the actors. The existing system and transport TMS can be seen as a separate system that supports the execution of logistical services.

ity. Based on the model, data sharing within ODEs is not dependent on a single system or actor. Instead, it emerges through the orchestration between multiple actors, involving both technical and organizational components, and can therefore be understood as a socio-technical system.

In the following sections, each theme is elaborated, with reference to the analytical structure shown in the analysis model (Figure 5). The analysis model illustrates the collected material from the interviews and how the different themes and sub-themes are connected and shape the dynamics of ODEs in the analysis. References to information or quotes from individual interviewees are made using the ID's defined in Table 2, to increase transparency of the results.

4.1 Data sharing models in the three cases

In the context of public sector freight logistics, data sharing (1), as illustrated in the analysis model (Figure 5), refers to the exchange of transport-related data between actors, such as municipalities, suppliers, and carriers. This information may include vehicle positions sampled at certain events, goods data, and delivery updates. Data sharing functions as *a central mechanism across all three cases*, but manifests in three distinct models: real-time logistical integrated data sharing, internally focused data sharing, and logistical collaboration through an open data platform. These data sharing models reflect variations in the platform's maturity level and coordination among actors. These variations provide the foundation for the sub-themes in the analysis model, consisting of: data sharing collaboration (1.1), data sharing challenges (1.2), and data sharing possibilities (1.3). Together,

these sub-themes provide a structure for analyzing how the data sharing is configured in the three cases

In Helsingborg Municipality, data sharing is facilitated by the more technically mature municipality-owned data sharing platform, the Sam-application, which contrasts with Södertörn Municipalities, where data sharing is primarily *internal*. The Sam application enables actors to *exchange logistics data* using geofencing technology (HBG2.3), illustrating a more mature level of data sharing collaboration (1.1). In contrast, data sharing in Södertörn Municipalities is primarily internal, supporting the municipal organization with activities such as *planning and reporting* (ST2.1). The system primarily functions as a procurement tool rather than a logistics platform for external actors. Although goods tracking is technically possible in Södertörn, the municipalities *rely on an external carrier* to facilitate transport notifications (ST2.5). This dependency prevents real-time updates, *reducing transparency and control* over transport data flows (ST2.7).

Predictive Movement represents yet another model. Their platform enables actors to share information on available transportation resources and delivery needs, facilitating the *joint use of vehicles and more efficient route planning*. As a respondent explained: “You have smaller actors who might not have their own individual vehicles, or they have their own individual vehicles, but they simply do not have enough goods to use them efficiently” (MP2.4). By synchronizing their bookings, actors can jointly operate fleets, emphasizing the platform’s role as a central data hub and possibilities for data sharing (1.3). However, the model depends on *availability and accessibility of data*, as incomplete data limits coordination: “If the information about the transport is not complete, [...] then no one can coordinate it. It is like saying my house is for rent, but never saying which days” (PM1.7).

4.1.1 Technical and organizational challenges

Data sharing involves both technical and organizational challenges (1.2) in the three cases. To enable efficient and automated data sharing, the data format must follow established requirements (ST2.5). However, smaller operators may *lack the technical skills* to interact with APIs. For them, *simpler solutions* such as apps are preferable (MP2.4). At the same time, larger actors, *despite data maturity, have challenges with data sharing*: “I would say that it very much depends on the data maturity of the supplier, which determines what they can deliver [...] it is not necessarily the case that the larger companies, which are data mature, are actually able to send the information either, because they are often very much locked into their systems” (ST2.5). The interviews also revealed a *divergence in attitudes* towards data sharing among logistics actors, while some stakeholders were positive, others saw additional data-sharing requirements as burdensome for resource-limited organizations: “Many of these companies are already struggling today [...] when you bring up something new, it just becomes too much” (HBG1.10). The technical and organizational challenges in the three cases are also illustrated in the general

conceptual model (Figure 6), which visualizes how both *data sharing* and the *flow of goods* are structured.

Summary – data sharing: Data sharing emerged as a central mechanism across all three cases, taking different forms depending on technical maturity and organizational structure among the involved actors. Across all cases, respondents emphasized the importance of having available and accessible data, which otherwise might constrain the functioning of the ecosystem.

4.2 Logistics data sharing platforms and operational challenges

Logistics data sharing platforms (2), as illustrated in the analysis model (Figure 5), refer to the design and implementation of digital platforms supporting municipal freight logistics. The design of these platforms varies significantly between cases, revealing both *technical opportunities* and *operational challenges*. These variations in platform design are reflected in how data sharing is implemented, influencing the integration and operation of data sharing in the three cases. These differences are closely related to the data sharing models identified in the previous section, influencing the orchestration of the data sharing.

In Helsingborg Municipality and Predictive Movement, the platforms are designed to support more integrated data sharing approaches among actors such as carriers (external logistics actors), logistics operators (external logistics actors), and suppliers. In Helsingborg Municipality, the digital platform is integrated through the Sam-application, which functions as a digital infrastructure for sharing transport data within the municipality and among external actors, indicating a more mature platform standardization (2.1). The application also enables logistics operators to define their own distribution zones. As one respondent explained: “The carrier sets up their own zones [...] then the application automatically detects that they are probably picking up goods” (HBG2.5). However, because zones are *uniquely named* by each company, coordination becomes “a bit of a guessing game” (HBG2.5), highlighting platform challenges (2.3).

In contrast, Södertörn Municipalities rely on an external carrier acting as a data intermediary. This setup *limits the municipalities’* full visibility into historical data and delivery reports and prevents independent changes, creating constraints (2.3) by relying on the carrier (ST2.6; ST2.7). Predictive Movement represents a more collaborative, open-source platform-based approach, enabling coordination of goods transport, public transport, and on-demand mobility. It aims to *improve coordination and service levels* (2.2) without increasing transport operations (PM1.1; PM2.1), and also functions as an intermediary layer that integrates with existing systems (PM1.3). Its open data architecture allows municipalities with technical capacity to adapt the system to specific requirements, while others may

rely on a more general solution: “if you have someone skilled in a municipality [...] then it is possible to do it” (PM1.10).

While digital platforms offer structured solutions for data sharing, their practical implementation reveals *operational challenges* (2.3). In Helsingborg Municipality, for example, drivers must *manually start delivery runs* in the app and ensure that the vehicle is within the designated zone, which is not straightforward: “We do not know exactly where they stop [...] they might stop 50 meters away, so the zone has to be generously defined” (HBG2.5). Given these operational challenges, several respondents (HBG4.16; PF1.9) stressed the importance of simplicity: “Even the smallest manual task [...] becomes a risk that it will not be done” (HBG4.16). Proposed, but not yet implemented solutions include *automation, such as fixed installations* in vehicles (HBG4.16). The existing solutions and operational challenges related to logistics data sharing platforms are also illustrated in the general conceptual model (Figure 6). For example, in the Sam-application, a limitation is shown by the arrow between the receiver of goods and the platform, which reflects constraints related to the external actor. This results in insufficient data sharing, such as the limited visibility of the delivery reports.

To address the limitations of existing platform implementations, the findings highlight the importance of interoperability and more integrated system architectures. Given these limitations, Södertörn Municipalities has *considered acquiring* its own TMS or delivery platform (ST2.2, ST1.4). A platform could also be procured together with other municipalities, since acquiring a platform requires *specific competence*, which may not always be available locally (ST1.36W). Such a *solution* could help address the lack of standardization underlying the operational challenges associated with existing platforms. It might include a dedicated Electronic Data Interchange (EDI) hub shared across municipalities to standardize communication and reduce costs (ST2.3). However, its *external value remains uncertain*: “There are solutions for this. But in the end, it is a matter of cost. Do we get the benefits back? Do the benefits outweigh the costs?” (ST1.6).

In addition to acquiring their own platform, respondents emphasized the importance of *integrating multiple systems*, which is illustrated in the general conceptual model (Figure 6), to improve interoperability. However, one respondent reflected on the *challenges of combining transport and e-commerce systems*: “We are about to procure an e-commerce system [...] and I do not know how to handle transport in these systems. [...] If that’s not possible, then maybe we need to have something parallel [...] transport separately and the e-commerce system separately. [...] somehow integrate them with each other” (HBG1.30W). Another respondent expanded on this idea, emphasizing the *potential of broader system integration*: “It is not just the TMS that is integrated with this platform, but several of these systems [...] It would be great if the transport order were created directly from the purchasing process and it is integrated” (PM1.34W). The integration of the TMS is also illustrated in the general conceptual model (Figure 6) through a cylinder-shaped representation. This figure illustrates that the TMS can either be integrated

with other systems, such as the platform, or run in parallel.

Summary – platform: Across the cases, respondents emphasized the importance of interoperable systems to support more efficient logistical coordination. The design and functionality of digital platforms for municipal freight logistics vary across the cases, revealing both technical opportunities and operational challenges.

4.3 Roles and Governance Approaches

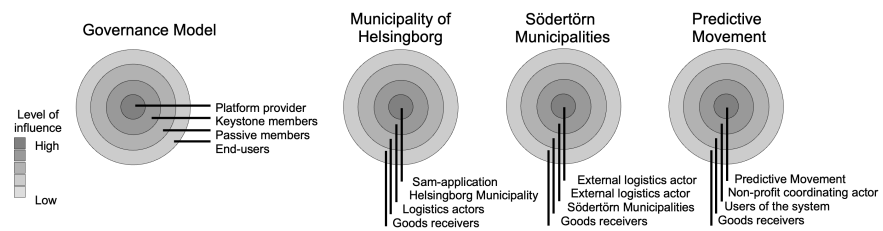


Figure 7: Overview of various governance models across the three cases, where each is placed in the governance model inspired by the “onion model” by Nakakoji et al. [51] and according to Runeson et al. [70]. Helsingborg Municipality (Sam-application) and Predictive Movement are placed as central actors, whereas in the case of Södertörn Municipalities, the external actor acts as the central role, which limits the control of the municipalities on the platform. Other ecosystem actors, such as logistic actors, municipalities, users of the systems, and receivers of goods, are also placed in different layers, depending on their influence on the ecosystem.

Building on prior research (Section 2.4), we find that governance structures and roles differ across the cases within the ecosystems. These differences shape how control, coordination, and participation are organized, reflecting *different responsibilities and governance approaches*. More specifically, we identify three distinct governance roles: *neutral facilitator*, *central actor*, and *contractual dependents*, including involvement of different actors (3.1). These influenced how collaboration, control, and competition between the involved actors (3.2) are distributed among the actors in the ecosystem.

In the Helsingborg case, the municipality acts as a *neutral facilitator* using the Sam-application to foster participation: “The idea with this has been that the companies themselves should see an opportunity [...] we as a municipality, and perhaps as a more neutral party, can serve as a good initial step” (HBG4.13). The neutral position helped reduce competition and foster engagement among involved

actors: “It becomes less competition-focused from the outset [...] compared to if it had been profit-driven organizations” (HBG4.14). The governance approach of Helsingborg Municipality using the Sam-application is also reflected in the governance model (Figure 7). In which the Sam-application and the municipality serve as a central point and keystone actor with strong influence on the ecosystem, fostering engagement for other actors involved in the ecosystem. However, these other actors have less influence on the ecosystem than the Sam-application and Helsingborg Municipality, as they are further away from the central governance.

In contrast to the neutral facilitation in Helsingborg Municipality, Predictive Movement emphasized the need for a *central actor* to manage the system, ideally a non-profit entity such as a university, a governmental institution, or a municipality (PM2.7; PM1.3). This governance structure of Predictive Movement is also illustrated in the governance model (Figure 7), where Predictive Movement has a central role, and a non-profit organization, such as a university or a municipality, acts as a keystone member, managing control over the ecosystem. However, others argued that the *governance should not be a subject for one municipality*: “It is not about a small municipality driving this, but rather that it should be a national or even EU-level requirement [...]” (HBG2.9). This highlights expectations for interoperability and standardization to be driven by centralized actors, rather than municipalities alone.

Another governance approach was evident in Södertörn, where the municipalities rely on the external actor to manage freight logistics operations. Data sharing is used for internal reporting and follow-up purposes (ST2.1), and the municipality *depends on the external actor* for different logistical services (ST2.6; ST2.7). This, in turn, made the municipality contractually bound to the external actor for logistical services. This governance structure is also reflected in the governance model (Figure 7), where the external actor assumes the central role (first layer), thus restricting the control (second layer) of municipalities in the ecosystem. The municipalities are therefore placed in the third layer due to the limitations imposed in the second layer. For an external perspective, a private actor (PF1.3), emphasized the role of *contractual clarity* (3.2) to have secure and transparent collaboration. From their perspective: “In these municipal agreements [...] it is very clear what will happen going forward [...] without a very clear agreement, the supplier might have tried to look there [...] and pick the raisins out of the cake” (PF1.3).

Summary – roles and governance approaches:

Roles concerning data sharing vary across cases, reflecting different responsibilities and governance approaches. The cases acted as neutral facilitators, central actors, or contractual dependents. These approaches shape how collaboration and control are distributed among actors in the ecosystems, influencing the coordination of data sharing and logistics operations.

4.4 Sensitive data

Handling of sensitive data introduces tensions between *transparency, confidentiality, and compliance with data protection regulations such as the GDPR* [24], shaping how data sharing can be implemented across the cases. These tensions are reflected across the cases, where the handling of sensitive data (4.1) and legal considerations (4.3) emerged as recurring concerns. Municipalities operate under the principles of *public access to information*, which can create tension with private actors' need for secrecy. As one municipal representative from the Helsingborg Municipality explained: "contract with a municipality can be requested as public information [...] it is already quite transparent" (HBG4.6). While companies can *request confidentiality* during public procurement processes, such requests are not always granted, as secrecy assessments are required (HBG4.7).

Similar concerns were raised by other respondents in Södertörn Municipalities, who emphasized removing certain types of data, such as receiver registers and names, to *comply with GDPR* (ST2.4). Also, the need for confidentiality depends on whether the data is commercially sensitive (ST2.10). Private actors can consider this data openness as a risk. A supplier involved in the Sam-application explained that municipal contracts can be difficult to interpret without direct involvement: "If you are not actively involved in the contract [...] you might read the documents and think, I would never have signed this, but that is not how it works in practice" (PF1.3).

Concerns about *data exposure and market position* were also raised in the Predictive Movement case: "It is this uncertainty about what it means for my own business [...] they do not want to lose their place in the market" (PM1.8). To mitigate these risks, actors in the cases described strategies to share data (4.2). One strategy emphasized was *minimal data sharing*, where only the information strictly necessary to complete a task should be available (PM1.1). *Voluntary consent* was also highlighted as a key mechanism, allowing users to approve of data sharing under specific conditions: "I think this idea of voluntarily sharing your data [...] is something we should not forget" (PM1.15). Despite these concerns, some respondents acknowledged that a *certain level of risk may be necessary* to enable progress. As one supplier explained: "Of course, I expose myself as a supplier, and that is the risk I have to take in exchange for a potential gain" (PF1.4).

Summary – sensitive data: The handling of sensitive data emerged as a concern related to transparency, confidentiality, and compliance with regulations. Municipalities operate under the principle of public access, which can create tension with private actors' need for secrecy. Strategies such as minimal data sharing and voluntary consent were emphasized to mitigate challenges and foster collaboration.

4.5 Data quality

Data quality varies across the cases and functions as a key component for effective data sharing, shaping how data can be used for coordination and decision-making within the ecosystem. We analyze these variations using four key dimensions of data quality [77, 6]: *accuracy*, *completeness*, *consistency/compliance*, and *timeliness*. These dimensions are therefore used as an analytical framework for the different quality variations among the cases.

In terms of *accuracy*, a respondent in Helsingborg municipality emphasized the *need for more granular and usable data*, highlighting data quality possibilities (5.2). However, the Sam-application is considered a valuable initial step, but lacks data: “I would have liked to get more information related to fuel type, the company, and the individual employee driving” (HBG4.15). This illustrates how data quality supports technical integration, environmental, and social goals. However, another respondent from Helsingborg municipality gave *lower priority to data quality*: “Data quality is the aspect we have focused on the least. [...] We want to get this started, to begin collecting and sharing data. [...] We may have geofencing zones [...] that are not entirely accurate [...] but that is not what matters most to us at this stage” (HBG1.12W). This highlights a trade-off (5.1) between data quality and the volume of data, where data with missing details may be acceptable to enable collaboration.

Similar challenges in managing the *trade-off between accuracy and practical considerations* were evident in the case of Predictive Movement, where data quality is the foundation for their digital twins for transport simulations. However, limited real-world data often results in the use of synthetic data, raising questions about how accurate the data is: “It is a question of how much you’re willing to accept” (PM1.7). This concern relates not only to accuracy, but also to *timeliness*, as outdated data can affect the trustworthiness of digital twins.

Regarding *completeness*, in Södertörn Municipalities, data quality depends on the external consolidation terminal and the level of data maturity among suppliers. Some actors provided detailed information, while others could only deliver limited input, such as Excel files or global location number (GLN), requiring enrichment by the carrier using internal systems: “There are some actors who are very good [...] while others can [...] only send an Excel file with weight and a GLN number” (ST2.5). Another respondent also emphasized the importance of data quality requirements (5.3) such as *specific data fields*, such as origin, destination, pickup and delivery times, and goods dimensions, as inaccurate or missing data can cause operational problems (PM2.6).

For *consistency/compliance*, to address the challenges with variation in maturity among suppliers, Södertörn Municipalities has adopted *data standards*, developed with the Swedish Association of Local Authorities and Regions (SALAR)², although challenges remain (ST2.19). Issues related to standards were also noted

²<https://extra.skr.se/englishpages.411.html>

in Helsingborg municipality, where *aligning data* from multiple systems remains difficult. To facilitate integration, the municipality is exploring using GLN numbers: “We have started looking into GLN numbers [...] so that we can combine and understand the data we receive” (HBG1.3).

Summary – data quality: There are variations in data accuracy, completeness, consistency/compliance, and timeliness across the cases. These aspects can influence how the ecosystem functions in terms of efficiency and integration. In the studied cases, actors balance ideal data quality against practical limitations and a willingness to share data.

4.6 Procurement

Public procurement functions as both an enabler and a constraint for data sharing, shaping how requirements and contractual agreements influence integration in municipal freight logistics. Across all cases, procurement influenced data sharing through *specific requirements*. Interviews highlighted several key aspects, including *needs analysis*, *market analysis*, *procurement possibilities*, and *the time-bound aspect of procurement agreements* (ST2.12). These key aspects are related to the Swedish Public Procurement Act (2016:1145), which regulates how public procurement should be conducted and addresses aspects such as transparency, competition, environmental, and social considerations. The *needs analysis* was described as an initial step in the procurement process contributing to procurement-related market analysis (6.3), where the respondents emphasized the importance of questioning the need: “Do we really need this, or are we just buying something we have always bought?” (HBG4.5).

This market research approach was then followed by the *market analysis*, which aims to ensure that requirements are realistic and aligned with market capacity. A respondent explained: “You ask questions to find out what is reasonable [...] we do not want to end up in a situation where the requirements are so strict that we get no offers” (HBG4.11). Specifications must *balance ambition with cost-efficiency*: “You can specify anything. [...] it must not become too cost-driving” (ST2.18). After needs and market analysis, procurement requirements have a central role in managing the behavior of involved actors and influencing data sharing (6.1). As these requirements are often *non-binding* (HBG4.9, HBG1.2), they do not enforce compliance among stakeholders: “We have started setting requirements to collect data. [...] we had not made it a mandatory requirement, only a recommended one. [...]” (HBG1.2). As these are non-binding, they do not force compliance, and this complexity was further reflected by one respondent, who explained that despite municipalities having direct control, procurement still proves to be a challenging process: “Procurement might be considered in the area where we have the greatest control [...] but I still find it very difficult, because it requires getting

many stakeholders on board and changing working practices” (HBG1.14W). This reduces the likelihood of data sharing among stakeholders, which leads to uneven participation across the ecosystem.

However, *specific requirements*, such as providing logistical data, were seen as a solution: “One could write that they must provide their driving data” (PM1.6), while flexibility in data formats may improve compliance: “We can not require them to use the app if they have another system that works just as well” (HBG2.2). Feasibility also depends on the type of logistic actors, those who acquire their transport may face greater challenges (HBG1.2). Furthermore, procurement was described to function as both a central *governance mechanism and a constraint*, highlighting procurement possibilities (6.2). When municipalities are contractually bound to providers, it may limit their flexibility. However, to overcome this, a dedicated platform could allow Södertörn Municipalities to avoid dependency on a logistics service provider: “For us, it would mean that we are not tied to one transport provider, but rather free” (ST2.3).

Summary – procurement: Public procurement acts as both an enabler and a constraint for digital integration in municipal freight logistics. Procurement requirements have a central role in shaping the behavior of suppliers. Key aspects, include needs analysis, market evaluation, and the time-bound aspect of procurement agreements.

4.7 Sustainability aspects

Sustainability can be viewed from several perspectives, in which frameworks such as the European Sustainability Reporting Standards (ESRS) [21] address three categories: Environmental, Social, and Governance. In this study, however, the cases examined primarily focus on environmental aspects. Data sharing enables *opportunities* (7.2) to integrate environmental sustainability objectives, specifically those aspects related to reducing emissions and air pollution into municipal freight logistics, but its implementation is limited by *challenges* (7.3) in relation to prioritization and data accessibility.

Respondents described how data sharing can support more sustainable logistics practices. In Helsingborg Municipality, for example, there is an ambition to integrate more *sustainability evaluation* into procurement, planning, and follow-up (HBG4.3; HBG4.11). In Södertörn Municipalities, similar solutions were described, where sustainability monitoring could be enabled by *tracking vehicles, fuel types, and dates for delivery*. However, these efforts are often *deprioritized* (ST2.16). Another challenge emphasized concerns *accessing emissions data*, particularly when external carriers are involved: “It would have been easier to get an overview [...] but it is a bit difficult. [...] If they send just that one pallet on a truck, then the environmental impact becomes very large” (ST2.16).

While these challenges exist, one respondent described a *conceptual scenario* that involves calculating the sustainability impact of a specific delivery based on its volume, vehicle type, fuel consumption, and distance traveled, indicating sustainability requirements (7.1), potentially enabling more informed decisions when ordering transport services (HBG3.3). Emissions could also be reduced by adjusting delivery schedules (HBG4.3) or by improving vehicle fill rates (ST2.17). However, as another respondent explained, communicating *concrete numbers* can sometimes be more effective than sharing abstract ones: “It is almost more important to be able to show, okay, but we have reduction of vehicles by three, instead of being able to state the exact number of kilograms of CO2 saved” (PM1.16W).

Summary – sustainability aspects: Data sharing can support more sustainable freight logistics practices by enabling integration and monitoring of key sustainability aspects at a detailed level. These aspects are, for instance, goods volume, vehicle type, fuel consumption, and distance traveled.

4.8 Summary proposition

As a step towards theorizing the phenomenon of public-private optimization of municipal and regional freight logistics, we derived the conceptual model of constructs and actors, as presented in Figure 6. Here, we further the process by summarizing the above-reported findings in terms of proposition sketches, to be refined and validated in subsequent work, see Table 4.

We synthesize across our surveyed cases that data availability and accessibility are at the core of the envisaged optimization of freight logistics (P1). The platforms play a key role in enabling data sharing, where technical interoperability across systems and actors is foundational (P2). Platforms, however, only provide the technical means. Effective and trusted coordination and governance mechanisms are critical for facilitating and enabling any sharing and collaboration at large (P3). When sharing data, it is also necessary to balance sensitive data with benefits for actors (P4), such as market exposure and efficiency improvements. However, data quality affects the efficiency and integration of the data ecosystem (P5), where public procurement requirements can enforce and constrain data sharing depending on the context (P6). To reach freight logistics optimization, it is, however, necessary to have detailed transport data, influencing the environmental sustainability (P7).

ID	Proposition Sketch
PS1	Data availability and accessibility is at the core of freight logistics optimization.
PS2	Technical interoperability across systems and actors is foundational for data sharing.
PS3	Public actors may take different governance roles, but the central actor must be trusted as being fair.
PS4	Risks related to sensitive data must be balanced with benefits for actors.
PS5	Data quality impacts the data ecosystem efficiency and integration
PS6	Public procurement requirements may enforce <i>and</i> constrain data sharing.
PS7	Detailed transport data are needed to perform valid freight logistics optimization with respect to environmental sustainability.

Table 4: Propositions sketches derived from the results above, and aimed for further refinement and validation in future work.

5 Discussion

In the following section, we discuss the findings in relation to prior research. The discussion is organized around three areas: platform configuration and design, enabling factors for data sharing, and aspects related to sustainable freight transport. Additionally, we further extend the general conceptual model (Figure 6) by integrating enabling factors, illustrated in Figure 8.

5.1 Platform configuration and design to enable data sharing in municipal and regional last-mile freight logistics

The findings show that platform configuration plays an important role in shaping how data sharing is structured and implemented in public-private freight ecosystems. These findings address RQ1 by showing how relationships between involved actors in the data-sharing ecosystem are enabled through different platform configurations. For regions and municipalities to achieve more efficient and sustainable last-mile freight logistics, data sharing is essential. It functions as a central mechanism that fosters integration and drives value creation, including operational value, such as improved routing and co-loading, as well as value in the form of increased transparency and coordination, and, to some extent, sustainability-related value.

We observed that data sharing among actors in the ODE generates significant value, highlighting the need to encourage actors to recognize the value of data sharing. Such value of data sharing can be seen in practical applications, includ-

ing co-loading and more efficient route planning. This observation is also in line with Runeson et al. [70], who emphasize data value and collaboration around data as main business drivers for ODEs. Although Möller et al. [48] identify visibility and optimization services as dominant value propositions in data-driven logistics, our findings extend this perspective by showing that value creation is not only enabled through such data-driven services, but also shaped by platform configurations, governance structures, and varying levels of technical maturity among actors.

While data sharing is crucial to ODEs, its effectiveness depends on a technological platform architecture that enables interoperability among actors and systems. The platform serves as the backbone of the ecosystem, creating an environment that allows for effective data sharing. This finding is in line with Ofe and de Reuver [52], who highlight interoperability as a key enabler of data sharing in data platform ecosystems, where our findings also indicate that limitations in interoperability may constrain data sharing and value creation in ODEs. Connected to the platform, there are relationships between the platform, involved actors, and systems. This is illustrated in Figure 8, which builds further on the ODE model created by Larsson et al. [36], by adding context and a broader spectrum. In Figure 8, we illustrate how the general conceptual model (Figure 6) is underpinned by enabling factors. These factors are important to the functioning of the ecosystem, enabling data sharing in the ecosystem. However, the analysis revealed limitations in platform design and operation in the studied cases, primarily due to a lack of interoperability between systems. One involved system is the TMS, which frequently acts as a standalone system due to the lack of interoperability.

We emphasize the importance of having ODEs that foster interoperability among different actors and systems. This aligns with prior research that highlights system interoperability as a key element for effective logistics operations [59]. This includes, for example, integrating systems such as transport and e-commerce systems. Furthermore, operational challenges exist, such as manual processes, a lack of automation, inadequate technical skills, and system lock-in. This further underscores the need for more interoperable solutions, where the ODE can act as a technical framework [36], promoting standardized solutions and reducing limitations such as system lock-in among stakeholders.

5.2 Enabling factors for data sharing

In addition to the platform configuration and design, our findings identify a set of interrelated enabling factors, including data quality, legal aspects, procurement, and governance structures, that shape how data sharing is realized in practice. These findings address RQ2 by indicating that data sharing in ODEs is not only a technical challenge but is also influenced by socio-technical and organizational aspects. These enabling factors are also identified in inter-organizational data sharing, such as challenges related to data quality, legal uncertainty, and coordination

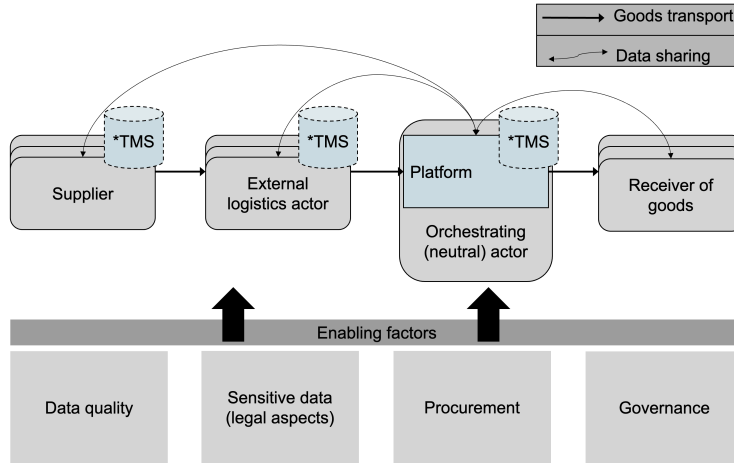


Figure 8: Conceptual model with enabling factors underpinning the ecosystem with data quality, sensitive data, procurement, and governance structure. Each of the factors has an impact on the data sharing and freight logistics operation in the ecosystem.

among actors [33]. Our findings contribute to this research area by showing how these challenges manifest and interact in the context of ODEs, shaping how data sharing is evident in practice.

Figure 8, synthesizes these findings by illustrating how platform configuration and enabling factors together shape data sharing in ODEs. The figure highlights how technical factors such as data quality and organizational and institutional factors such as governance, legal aspects, and procurement influence data sharing processes. These factors enable or constrain how actors interact and share data within the ecosystem.

Data quality is a critical factor for data sharing, though a tradeoff exists between volume and data quality, increasing the complexity of reaching a balance. Inadequate data quality can hinder the ecosystem from reaching full potential [36] due to its importance in terms of value and usability to the ecosystem. However, the studied cases revealed different requirements. While some respondents highlighted the need for a large volume of data for platform functionality, others emphasized the need for more granular and usable data, such as specific data fields (PM2.6) for transportation (HBG4.15). Given that both aspects can have an essential role in the functioning of the ecosystem, there is a need to consider the requirements depending on the scenario. This aligns with prior research by Strong et al. [77], who emphasize that data quality is context-dependent and defined by its fitness for use. Our findings further suggest that actors within ODEs prioritize different dimensions of data quality, such as volume or data quality, thereby shaping how

data sharing practices are implemented across the ecosystem.

In addition to data quality, legal aspects such as GDPR [24] play an important role in the ODE, yet uncertainty around legal requirements exists [70, 62]. To mitigate this and encourage data sharing, strategies such as minimal data sharing and voluntary consent can therefore be a solution, complemented by clearer legal guidelines [17, 43]. These findings therefore indicate that legal uncertainty can create barriers, where unclear regulations can reduce willingness among actors to participate in the data sharing.

Together with legal aspects, procurement emerges as both a central governance mechanism and a constraint. Although municipalities feel that procurement is an area where they have considerable influence, requirements related to data sharing are often non-binding. We therefore argue for having more binding requirements in the procurement agreements, since procurement functions as a critical governance mechanism, where binding requirements can influence the extent to which data sharing is realized among actors. If non-binding requirements are used, this can result in reduced participation among actors and limited effectiveness of the ODEs.

Regarding governance, it has an essential role in data sharing [7], as it contributes to ecosystem orchestration, establishes standardization, builds trust, and fosters collaborations among actors [36]. Municipalities can assume the role of a keystone actor, having a larger impact on the ecosystem [32, 27]. For example, if the municipality acts as a neutral actor, it can reduce competition and orchestrate collaboration among stakeholders (HBG4.14) in various governance structures, including community-based or keystone-centric structures [70, 53]. However, opinions vary on whether governance should be managed by local municipalities or centralized to a higher level, such as the EU. These findings emphasize that governance not only orchestrates the ecosystem but also influences the control, shaping the collaboration among involved stakeholders.

5.3 Sustainable freight transport

Sustainable freight transport depends on data sharing to enhance logistics efficiency and enable co-loading. However, our findings indicate that such data sharing is often constrained by limited data accessibility, insufficient prioritization, and challenges in integrating data into key structures such as procurement. Prior research has highlighted the importance of data accuracy for achieving low-carbon operations [46]. However, our findings indicate that in ODEs, the challenge is not solely related to data accuracy but also to the integration and prioritization of sustainability-related data between actors.

While some respondents described combinations of data such as vehicle type, fuel type, and distance traveled as useful for enabling more informed decision-making, these examples were often conceptual and not fully implemented in practice. This indicates that the key challenge lies not in identifying relevant data, but in establishing the standards by which such data can be integrated into oper-

ational processes, collected, and shared among stakeholders. Achieving environmental goals, including national [81] and global sustainability targets [86], highlights the need for data-sharing among actors to be prioritized. Accordingly, this shows that ODE can contribute to more efficient and sustainable freight transport, provided that data is accessible and integrated within governance and procurement structures.

6 Conclusion

This study examined how data sharing practices within open data ecosystems (ODEs) are shaped in the context of municipal and regional last-mile freight logistics in Sweden. Through a qualitative multiple-case study of three cases, the findings show that data sharing functions as a central coordination mechanism, enabling integration and value creation across actors (RQ1).

The findings contribute to research and theoretical perspectives on ODEs by showing that the functioning of ODEs is not only a technical configuration but also depends on several interrelated socio-technical aspects, including technological platforms and enabling factors such as data quality, handling of sensitive data, procurement, and governance structures (RQ2). These aspects shaped the development of a conceptual model illustrating how enabling factors together underpin the functioning of ODEs in last-mile freight logistics. From a practical perspective, the study contributes by highlighting the importance of established and standardized governance structures, including mandatory procurement requirements and interoperable platform design, to enable effective data sharing.

The findings further show that municipalities can assume the role of neutral keystone actors (RQ3), orchestrating the ecosystem by coordinating actors and facilitating data sharing, for instance through procurement practices. This also suggests that having clear governance structures and responsibilities is critical for enabling efficient data sharing in public-private domains. The study also indicates that ODEs have the potential to contribute to more sustainable freight logistics; however, this is dependent on the integration of data into governance and operational practices.

However, as this is an exploratory study, the focus on Swedish municipalities and the limited sample size may restrict transferability to other contexts. The findings should be interpreted in this context, and therefore, we do not make any claim of universal generalization. Future research should examine additional cases and governance models, both in public and private domains, and further explore practices related to data sharing, including platform design, data quality, legal frameworks, governance structures, interoperability, and business models.

Acknowledgments

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Appendix: Interview questions

Below are the interview questions used during the first round of semi-structured interviews conducted with the three cases. The questions are organized according to the research questions from which they were derived.

Research Question 1 (RQ1): What are the conceptual relations and data sharing practices between actors in the last-mile freight transport of goods on behalf of public actors?

Do you share data within freight transport, and if so, how do you share data? What are the main objectives of sharing data? What value does the data have for the parties involved?

What are the main objectives of accessing the shared data? What type of data do you usually share or access? How do you work with sensitive data?

Research Question 2 (RQ2): How do actors address quality control, legal compliance, sustainability, governance, and other aspects that they consider important?

How do you think the quality of shared data affects your business? Do you have any kind of system or standard to ensure that the data shared is of high quality? If so, how do you work with that system?

Do you have any system to protect the integrity of shared data? If so, how do you work with that system?

When you work with data sharing, are there any legal requirements/policies that affect how you work? How do you think it works and does it need to be changed? Are there any legal barriers that affect how you work with shared data?

Are there any other aspects related to data sharing in freight transport that you consider important?

Research Question 3 (RQ3): What specific roles do public actors undertake?

What roles do you think municipal actors take on in data sharing? We often talk about data consumers, producers or platform providers. Is this something you recognise? How do you work with competition between different actors and data sharing? What roles do you see other actors playing in data sharing related to freight transport? If there is one, which actor do you think takes on the role of platform provider/main responsible party, i.e., enabling data sharing? Why do you think this actor takes on this role?

DESIGN INSIGHTS FOR A FLEXIBLE AND INTEROPERABLE DATA SHARING PLATFORM FOR LAST-MILE LOGISTICS

John Larsson, Johan Linåker, Per Runeson

Abstract

Data sharing through an open data ecosystem has been suggested as an approach to increase efficiency in last-mile municipal logistics and thereby contribute to reducing greenhouse gas emissions. However, previous studies indicate that existing data sharing platforms have challenges with interoperability and flexibility. This study therefore aims to investigate how other transport domains and regulatory frameworks can provide design insights to mitigate these challenges. To achieve this, the study adopts a design science approach, moving from the problem domain as observed in three cases toward the solution domain of data sharing platforms. The study identifies cross-sector design insights and associated mechanisms, including boundary resources, governance approaches and certified platforms, highlighting how these can be supportive functions for a more flexible and interoperable data sharing platform. However, we also conclude that platform design needs a set of configurations that influence the design of the data sharing platform to meet varying needs.

1 Introduction

Last-mile logistics represents the final stage of the transport journey and plays a significant role in the supply chain of goods [55]. This includes freight logistics in the public sector, for example, procured by municipalities or regional governmental entities. However, last-mile logistics is a major contributor to greenhouse gas emissions to the environment [26], and the emission volumes are expected to increase in the future [84]. To achieve a reduction in emissions from last-mile freight logistics [22], innovative solutions are required.

One proposed approach is data sharing through an open data ecosystem, where data sharing has shown potential to enable more efficient last-mile freight transport [37]. An open data ecosystem refers to a community of actors collaborating around data, supported by a technological platform [70], which creates the technical environment enabling data sharing collaboration. We have previously examined in two studies in the public sector [36, 37] how data sharing can be integrated with the logistics sector and how such integration may contribute to improved efficiency among the actors involved in municipal last-mile logistics. One of these studies [37] employed a qualitative multiple-case study investigating three regional and municipal cases with diverse architecture, governance, and maturity levels of data sharing practices.

In prior research, we identified several shortcomings that limit data sharing between actors using technological platforms, including challenges related to interoperability [59, 52], ecosystem governance [7], and the lack of a standardized format for the shared data [6]. While previous studies have mainly focused on how the mentioned challenges are addressed in public transport logistics [64, 39], to the best of our knowledge [36], there is limited research on how design insights from more mature and regulated domains can be adapted to municipal last-mile freight logistics.

To address this research gap, we focus on cross-sector contexts by synthesizing design insights from the related public transport sector, focusing on a reference case, Samtrafiken, and from the emerging regulatory development in freight logistics, Electronic Freight Transport Information (eFTI). We chose to focus on Samtrafiken, an organization co-owned by Swedish transport authorities and public transport actors [64] that also operates the open data platform Trafiklab [65]. We consider Samtrafiken as a more technically mature solution, while eFTI is an emerging regulatory framework, covering standardized platforms and data sharing in freight transport. By synthesizing these two domains, we identified central design insights and supporting mechanisms, such as boundary resources, governance, and certified platforms, which contribute to a deeper understanding of how more flexible and interoperable data sharing platforms can be designed for municipal last-mile freight logistics. Accordingly, we explore the following research questions:

RQ1: *What design insights and mechanisms can support the development of flexible and interoperable data sharing platforms in municipal last-mile freight logistics?*

RQ2: *What different design approaches to data sharing platforms can be identified in cross-sectional domains based on boundary resources, governance structures, and platform configurations?*

The paper is structured as follows: Section 2, presents background, Section 3 presents the methodological approach for this study as well as the problem context together with the design baseline, Section 4 presents our findings in terms of design insights, in Section 5 we reflect on the outcomes, and Section 6 concludes the study.

2 Background and related work

This section provides background to the study, including concepts such as open data ecosystems, platforms, and governance. Taken together, these concepts provide perspectives for how data sharing platforms can be structured and governed within an open data ecosystem.

2.1 Open data ecosystem

An open data ecosystem (ODE) is not consistently defined in the literature [53]. However, an ODE can be defined as “a networked community of actors (organizations and individuals), which base their relations to each other on a common interest [70], supported by an underpinning technological platform” [31]. Such an ecosystem allows actors to process shared data [53], create value, innovate, and enable new businesses. Actors also collaborate on the sharing of data and boundary resources by exchanging information, resources, and artifacts [31]. Within ODEs, different levels of data openness can be observed, as defined by the Open Data Institute through their spectrum of openness [14]. This spectrum characterizes data ranging from closed to shared to open, which can guide openness in the ODE [70], mediating the organizational risk with opportunities for innovation [18].

2.2 Platform

Within such an ecosystem, a data sharing platform can be conceptualized as a technical infrastructure for data sharing between public and private actors. The platform can have multiple characteristics, such as technical architecture, governance, and interfaces, such as Application Programming Interfaces (APIs) [66]. Furthermore, the platform enables actors to process data, promote innovation, and create value among involved actors. Tiwana et al. [78] also describe that platforms exhibit variation in their technical and organizational structures, where the platform design can be dependent on the applied context.

Furthermore, a data sharing platform is described by de Mildt et al. [47] as a central element that provides a foundation, which can be extended through complementary third-party software modules. These modules enable collaboration between different software systems. However, in addition to its technical aspects, a data sharing platform also encompasses a socio-technical dimension, which includes organizational arrangements and standards, influencing the system and involved actors. Pan et al. [59] describe the importance of digital interoperability between systems and involved actors. They also describe four major challenges related to digital interoperability: *Data sharing formats, communication, security, and type of data needed*. Furthermore, there are various proposed solutions to these key challenges, with *smart infrastructure and communities* being one solution. This solution highlights how data sharing and interoperability are central not only to effective logistics solutions but also to activities such as efficient planning and communication between actors.

2.3 Governance

Platform governance is described by Bartolomucci et al. [7] as a central concept within the context of data sharing. This is also emphasized by Dal Bianco et al. [10], who refer to three different governance structures: “organization-centric, consortium-based, and community-based ecosystems”. An organization-centric ecosystem refers to a governance managed by a single actor. In contrast, a consortium-based ecosystem is governed by an organization whose ownership lies with the actors participating in the ecosystem. Lastly, a community-based ecosystem means that control lies with the members of the ecosystem, resulting in a more decentralized form of governance structure.

In our previous research, trust is also found to be a central factor from a governance perspective in data sharing ecosystems [36]. This is considered a challenge, although trust can be fostered through the establishment of a neutral actor orchestrating the ecosystem [70]. Such a neutral actor may occupy a central coordinating position within the ecosystem, contributing to trust and enabling more efficient data sharing.

3 Design science research approach

This study is positioned as an analytical design study within the design science approach. Design science refers to the development of *design knowledge* to address context-specific *real-world problems* [19], involving activities such as *problem conceptualization, solution design, and validation* [68]. The design knowledge may be expressed as *technological rules*, i.e., “field-tested and grounded exemplars of how a problem can be solved” [3].

We build on data collection from previous work (Section 3.1), we revisit the data analysis (Section 3.2). As explained in relation to the problem domain (Sec-

tion 3.3) and solution domain (Section 3.4), we integrate these domains in the development of design insights, which can be expressed as a first phase of establishing technological rules. However, the study does not include all *constituents of the design science paradigm* [68]. Instead, it builds on a deeper understanding of the problem area derived from previous studies [36, 37], and moves toward the solution domain by exploring and synthesizing design insights in a more mature, established logistics domain and emerging regulatory frameworks.

3.1 Data collection

This study builds on multiple information sources, including both existing literature and empirical data, as well as design insights derived from established approaches within the domain. The research process was initiated with a literature review [36], and further expanded in a multiple-case study [37], where empirical data were collected. The previous research formed the basis for our problem domain (Section 3.3) and provided a contextual understanding of the identified challenges. To explore established data sharing approaches within the logistics domain, we conducted exploratory discussions with two experts in the field. The first expert has several years of experience in the field and conducts research on data sharing in the logistics sector, with a focus on public transportation. The second expert has extensive professional experience with data sharing in logistics, with a focus on informatics.

These discussions led us to the more mature establishment within public transport logistics, Samtrafiken, and the emerging regulatory framework, eFTI. Furthermore, to derive design insights from the identified contextual areas of Samtrafiken and eFTI, we explored existing academic literature in databases such as Google Scholar and Scopus, together with publicly accessible documentation and grey literature. To ensure relevance, inclusion and exclusion criteria were applied. Inclusion criteria covered literature related to data sharing in public transport logistics, including Samtrafiken and Trafiklab, and the eFTI framework. Exclusion criteria were applied to remove sources not covering the scope of the study, such as literature focusing only on public transport logistics without data sharing or a platform design perspective.

3.2 Data analysis

Based on the identified information sources, the previously collected data, combined with the two experts' perspectives, were analyzed, which formed the basis for the design insights presented in the results of this study. The analysis was conducted through a thematic analysis inspired by Braun and Clarke [12]. Initially, we started by reviewing relevant sources to understand the data, after which we identified related key concepts. These key concepts were subsequently examined and compared, leading to the development of recurring themes. These themes were

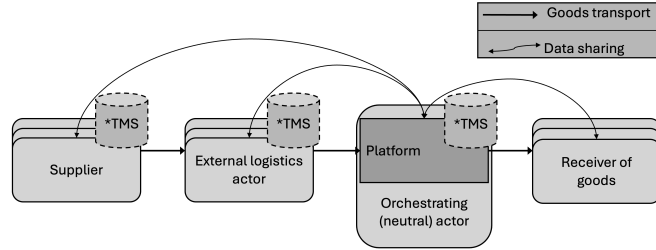


Figure 1: General conceptual model adopted from Larsson et al. [37] describing the ecosystem of the three previous cases. The figure describes data sharing, the stakeholders involved, the data sharing platform, together with the TMS.

then abstracted to a higher level, forming the foundation for the design insights presented in the results.

3.3 Problem domain and design baseline

Across the three studied last-mile logistics cases in our previous study [37], we identified a shared problem context that relates to fragmented data sharing, limited interoperability, limited governance structures, and lack of standardized data formats. These challenges form the design baseline of this study. Some of the components of the problem context are also illustrated through the general contextual model presented in Figure 1. The figure describes the platform context with the involved actors and data sharing, illustrating the flow of goods and data between involved actors in the ecosystem. It also describes the interaction between data sharing platforms and transport management systems (TMS), where the data sharing platform and TMS act as separate systems.

A common and recurring problem across the cases concerns insufficient and fragmented data sharing in the existing data platforms. The data being shared is not based on standardized formats, which reduces the data quality. In addition, the existing data sharing platforms often require manual handling with mobile apps or documents to share data, creating further barriers to efficient data sharing among involved actors. Another recurring issue relates to governance structures and the influence of municipalities within the data sharing ecosystem. The municipalities experience a mismatch between their areas of control and their actual influence over the data sharing practices, despite being able to influence the practices, for example, in the procurement processes. This creates challenges in the governance structure, limiting the orchestrating actors from further developing the data sharing practices in their ecosystem. Among the studied cases [37], there is a variation of governance structures, encompassing *neutral facilitators*, *central actors*, and *contractual dependents*. Platform interoperability also emerges as a shared challenge

across the studied cases. For instance, internal limitations in communication in existing systems create boundaries, limiting the ability to share data.

Finally, implementation represents a recurring aspect of the problem context. Our previous study [37] indicates fragmented approaches to how data sharing platforms could be implemented and used. There are differences in technical competence among involved municipalities and involved actors, which further strengthen the barriers to implementation. In addition, it can be difficult to motivate the investment in data sharing platforms among resource-constrained actors. Collectively, the identified challenges across the three previously studied cases can be abstracted into a shared *problem conceptualization* [68] at a general level rather than at a case-specific level, which serves as the starting point for this design study.

3.4 Solution domain

Building on the problem domain and its problem conceptualization, this study moves toward the solution domain, aiming to develop design insights that contribute to a deeper understanding of design possibilities. These insights are derived through the synthesis of existing knowledge from previous studies, presented in the problem domain. To complement these design insights and gain an external perspective from other contexts, our study builds on insights from the public transportation sector, specifically the more technically mature actor Samtrafiken, as well as the emerging regulatory framework eFTI. The synthesized design insights, therefore, contribute to an indication of how a data sharing platform within the context of ODEs can be structured to address challenges related to, for instance, governance, reference architecture, and boundary resources. The study thus contributes by changing the scope from problem conceptualization toward the solution domain by contributing towards the elements of an emerging theory.

3.5 Technological Rules

As explained by Runeson et al. [68], technological rules cover both the *problem domain* and the *solution domain*, and are derived from constructs from these, typically expressed in the format: *To achieve <Effect> in <Context> apply <Intervention>*. In this study, the identified challenges in the problem domain relate to the design insights in the solution domain, presenting insights such as boundary resources, reference architecture, and governance structures. Given that this study is an analytical design study that moves from the problem domain toward the solution domain, the presented design insights do not include completed or validated technological rules. However, the insights indicate potential properties for a flexible and interoperable data sharing platform, which can act as a guide for both practitioners and continued research.

3.6 Threats to validity

The following section presents the identified threats to validity [60] based on the study's methodological approach, including construct validity, internal validity, external validity, and reliability. It also outlines the strategies used to mitigate these validity threats.

Regarding *construct validity*, it concerns the potential for selection bias in identifying relevant established approaches within the domain. As the selection of these approaches was informed by discussions with experts in the domain, we argue that this reduced and mitigated this risk. However, there is a possibility that other alternative relevant areas could have been identified.

Regarding *internal validity*, there is a risk of prior knowledge and experience influencing the identification of insights. To mitigate this, we attempt to analyze from an abstract perspective, focusing on patterns and design insights. Finally, there is also a risk of misinterpreting the secondary data analyzed in the study. To mitigate this, we as researchers have discussed the analyses and design insights by critically reviewing interpretations of the data. Nevertheless, this should still be taken into account when reading the findings.

In relation to *external validity*, the primary concern relates to the generalization of the findings to other domains. Rather than generalizing directly across the prior cases and contexts, we make analytical generalization by abstracting empirical data and design insights into a higher abstraction level, in order to identify patterns and relevant insights. To further strengthen this approach and the robustness of the study, the study explores perspectives from two distinct domains in the logistics sector, a more mature case within public transportation, Samtrafiken, and an emerging regulatory framework, eFTI. Although we do not claim that the findings of this study can be universally generalized, there is a possibility that the insights may be transferable to similar contexts.

To enhance *reliability*, we maintain transparency regarding how the explored findings have been analyzed. This includes transparency regarding procedures such as keywords and databases used. However, there is an inherent risk associated with this type of analytical study, specifically the interpretation of the collected data. Other researchers might interpret the collected data in various ways, which can result in variation in the selected design insights. Therefore, this should be taken into account when assessing the reliability of the study.

4 Results

Using the design science methodology, we identify several design insights from the public transport sector and the emerging regulatory framework underpinning design decisions towards a more flexible platform with standardized boundary resources. The findings are collectively synthesized in Figure 2, illustrating three sections consisting of *design insights*, *design mechanisms*, and the *data sharing*

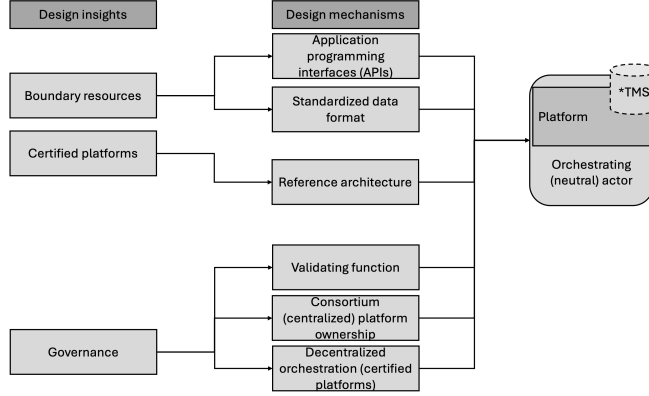


Figure 2: The figure illustrates the design insights (left side) and associated design mechanisms (middle), and how these elements influence the orchestration of data sharing platforms (right side). This includes elements such as boundary resources, reference architecture, and governance structure.

platform. The figure also highlights how the design insights and design mechanisms are related and how these could be integrated with the data sharing platform. Each of the concepts and their relations is elaborated in subsequent sections.

4.1 Boundary resources

Boundary resources can be defined as software tools and regulations that serve as interfaces between the platform and external stakeholders [25], constituting an essential component of the ecosystem. Boundary resources can also enable flexible and interoperable data sharing, underpinned by key mechanisms such as APIs and standardized data formats. Standardized APIs can be identified as key design mechanisms in public transport logistics [80], enabling interaction between the platform and actors in the ecosystem. These APIs include both static and real-time APIs, depending on the type of data, for instance, timetables or route disturbance [79]. APIs rely on standardized data formats, using formats such as General Transit Feed Specification (GTFS), Network and Timetable Exchange (NeTEx), and Service Interface for Real-time Information (SIRI) [64], contributing to enhanced data quality in the ecosystem. *Standardized data formats* represent another design mechanism, facilitating interoperability. For instance, the GTFS standard provides schedule and geographical data [41], enabling public transport data to be open, facilitating reuse of data [64]. In addition to GTFS, there are the EU standards NeTEx and SIRI, which cover static and real-time data in public transport logistics. However, due to the complexity of the standard, there is a need for a clear scope for the implementations. One approach is to use a national profile, which can

be applied to key aspects covering how data should be presented, such as timetables [64]. In some cases, actors also adopt existing profiles from other contexts, allowing for the implementation of already established solutions.

Design insight – Boundary resources: Standardized boundary resources, such as APIs and standardized data formats, is essential for interoperability between involved actors by facilitating well-defined interfaces for data sharing.

4.2 Governance structure

In the context of Samtrafiken, we also find governance structure as a key design insight for interoperable data sharing by creating orchestration among actors, facilitated by mechanisms such as centralized orchestration and validating functions. There are, therefore, several aspects to consider: first, as an organization itself, and second, as a central orchestrating actor within the ecosystem. The organization acts as a centralized actor consisting of a *consortium* of stakeholders, forming a consortium-based platform ownership structure. From an organizational perspective, this refers to the ownership structure of the platform. However, from the ecosystem level, the governance structure implies a centralized governance arrangement led by a somewhat neutral and independent actor. This can contribute to stability within the ecosystem and support adherence to established standards [41]. For example, when initially working with GTFS, Google emphasized using data sharing according to the standardized form and declined other forms, such as planning APIs. Through collaboration, the industry adopted and adhered to the standards in GTFS [65]. The platform provider also offered to help actors to transform data into certain standards, who otherwise might be restricted by available resources, both due to the expenses of transforming data, but also as a *validating function* to sustain the data quality when transforming data between standards [40].

Design insight – Governance: In the public transport sector and in the studied case of Samtrafiken, the platform is governed through a consortium-based arrangement, where the orchestrating actor also assumes a standardizing and validating role.

4.3 Certified platforms and decentralized orchestration

We identified the Electronic Freight Transport Information (eFTI) framework as a design approach for enabling flexible and interoperable data sharing by including

certification of platforms supported by mechanisms such as decentralized governance and reference architectures. This framework applies in the context of freight logistics and promotes a shift from physical paper documents to a digital solution, allowing for data sharing on certified standardized platforms [23]. This transition aims to support a more efficient logistics sector by lowering the administrative burdens and providing more sustainable logistics solutions. To facilitate data sharing, the framework requires the data to be shared in a standardized, machine-readable format that complies with common data format specifications.

The framework builds on *certified eFTI platforms*, which are intended to facilitate secure data sharing between involved actors within the ecosystem [23]. There are also *functional requirements* on these platforms, where common technical specifications are intended to promote interoperability between platforms and prevent actors from being locked into a specific platform. The certification of the platforms is also intended to foster trust among authorities and involved actors, where the certification is carried out by designated accreditation bodies appointed by responsible authorities. The relevant authorities are responsible for developing eFTI gateways, which enable connections to the respective platforms by allowing operators to integrate with them [56], where each country orchestrates its own gateway, but it can also be shared between countries [57].

The Open Logistics Foundation (OLF) [57] presents one approach to implementing eFTI platforms by fostering collaboration around reference architectures for platforms, governance structures, and standardization, thereby supporting compliance with the requirements of the framework. Viewed collectively, OLF illustrates an alternative orchestration model, where, instead of having governance based on a single platform, the governance is structured around collaborations around standards, fostering interoperability through reference architectures.

Design insight – Certified platforms: The eFTI framework promotes data sharing based on certified platforms to support more sustainable logistics solutions. Instead of relying on a shared platform, interoperability is achieved through decentralized certified platforms that adhere to standardized formats, thereby fostering data sharing and collaboration between actors.

5 Discussion

This section discusses the study's findings as they apply to the problem domain of freight transport in a municipal context, aiming to improve the efficiency of last-mile logistics. The discussion begins with standardized data sharing and platform interoperability, followed by the section on governance and orchestration of data sharing platforms.

5.1 Standardized data sharing

Two of the three previously studied cases [37] highlight challenges in freight logistics related to the lack of standardized data sharing practices. This, in turn, reduces data quality and hinders the efficiency of the ecosystem, constituting a major challenge.

In contrast, the cross-sectional domains explored in this study – particularly the more mature and established case of Samtrafiken and the emerging regulatory framework eFTI – illustrate several design insights that may help to mitigate these challenges, as visualized in Figure 2. In particular, these include using standardized boundary resources in the form of APIs, as well as standardized data formats. Regarding APIs, these can contribute to more standardized data sharing by providing a consistent interface between databases and systems. This enables different systems to communicate in a more structured way, fostering data sharing, which in turn can create value for the ecosystem.

An additional design insight that can act as a complement to APIs is standardized data formats. The findings of this study show that a variety of data formats are used within the public transport sector, including established standards such as GTFS and NeTEx. These standards define the data points to be included in the shared data, which in turn improves the structure and supports greater interoperability within the ecosystem. Similar standardization initiatives could also be applied in the domain of freight logistics, where the shared data follows consistent data structures, resulting in higher data quality, more efficient data sharing, and promoting interoperability [41], which is essential for effective data sharing [59].

5.2 Platform interoperability

Several of the previously studied cases in our empirical study illustrate internal interoperability challenges. These challenges limit the ability of systems to communicate efficiently within each case, creating barriers to developing efficient data sharing practices within ecosystems. The design insights and associated mechanisms identified in this study contribute to several potential approaches to mitigate these challenges. This includes design insights such as *certified platforms*, supported by the design mechanism of *reference architecture*.

Regarding the certified platforms and reference architecture, important lessons can be drawn from eFTI and the OFL. Certified platforms can contribute to improved interoperability by ensuring compliance with standards and fostering compatible systems. Reference architectures are also available from organizations such as the Open Logistics Foundation and can contribute to ensuring that stakeholders adopt a common system design, thereby contributing to greater interoperability.

Taken together, the findings indicate multiple mitigating actions to improve interoperability between the systems involved in the ecosystem. As Pan et al. [59] note, effective interoperability between systems is central to achieving efficient logistics solutions, which further underscores the importance of design proper-

ties. However, it may be important to note that platform design does not need to be a single solution but rather a set of configurations, as the platform is context-dependent [78].

5.3 Governance and orchestration of certified data sharing platforms

The previously studied cases present several challenges related to governance structures. More specifically, there is a mismatch between the area of responsibility and actual influence. These governance structures include a neutral facilitator, a central actor, and contractual dependents. The findings and prior related work [7] indicate that governance structures have an important role in the orchestration of data sharing platforms. For instance, having clearer governance structures combined with validating functions can serve as guidance on how to share data that meets specific requirements, ensuring higher data quality.

In the case of Samtrafiken, the actor undertakes a centralized consortium governance [10] role and assumes greater orchestrating responsibility within the ecosystem. Samtrafiken also undertakes this orchestrating role with a validation function. This enables actors to participate in the ecosystem and share data that complies with specific requirements. Taking this centralized role, Samtrafiken can be regarded as a somewhat neutral actor [36]. This, in turn, creates the conditions for trust in Samtrafiken, which can promote more efficient logistics through increased data sharing.

6 Conclusion

This study explores design insights for flexible and interoperable data sharing platforms for municipal last-mile logistics from an open-data ecosystem perspective. The study follows a design science methodological approach, building on a problem context identified in previous studies and positioning itself between the problem domain and the solution domain.

We identified several design insights and underlying mechanisms that support the development of flexible and interoperable data sharing platforms in municipal last-mile freight logistics (RQ1). These include boundary resources, such as APIs and data formats, together with certified platforms with complementary reference architecture and governance structure. Also, centralized and decentralized approaches that are supported by validating functions. Furthermore, the findings show how interoperability can be enabled by different combinations of boundary resources, governance structures, and platform configurations (RQ2). When taking these combinations into consideration, it is important to note that the platform design does not need to depend on a single solution but instead consists of different configurations.

Looking ahead, future research should take the insights and investigate how a flexible and interoperable platform could be structured in enhanced technical detail. In addition, future research is needed to abstract these results further and validate the design insights in practice. These directions for future work are also consistent with the design science approach, following the progress from the problem domain towards constructs in the solution domain.

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