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

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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.

Keywords

Open data ecosystem, sharing of data, collaboration in logistics

1. Introduction

According to a forecast by the Swedish Transport Administration [1], 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 [2] 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 [3].

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[4]. One means of contextualizing such sharing and collaboration is through the lens of Open Data Ecosystems (ODEs)[5].

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 [6] based on snowball search [7], exploration in the archives of the Swedish Transport Administration (Trafikverket), and exploration in the Scopus database.

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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.

To analyze the results, we conducted a thematic analysis inspired by Braun and Clarke [8]. 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 [6]. 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.

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 [8] was conducted on selected scientific texts inspired by the guide of six steps, and the data was analyzed in a spreadsheet[1]. 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 [7], where a starting set of two articles were chosen [5, 9]. Both forward and backward snowballing were carried out [7]. 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.

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

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

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[10, 5, 11]. However, Runeson et al. [5] 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. [12]. 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 [13, 10, 11, 14, 12, 15], comprising essential ones, such as *data providers, service providers*, and *data users* [12, 10]. *Intermediaries*, act as links facilitating data use for different actors [10]. Additionally, Immonen et al. define a comprehensive set of roles [13]: *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 [10], for example, a government or an authority [16, 17]. 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 [17].

Quality of data in ODEs. The data quality affects both the usability of the data and how much the ODE is utilized [18, 10, 19]. The ecosystem does not reach its full capacity when data quality is low [18, 20]. Several criteria related to how quality can be ensured in an ODE are also described in the literature [20, 21, 18, 22, 23]. It is also emphasized that there is no general definition of what constitutes data quality [20]. However, some guidelines can be used to influence the quality of shared data [20, 21]:

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 [20].
2. Understandability/Accessibility– how easily data consumers can find, access, and perceive the data and metadata correctly. [20, 21, 24].
3. Accuracy – how accurate the data is and how it is described with metadata [20, 21, 24, 23]. Also, metadata may contribute to interoperability [12].
4. Timeliness – how up-to-date is the shared data, including the up-to-date metadata [20, 21, 24].
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 [20, 21, 23].

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 [20, 24].
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 [25, 26].
8. Consistency/Compliance – how the data complies with standards. Data and metadata should conform to a consistent format throughout the database [20, 21] and be available in electronic, machine-readable format [20, 19, 11]. Standards may also support interoperability of the data since the actors can work on the same level [9, 13].

Legal aspects of ODEs. Fully open data should be licensed free to use [20]. However, there is legal uncertainty about the sharing and reuse of the data [25, 22] 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 [18, 22]. One study also described that licensing is important because it tells where and who can use the shared data [12]. However, the implementation of laws and regulations within ODEs can also act as a barrier that prevents the use of ODEs [27, 28, 18, 11]. Moreover, the laws can act as a driving wheel but also as a "red tape" where actors instead have more variables to deal with [27].

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 [29, 30, 31, 32, 9], describe ODEs in public transport. The quality and standard of the data can have a major impact on the functioning of the ecosystem [30]. 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 [30, 31].

Actors and elements of ODEs in public transport logistics. Three studies [29, 32, 9] 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 [32]. 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 [32].

Governance of ODEs in public transport logistics. ODEs can be mapped to an organizational structure model, called the "onion model" [33]. 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 [29]. 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 [29]. Samtrafiken has the opportunity to transform the incoming data to meet a certain standard instead [32]. 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 [34, 35, 36, 37]. In such collaboration, entities can exchange different resources, such as freight flows, traffic flows, or goods flows [37]. Involved actors work together to achieve different goals, such as reducing operational costs, improving service, and minimizing the environmental impact[36]. HC can therefore lead to a more efficient transport sector [37] and a win-win situation, if the involved parties first examine whether they are strategically suited to cooperate with each other [34]. Further, products to be transported must be compatible, for instance, the goods transport environment [36].

Regarding information sharing, it is important to have effective communication between the involved actors[38]. A majority (70%) of HC fail due to factors, such as incompatible partners, information not collected efficiently, poor decision-making, and inadequate communication [36]. Information sharing between actors can be considered the "glue" that enables actors to collaborate and manage the relationships [39].

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 [35].

Trust has an important function for HC [40, 39, 35, 41]. Mistrust among actors can hinder collaboration [40] and may stem from fear of sharing information, which competitors could exploit [39]. Furthermore, actors do not want to invest in others' benefits, hence a neutral publicly funded platform could be a solution to this[37]. This neutral organizer can also help with the coordination and management of the data being shared [36].

Legal aspects in connection to Horizontal Collaboration. Governance can be regulated formally and informally [39]. 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 GDPR [2]and the Competition Act, is important to consider for any actors involved in the collaboration [37, 42]. Furthermore, when actors collaborate and share data, it is important that competition is not restricted, as it otherwise can lead to cartel formations [42, 35, 43].

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* [10, 5, 11]. 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 [36, 39].

Regarding the ODEs for logistics, research has focused on ODEs in the public transport context[29, 32, 9], but the connection between ODEs and freight logistics was not explored. However, the concept of *Horizontal Collaboration* was found [37, 34, 35, 36] 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. [35], 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.

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

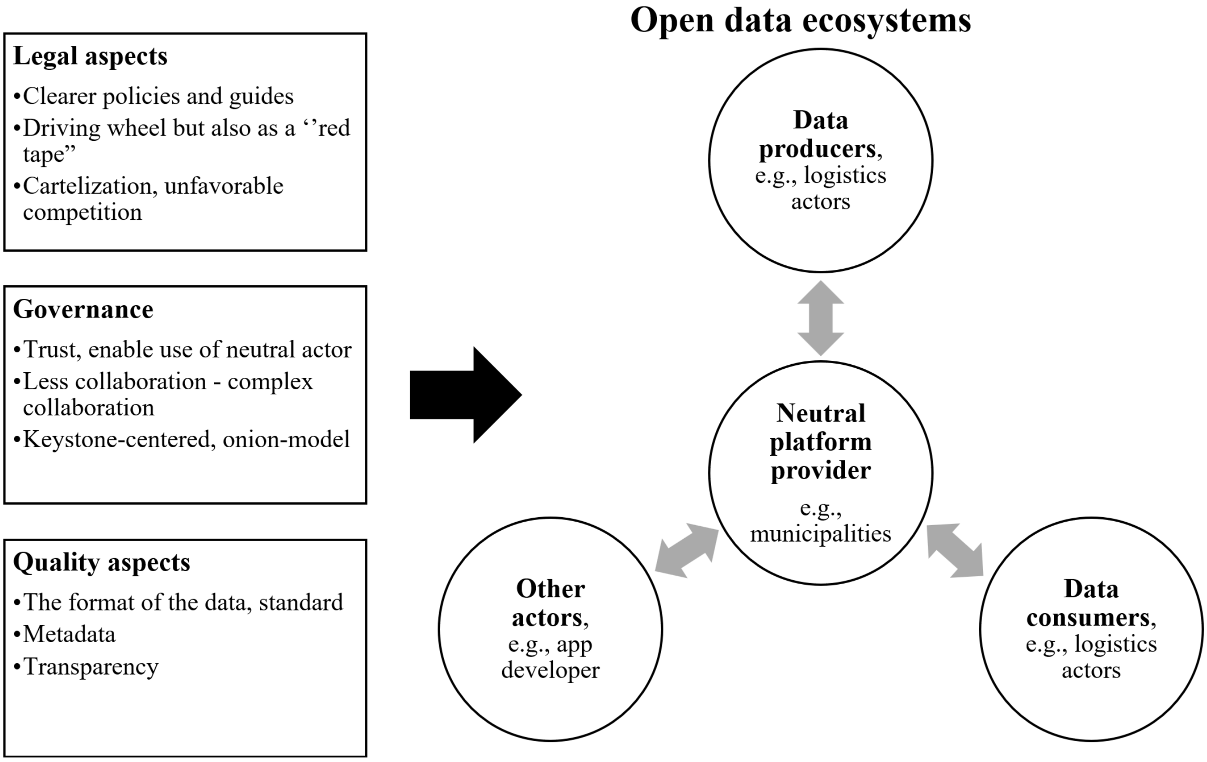

Figure 1: Open data ecosystems and the involved actors and aspects. Actors in the ecosystem can have one or multiple roles, for instance, both producing and consuming data.

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 have significant impacts. Governance pertains to how the governance of the actors is conducted, such as the so-called keystone-centered model [10], or the "onion model" [9]. 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 [17].

Utilizing a neutral platform provider can increase trust among different actors, enabling better collaboration [36, 37, 9], as mistrust may otherwise act as a barrier to collaboration [40]. 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 [18, 10, 19]. As there is no universal definition of data quality [20], but as depicted in Figure 1 and indicated in the results, there are guidelines that can assist users of ODEs [20, 21], 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 [29]. 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 [25, 22]. Moreover, laws and regulations can act as “red tape” and instead harm data sharing [27]. 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 [36].

4.2. Threats to validity

We discuss factors affecting the results, with respect to study selection validity, data validity, and research validity [44]. 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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