

The business model for federated data spaces to facilitate synchromodal logistics

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Abstract: *The logistics industry is undergoing significant transformations, where data sharing has become a critical factor for collaboration and sustainable logistics practices. This paper discusses the development of a taxonomy for business models of federated data spaces in the logistics industry, focusing on their application in synchromodal transport. This foundational study clarifies the operational and economic implications and serves as a basis for innovative business models. Our findings highlight the potential of federated data spaces for improving collaboration and value creation across logistics stakeholders. This study adds to the conversation on digital logistics by proposing business models that leverage data spaces for competitive advantage, implying that these are critical in transforming logistical operations into more efficient, adaptive, and financially viable systems.*

Keywords: *Business model, Data space, Physical Internet.*

Physical Internet (PI) Roadmap Fitness: *Select the most relevant area(s) for your paper according to the PI roadmaps adopted in Europe and Japan: ☐ PI Nodes (Customer Interfaces, Logistic Hubs, Deployment Centers, Factories), ☐ Transportation Equipment, ☐ PI Networks, ☒ System of Logistics Networks, ☐ Vertical Supply Consolidation, ☐ Horizontal Supply Chain Alignment, ☐ Logistics/Commercial Data Platform, ☒ Access and Adoption, ☐ Governance.*

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1. Introduction

The connection between synchromodality and federated data spaces enhances dynamic freight transport planning, the ability to anticipate and manage interruptions or delays during transport, and the efficiency of rerouting or changing transportation modes (Pulido et al., 2024). It also opens avenues for innovative business models that have implications for different actors: those who aim to establish a data space and those who want to determine whether they should enter an existing data space (D'Hauwers et al., 2022). Business models can leverage data relationships among actors in synchromodality by developing new services, optimizing resource utilization, and creating value for stakeholders.

An important building block within a data space is aligning a heterogeneous set of inter-organizational partners who interact for a focal value proposition to materialize (Adner, 2016). From a business perspective, existing knowledge about value creation for the involved actors in the data space is limited. According to the IEDS project (2023), which surveyed 219 German companies, the most significant economic barrier to data sharing was the unclear benefit of data exchange, cited by 68% of companies. Additionally, 59% acknowledged the absence of a suitable business model. IDSA (2024)

A review of data space adoption within the IDSA (2024) radar reveals a diverse landscape. While various sectors are exploring and implementing data spaces, maturity levels differ

significantly, with few projects reaching advanced deployment stages. Furthermore, a key challenge lies in aligning shared interests to develop business models. These models should prioritize strong governance, ensure seamless interoperability, and deliver value propositions for all participants. In this context, this research seeks to address the following critical question:

- What is the business model taxonomy for a data space for synchromodality?

By addressing the abovementioned question, this paper explores the business model related to the synchromodal data space concept from the perspective of the different roles involved: data consumers, data providers, and data space orchestrators.

2. Background on data spaces for transport

Data spaces are the foundational elements from which interested parties can obtain added services and solutions (Gawer, 2009, p. 54). The market is seeing an increase in the use of data spaces, which allow for the sharing of data and the provision of additional services and analytics (Schrieck et al., 2016; van den Broek & van Veenstra, 2018). Based on their intended use, data spaces can be implemented in two ways: federated, where data space operations are more decentralized, or centralized, where a single entity primarily manages data space.

The federated data space provides individual enterprises with tools to register and participate while concealing the complexities of data sharing (DTLF, 2022). Federated data space is a network of multiple platforms and a peer-to-peer solution utilized by the involved parties. According to Otto & Jarke, (2019) and Tiwana et al., (2010), it employs a "shared ownership" approach, meaning that it is not just applied in one central organization. As a result, a federated data space (DS) is scalable since it allows for involvement from other parties, even competitors. Sharing data with competitors can establish standards, while sharing data with suppliers helps optimize supply chains (De Prieëlle et al., 2020).

3. Business models landscape

A business model encompasses an organization's strategic framework to generate, deliver, and capture value in various social, economic, or other forms. In modern logistics, growing digitization and the significance of data sharing have influenced several business activities, resulting in new product and service offerings and creating new types of business relationships (FAN & ZHOU, 2011; Rachinger et al., 2019). Data space could serve as a solution, but adoption concerns such as unclear benefits, unclear cost structure, and a lack of trust in the system have been recognized as significant obstacles (Hutterer & Barbara, 2024). These obstacles indicate that to drive the development of such innovations and digital transformation, it is necessary to investigate new business model opportunities (Prem, 2015; Strandhagen et al., 2017). A shared understanding is also required to help scale the innovation element of the sector, allowing different players to explore new business opportunities.

There is extensive literature available on business models for big data (Katrakazas et al., 2019; Kim et al., 2016), centralized platforms (Abrahamsson et al., 2003), multi-sided platforms (Hoch & Brad, 2021), decentralized business ecosystem (Lage et al., 2022; Radonjic-Simic et al., 2017; Radonjic-Simic & Pfisterer, 2019; Tumasjan & Beutel, 2019; Wang et al., 2019) and open data ecosystems (Immonen et al., 2014; Kitsios et al., 2017). However, a specific focus on business models for data spaces facilitating freight transport remains underexplored, this highlights a research opportunity.

Establishing a taxonomy that encompasses different facets of business model development could be a fundamental step in this direction (Notteboom et al., 2017). The taxonomy seeks to identify the fundamental components of these business models and to provide a template for innovation based on the results of the study (Möller et al., 2020). Taxonomy for big data (Hartmann et al., 2016), data-driven business models (Dehnert et al., 2021; Engelbrecht et al., 2016; Möller et al., 2020), and data ecosystems (Gelhaar et al., 2021) are addressed well in the available academic literature. However, not much research has been done on defining the taxonomy for data space that supports synchromodal transport.

This approach can be instrumental in developing a taxonomy for business models in federated data spaces, facilitating synchromodal logistics by allowing for a comprehensive analysis of value creation, value delivery, value proposition and the scope of DS revenue (Lüdeke-Freund et al., 2019). These elements are crucial in ensuring that the business model not only meets the operational needs of synchromodal logistics, but also coincides with the logistics sector's overall goals of efficiency, sustainability, and innovation.

4. Designing the transport data spaces business taxonomy

Shared values and common interests are considered crucial success factors for data spaces (Vasilescu, 2023). However, despite existing sector-specific initiatives like the Catena-X Automotive Network (2022) and Fenix Network (2019), current practices and literature lack discussion on implementing data spaces for broader business value. This gap extends to finding shared interests that would enable expansion and the creation of a unified business framework across sectors. As this field is still relatively new, there's an opportunity to bridge this gap by either expanding existing initiatives or fostering collaboration to develop shared interests. We developed a taxonomy encompassing various components and characteristics to describe business models for data spaces in the freight transport sector based on Nickerson et al. (2013). This analysis captures the characteristics of data spaces relevant to the logistics industry, integrating them within the broader landscape of *digital business models* in data ecosystems. The framework enables stakeholders to consider a wide range of components and characteristics when designing or analyzing business models derived from data spaces in freight transport. It aligns with traditional transport concepts, such as multimodality and intermodality, and newly developed concepts, such as synchromodality.

The data used to develop the taxonomy is comprised of three main components. The first is a review of the literature related to business model taxonomies for data spaces; since this field is still in its early stages, we have included literature that pertains to data-driven and big data digital business models like IEDS project (2023), Schweihoff et al. (2022) or Wiener et al. (2020) as well as digital logistics business models such as Möller et al. (2019), Möller et al. (2020) or Mikl et al. (2021). The second component involves an examination of the current data spaces and the use cases developed for the logistics domain, as registered within the International Data Space Association (IDSA) radar. The third component is the concept of synchromodal freight transport, which ultimately is the intended application of the taxonomy. However, it is not restricted only to synchromodality.

4.1 Data Space Business Model Meta-characteristics

Following the taxonomy-building process, we determine the following meta-characteristics as the principal attribute from which all other relevant characteristics derive, ensuring coherence and relevance in the taxonomy (Nickerson et al., 2013). We aim to distinguish potential

business models for data space for freight transport. The resulting taxonomy is presented in Figure 1 and is explained in the following subchapters.

4.1.1 Data Space Foundation

The **data space foundation** addresses the essential principles and frameworks that underpin the business model of data spaces. This is necessary as a data space is being developed, outlining the structure that a particular data space will follow. The first dimension concerns the nature of the data space's **development**. The first type is the *Data Space*, which, according to IDSA (2024), is a decentralized system governed by rules that enable safe and reliable data exchange among its members, enabling trust and data sovereignty. It is implemented through one or more infrastructures and supports a variety of use cases. On the other hand, a *Use Case* is a specific scenario that demonstrates how the principles of data space are applied to share data to achieve a particular goal or outcome. The European strategy for data influences the **perspective** dimension, which aims to position Europe as a leading example of an economy empowered by data that makes better decisions—both in the private and the public sector (European Commission, 2020).

According to IDSA (2024), the **maturity** of each development is relevant to explaining the initiative framework, starting from an *Exploratory* level, which consists of identifying interest and feasibility within a specific domain by gathering stakeholders and discussing potential use cases. On the maximum levels, we find the *Operational*, where the data space is tested and launches its first market-ready use case, enabling data exchange and value creation, and *Scaling*, where the data space demonstrates market viability, sustainability, and growth, adapting to and attracting new members and use cases. Finally, the **case pattern** reflects the diverse motivations and goals driving ecosystem members to share data IDSA (2024).

4.1.2 Actor

The business models for a data ecosystem have implications for different actors: those who aim to establish a data space and those who want to determine whether they should enter an existing data space. Depending on their role, these actors may provide, receive data, or perform other activities (D'Hauwers et al., 2022). The **actor** element outlines the various stakeholders' roles within the data space, specifically focusing on the freight transport domain.

The **Data Space (DS) roles** are identified through an analysis of 64 use cases conducted by the IEDS project (2023). This approach provides an in-depth understanding of contemporary data-driven business models and ecosystems. The roles of the participants are closely related to **Data Ownership**, which can be categorized as *Own Data*, *Derived Data with uncertain ownership*, or *Data owned by another entity* (Schweihoff et al., 2022). Regarding **Transport Stakeholders**, this approach includes those in conventional hinterland transport, such as intermodality and the synchromodal stakeholder network. The latter encompasses the same actors but introduces additional roles, including the orchestrator role (Ceulemans et al., 2024) and roles related to software and technology (Pulido et al., 2024).

4.1.3 Value

The **value** dimension captures the essence of business models by representing the benefits and utilities generated by applications in data spaces. **Value Creation** refers to the key processes and resources (Mikl et al., 2021) the data space enables. The characteristics of this dimension were derived from the iteration of the data spaces development database in the logistics domain reported by IDSA (2024). These characteristics originate from the fundamental attributes of data spaces aiming to "enable the sovereign and self-determined exchange of data via a standardized connection across company boundaries" (Pettenpohl et al., 2022, p. 29).

	Dimension	Characteristics								E/N	Approach		
DS Foundation	Development	Data Space				Use Case 1 2 3				E	IDSA (2024)		
	Perspective	Private 1 2 3			Public 1			Mixed			N	European Commission (2020)	
	Maturity	Exploratory		Preparatory		Implementation		Operational 1 2 3		Scaling		E	IDSA (2024)
	Case Pattern	Shared Cost 1 2		Joint Innovation 1 2 3		Shared Marketplace		Grater Community Good			N	IDSA (2024)	
Actor	DS Roles	Service Provider	Data Trustee	Data-infrastructure provider 1		App-Store Provider 1	Data Provider 2 3	Data Consumer 2 3	Ecosystem Orchestrator 1	Marketplace Operator	N	IEDS project (2023)	
	Data Ownership	Own Data 2 3			Derived data, ownership uncertain			Data owned by another entity 1			E	Schweihoff et al. (2022)	
	Transport Stakeholder	Shipper 2	Carrier 3	Infrastructure Management		LSP	Authority	Terminal Operator	Orchestrator	Software and Technology 1	N	Ceulemans et al. (2024) Pulido et al. (2024)	
	Stakeholder engagement	Data Sharing Agreements 1 2 3			Partnership Models		Consortiums 1 2		Independent Operations			N	Allen et al. (2014) OECD (2017)
Value	Value Creation	Data Sovereignty 1	Secure Data Sharing 1 2 3		SC. Efficiency 2 3	SC. Responsiveness 2	SC. Visibility 2 3	Sustainability Goals	Collaboration and Networking 1	Digital Automation	N	IDSA (2024) Logistics data spaces	
	Value Delivery	Provider & consumer matching 1		Shared Digital Twins		Process Optimization 2 3	(Big) Data analytics/enrichment		Real-time visibility 2 3	(Smart) Contractis management	N	Bastiaansen et al. (2020) Pulido et al. (2024) Möller et al. (2020)	
	Value Proposition	Selling data-based services		Optimization Services 1		Selling data	Selling analysis	Data-driven improvements 2	Data-enriched products & services 3	Data-driven services 1	N	Schweihoff et al. (2022) Möller et al. (2020)	
	DS Revenue	Fees 2		Pay-per-Use		Licensing		Commission		Subscription plan	Customized 1	N	Möller et al. (2019) IDSA (2024)
Resources	DS Infrastructure	Data Ecosystem 1 2 3			Marketplace			Hybrid			E	Schweihoff et al. (2022) IEDS project (2023)	
	Transport Mode	Truck		Rail			Ship/IWT 1 2 3			Air		N	Möller et al. (2020)
	Data Origin	Internal 2 3				External 1				N	Dehnert et al. (2021)		
	Data Source	Self-generated data 2 3		Existing data		Restricted data 2 3		Freely available		Provided by user 1	Acquired data	N	Schweihoff et al. (2022)
	Service Flow	Manually driven		Predefined time steps			Event-driven 1 2			Data stream 1 3		N	Dehnert et al. (2021)
	Source of Funding	EU		Government 1			Private 2 3			Other		N	IDSA (2024)

E: Exclusive dimension, N: Non-exclusive dimension, DS: Data Space, IWT: Inland Water Transport, LSP: Logistics Service Provider.

1 Data Space developer
2 Shipper
3 Barge Operator

Figure 1: Morphological box of data spaces business model taxonomy for the freight transport sector

Value Propositions represent the business's offerings (Möller et al., 2019), encompassing primarily services derived from data spaces alongside products such as enriched data assets. In this case, the mechanisms established for **Value Delivery** address how these value propositions are delivered to customers (Lüdeke-Freund et al., 2019), such as data space participants. This dimension integrates logistics data-sharing infrastructure solutions with data-driven business models in the logistics sector, focusing on transport concepts like intermodality and synchromodality. Finally, we propose a **Data Space Revenue Model** designed to capitalize on the deployment of the digital infrastructure via participation in data spaces. These models are guided by relevant literature (e.g., Möller et al. (2019)) and the current deployment models in data spaces according to IDSA (2024).

4.1.4 Resources

The **Resources** dimension encompasses the tangible and intangible assets required to operate the data space, providing essential elements to benefit participants. In this context, the **DS Infrastructure** — serving as a *Data Ecosystem*, a *Marketplace*, or a *hybrid* of both — is the cornerstone of the data space, with the data itself being the primary resource. The dependency of resources on the actor dimension is significant; for example, the **DS role** of a **Transport Stakeholder** (e.g., a shipper) as a *Data User* or *Data Provider* significantly differs from their role when acting as an *Ecosystem Orchestrator* within the data space.

The **Data Origin**, as introduced by Dehnert et al. (2021), represents whether the data input into the data space is *Internal*, meaning it comes from the data space itself, or *External*, meaning it comes from *Data Providers* regardless of their ownership. It is also necessary to identify the **Data Source**, which refers to data *self-generated* by an actor; this can also be *restricted* or *freely available data*.

The **Service Flow** depicts how the offerings are delivered. For instance, according to Dehnert et al. (2021), the user proactively requests the service in a manually driven context. This differs from an *event-driven* context, where a trigger activates the service flow, or *predefined time steps*, where the service is delivered at intervals. In a *data stream* context, the data (or the service in question) is continuously offered, real-time or on time, wherever relevant.

5. Application of the taxonomy

Synchromodality, a concept that emerged around 2010, emphasizes collaboration among stakeholders to dynamically select the most suitable mode of transportation at any given moment, whether it involves a combination of road, water, or rail, to move goods within the infrastructure network (Tavasszy et al., 2010). This concept extends beyond traditional intermodal transport by integrating transport network planning that accommodates real-time modal shifts and flexible arrangements resulting from mode-free (a-modal) booking (van Riessen et al., 2013). To enhance data exchange, access, and reliability within synchromodality, Pulido et al. (2024) have integrated data space functionalities to enable the attributes of synchromodality, especially regarding visibility and flexibility in Inland Water Transport. According to the description of the data space, the use case represented in Figure 2 involves the implementation of data space principles within the freight transport context, integrating relevant real-time data from different stakeholders, such as inland barges voyage information, cargo-specific information, transit route status, and terminal statuses. With such information, it is possible to identify triggers for relevant actions, such as rerouting or optimizing barge transit.

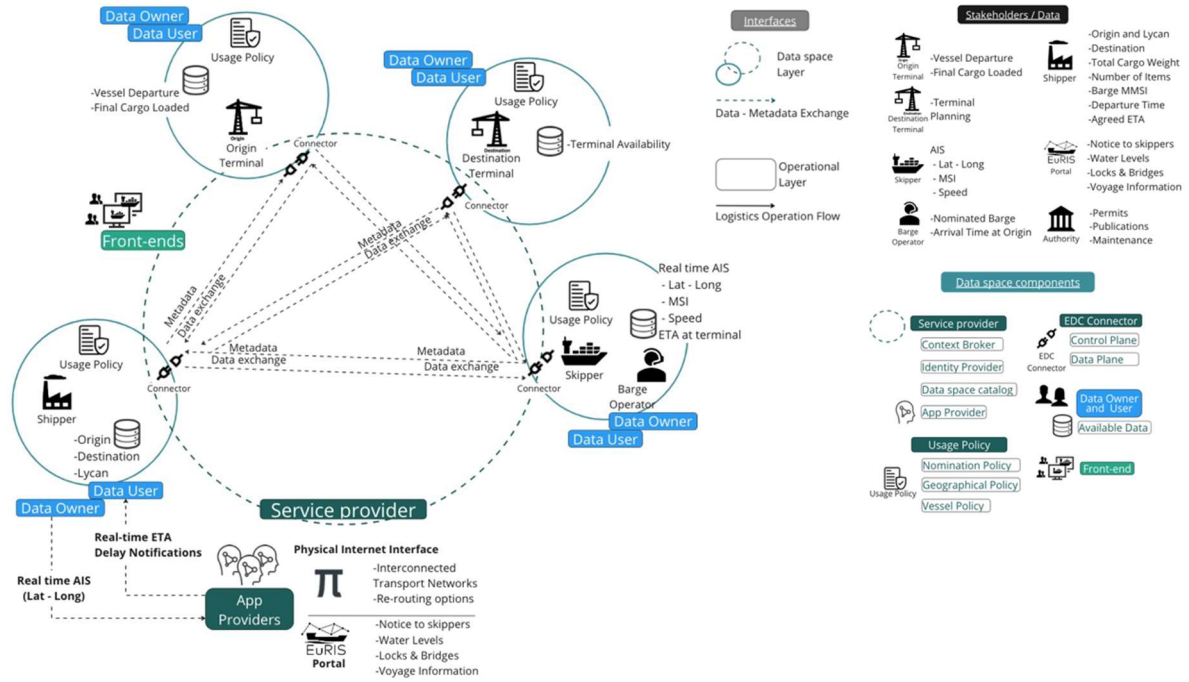


Figure 2: Synchromodal data space overview – Adapted from Pulido et al. (2024)

The morphological box displayed in Figure 1 captures the multidimensional aspects of the previously described synchromodal transport system's data space. Each dimension's subcategory is selected depending on the stakeholder's role in the data space and use case characteristics. The perspectives of the following three primary stakeholders are captured: the *data space developer* (green dot with the number 1) representing the interest of the data space, the *shipper* (orange dot with the number 2) being the entity facing challenges in their logistics process due to limited visibility on transport execution, and the *barge operator* (blue dot with the number 3), a company operating a large number of barges in Europe.

5.1 Business model for the data space for synchromodality

DS Foundation: The *Maturity* level is at an *Implementation* stage since the initiative has put its infrastructure and governance framework into practice. The first use case is functional, with data being exchanged between providers and recipients and the use case delivering its expected benefits (IDSA, 2024). It is worth highlighting the *case pattern*, as it represents a *Joint Innovation* for the participants. This concept is based on the understanding that customer innovation can only be realized when ecosystem members work together since no single member possesses all the necessary data. On the other hand, for the *data space developer* and the *shipper*, there is a mutual interest in sharing data to cope with a shared requirement (*Shared Cost*) such as process efficiency and transparency, where every member saves money and time by sharing the burden. (IDSA, 2024).

Actor: The initiative centers on deploying digital infrastructure, indicating a system in which the *data-infrastructure provider* plays a fundamental role. Applications accessible through an *App Store provider* are vital for accessing or processing data. For example, in the synchromodal data space, applications help monitor incidents across the inland navigation ecosystem. They also provide event alarms when the estimated time of arrival (ETA) deviates from the planned schedule, thereby offering monitoring of ETAs and transparency for cargo in transit. *Data*

owned by another entity, under the **Data Ownership** dimension from the data space developer, points to a model where ownership and control are distributed or assigned by other parties.

This frames the **DS role** of the *Ecosystem Orchestrator*, ensuring that all parties involved in the data space can participate and create value. It also identifies the different roles within the ecosystem and creates connections between them (IEDS project, 2023). **Transport Stakeholders**, such as *shippers* and *carriers*, acting as both *Data Owners* and *Data Consumers* suggests their dual role in providing data from their operations and consuming enriched data or services derived from the data space to optimize transport efficiency and reliability.

Value: This dimension captures value creation, delivery, and value proposition within the data space. The *data space developer* generates a safe environment for *collaboration and networking* as means of **value creation** offering *data-driven services* as their **value proposition**. This highlights a service model fueled by data analysis and insights. The *shipper* benefits from *real-time visibility*, vital for tracking and managing shipments efficiently. The *barge operator* seeks *data-enriched services*, indicating they can enhance their transport service offerings with data-derived insights by merging their data with the shipper's data for improved service.

The *data space developer* achieves the **DS Revenue** through a *customized* model that allows the developer to tailor services and solutions to the specific participants and their interest in data space. This approach enables the developer to charge based on the value delivered through these personalized services, potentially commanding a higher price for the added value of customization. Regarding the *Fees*, the *shipper* is charged yearly for participating in the data space as a data provider and consumer.

Resources: This section highlights how the *data space developer*, *shipper*, and *barge operator* acquire and utilize resources within a synchromodal transportation data space. All three stakeholders are integrated into a *Data Ecosystem*, leveraging necessary digital **DS infrastructure** in their operations. The *data space developer* integrates external data to create the baseline service for the data space, while both the *shipper* and *barge operator* primarily use internal data derived from their logistics activities to contribute to the ecosystem. The **Data Flow** for the *data space developer* and *shipper* is *event-driven* because, in synchromodality, responsiveness to situational changes is crucial. The *barge operator's* services are on a continuous *Data stream*, as real-time voyage information and status of barges are constantly shared, ensuring fast updates about events (triggers) and potential transport optimizations. Finally, the funding for the *data space developer* is sourced from government contributions, since the main initiative is generated from a government-funded project, contrary to the *shipper* and *barge operator*, which are private companies benefiting from the data space but paying a fee, as is the case for the *shipper*.

6. Concluding Discussion

The logistics sector exhibits a wide range of data sharing collaborations, creating diverse expectations for the supporting infrastructure such as data spaces. It is challenging to anticipate all potential uses, services or applications for such an infrastructure. However, well-designed data sharing ecosystems could give rise to new applications, products, and business models that have not yet been considered. (Bastiaansen et al., 2020).

Our research began with the identification of the business model building blocks for a data space dedicated to freight transport, where data exchange is crucial, such as in synchromodality, followed by the development of a baseline taxonomy. This taxonomy underscores the potential

operational value of implementing data spaces from the perspective of transport stakeholders and outlines the potential sources of economic returns that the data space generates for its own development. A significant portion of the developments we analyze within the data space radar in the logistics sector are driven or incentivized by governmental initiatives, such as funding for research and development projects. It is from these projects that the data spaces then evolve into commercial data space entities.

Our contribution to academia is to provide a synthesis of the data space BM taxonomy, which, by combining its elements, can lead to new developments in transport services that have not yet been realized, although the components are available and identified. Additionally, the dimensions and characteristics of the data space dimensions serve as a starting point for further development of more digital-driven transport services, especially in the realm of synchromodality. This includes aspects such as provider and consumer matching, shared digital twins, process optimization, (big) data analytics/enrichment, real-time visibility, and (smart) contracts management.

Our research provides practitioners and stakeholders with shared interests in freight transport a valuable guide to explore the development of data spaces that are both sustainable and financially viable. Companies can assess their current digitalization efforts, data sharing practices (internal and external), and data-driven initiatives against the identified building blocks, with a special focus on intermodal and synchromodal transport strategies. Additionally, developing mechanisms to generate revenue for the data space is crucial, as a business model can only be sustainable in the long run if it produces enough revenue to cover its costs.

Future research on business models for data spaces in synchromodality should concentrate on exploring the cost structures that support these models. By analyzing the business models of various transport stakeholders—a dimension not fully explored in this study—and scrutinizing the differences in revenue generation, we can obtain deeper insights into their financial viability. Furthermore, identifying existing and emerging services enabled by data spaces, like predictive analytics or dynamic routing/pricing, will reveal new revenue potential.

References

- Abrahamsson, M., Aldin, N., & Stahre, F. (2003). Logistics platforms for improved strategic flexibility. *International Journal of Logistics Research and Applications*, 6(3), 85–106. <https://doi.org/10.1080/1367556031000123061>
- Adner, R. (2016). Ecosystem as Structure: An Actionable Construct for Strategy. *Journal of Management*, 43(1), 39–58. <https://doi.org/10.1177/0149206316678451>
- Allen, C., Des Jardins, T. R., Heider, A., Lyman, K. A., McWilliams, L., Rein, A. L., Schachter, A. A., Singh, R., Sorondo, B., & Topper, J. (2014). Data governance and data sharing agreements for community-wide health information exchange: lessons from the beacon communities. *EGEMS*, 2(1).
- Bastiaansen, H. J. M., Nieuwenhuis, C. H. M., Zomer, G., Piest, J. P. S., van Sinderen, M., Dalmolen, s, & Hofman, W. J. (2020). *The logistics data sharing infrastructure – whitepaper*. Dinalog News - ICT & PROVISION OF INFORMATION.
- Catena-X Automotive Network e.V. (2022). *Catena-X Automotive Network*. Catena-X Operating Model Whitepaper. <https://catena-x.net/en/>
- Ceulemans, E., Cardenas, I., Vanelslander, T., & van Hassel, E. (2024). An overlooked dimension of Synchromodality: Unravelling its complex behavioural and organisational nature. *Department of Transport and Regional Economics, University of Antwerp*.
- Dehnert, M., Gleiss, A., & Reiss, F. (2021). What makes a data-driven business model? A consolidated taxonomy. *ECIS*.
- D'Hauwers, R., Walravens, N., & Ballon, P. (2022). Data Ecosystem Business Models: Value and control in Data Ecosystems. *Journal of Business Models*, 10(2), 1–30.

- Engelbrecht, A., Gerlach, J., & Widjaja, T. (2016). Understanding the anatomy of data-driven business models—towards an empirical taxonomy. *European Conference on Information Systems*. http://aisel.aisnet.org/ecis2016_rphttp://aisel.aisnet.org/ecis2016_rp/128
- European Commission. (2020). A European strategy for data. *COM(2020) 66 Final*. <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020DC0066>
- FAN, P., & ZHOU, G. (2011). *Analysis of the Business Model Innovation of the Technology of Internet of Things in Postal Logistics*. IEEE.
- Fenix Network. (2019). *A European Federated Network of Information eXchange in LogistiX*. About FENIX. <https://fenix-network.eu/>
- Gawer, A. (2009). *Platforms, markets, and innovation*. Edward Elgar.
- Gelhaar, J., Gürpınar, T., Henke, M., & Otto, B. (2021). Towards a taxonomy of incentive mechanisms for data sharing in data ecosystems. *PACIS*, 121.
- Hartmann, P. M., Zaki, M., Feldmann, N., & Neely, A. (2016). Capturing value from big data – a taxonomy of data-driven business models used by start-up firms. *International Journal of Operations and Production Management*, 36(10), 1382–1406. <https://doi.org/10.1108/IJOPM-02-2014-0098>
- Hoch, N. B., & Brad, S. (2021). Managing business model innovation: an innovative approach towards designing a digital ecosystem and multi-sided platform. *Business Process Management Journal*, 27(2), 415–438. <https://doi.org/10.1108/BPMJ-01-2020-0017>
- Hutterer Andreas, & Krumay Barbara. (2023). *The adoption of data spaces: Drivers toward federated data sharing*. University of Hawaii at Manoa.
- IDSa. (2024). *Data Spaces Radar*. Widening the Scope: The Anatomy of the Data Spaces Radar. <https://www.dataspaces-radar.org/>
- IEDS project. (2023). *Incentives and Economics of Data Sharing*. IEDS White Paper. <https://ieds-projekt.de/#Publikationen>
- Immonen, A., Palviainen, M., & Ovaska, E. (2014). Requirements of an open data based business ecosystem. *IEEE Access*, 2, 88–103. <https://doi.org/10.1109/ACCESS.2014.2302872>
- Katrakazas, C., Antoniou, C., Vazquez, N. S., Trochidis, I., & Arampatzis, S. (2019, June 1). Big data and emerging transportation challenges: Findings from the noesis project. *MT-ITS 2019 - 6th International Conference on Models and Technologies for Intelligent Transportation Systems*. <https://doi.org/10.1109/MTITS.2019.8883308>
- Kim, H., Choi, M., Jeon, B., & Kim, H. (2016). A study on the big data business model for the entrepreneurial ecosystem of the creative economy. *Lecture Notes in Electrical Engineering*, 368, 185–190. https://doi.org/10.1007/978-981-10-0068-3_24
- Kitsios, F., Papachristos, N., & Kamariotou, M. (2017). Business models for open data ecosystem: Challenges and motivations for entrepreneurship and innovation. *Proceedings - 2017 IEEE 19th Conference on Business Informatics, CBI 2017*, 1, 398–407. <https://doi.org/10.1109/CBI.2017.51>
- Lage, O., Saiz-Santos, M., & Zarzuelo, J. M. (2022). Decentralized platform economy: emerging blockchain-based decentralized platform business models. *Electronic Markets*, 32(3), 1707–1723. <https://doi.org/10.1007/s12525-022-00586-4>
- Lüdeke-Freund, F., Gold, S., & Bocken, N. M. P. (2019). A review and typology of circular economy business model patterns. *Journal of Industrial Ecology*, 23(1), 36–61.
- Mikl, J., Herold, D. M., Ćwiklicki, M., & Kummer, S. (2021). The impact of digital logistics start-ups on incumbent firms: a business model perspective. *International Journal of Logistics Management*, 32(4), 1461–1480. <https://doi.org/10.1108/IJLM-04-2020-0155>
- Möller, F., Bauhaus, H., Hoffmann, C., Niess, C., Otto, B., & Isst, F. (2019). Archetypes of Digital Business Models in Logistics Start-UPS. *ECIS*.
- Möller, F., Stachon, M., Hoffmann, C., Bauhaus, H., & Otto, B. (2020). Data-driven business models in logistics: A taxonomy of optimization and visibility services. *Hawaii International Conference on System Sciences*.
- Nickerson, R. C., Varshney, U., & Muntermann, J. (2013). A method for taxonomy development and its application in information systems. *European Journal of Information Systems*, 22, 336–359.
- Notteboom, T., Parola, F., Satta, G., & Risitano, M. (2017). A taxonomy of logistics centres: overcoming conceptual ambiguity. *Transport Reviews*, 37(3), 276–299. <https://doi.org/10.1080/01441647.2016.1231234>
- OECD. (2017). *OECD due diligence guidance for meaningful stakeholder engagement in the extractive sector*. OECD Publishing.

- Otto, B., & Jarke, M. (2019). Designing a multi-sided data platform: findings from the International Data Spaces case. *Electronic Markets*, 29(4), 561–580. <https://doi.org/10.1007/s12525-019-00362-x>
- Pettenpohl, H., Spiekermann, M., & Both, J. R. (2022). International data spaces in a nutshell. *Designing Data Spaces*; Springer: Cham, Switzerland, 29–40.
- Prem, E. (2015). *A digital transformation business model for innovation*. <https://www.researchgate.net/publication/284682831>
- Pulido, J. M., Cardenas, I. D., Carlan, V., Bergmans, T., & Vanelslander, T. (2024). Exploring the data space potential in Synchromodality [Manuscript submitted for publication]. *Department of Transport and Regional Economics, University of Antwerp*.
- Rachinger, M., Rauter, R., Müller, C., Vorraber, W., & Schirgi, E. (2019). Digitalization and its influence on business model innovation. *Journal of Manufacturing Technology Management*, 30(8), 1143–1160. <https://doi.org/10.1108/JMTM-01-2018-0020>
- Radonjic-Simic, M., & Pfisterer, D. (2019). Beyond platform economy: A comprehensive model for decentralized and self-organizing markets on internet-scale. *Computers*, 8(4). <https://doi.org/10.3390/computers8040090>
- Radonjic-Simic, M., Wolff, F., & Pfisterer, D. (2017). Analyzing an ecosystem for complex consumer services. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 10371 LNCS, 46–52. https://doi.org/10.1007/978-3-319-61240-9_5
- Schreieck, M., Wiesche, M., & Krcmar, H. (2016). *Design and Governance of Platform Ecosystems-Key Concepts and Issues for Future Research*. <https://www.researchgate.net/publication/303924671>
- Schweihoff, J. C., Jussen, I., Stachon, M., & Möller, F. (2022). Design options for data-driven business models in data-ecosystems. *INFORMATIK 2022*. https://doi.org/DOI:10.18420/inf2022_30
- Strandhagen, J. O., Vallandingham, L. R., Fragapane, G., Strandhagen, J. W., Stangeland, A. B. H., & Sharma, N. (2017). Logistics 4.0 and emerging sustainable business models. *Advances in Manufacturing*, 5(4), 359–369. <https://doi.org/10.1007/s40436-017-0198-1>
- Tavasszy, L. A., Van der Lugt, L. M., Janssen, G. R., & Hagdorn-van der Meijden, E. (2010). *Verkenning Synchromodaal Transportsysteem - hoofdrapport*.
- Tiwana, A., Konsynski, B., & Bush, A. A. (2010). Platform evolution: Coevolution of platform architecture, governance, and environmental dynamics. *Information Systems Research*, 21(4), 675–687. <https://doi.org/10.1287/isre.1100.0323>
- Tumasjan, A., & Beutel, T. (2019). Blockchain-Based Decentralized Business Models in the Sharing Economy: A Technology Adoption Perspective. In *Business Transformation through Blockchain* (pp. 77–120). Springer International Publishing. https://doi.org/10.1007/978-3-319-98911-2_3
- van den Broek, T., & van Veenstra, A. F. (2018). Governance of big data collaborations: How to balance regulatory compliance and disruptive innovation. *Technological Forecasting and Social Change*, 129, 330–338. <https://doi.org/10.1016/j.techfore.2017.09.040>
- Vasilescu, A. (2023). *Bachelor's Student Conference Proceedings Paper in LaTeX Template TScIT* 39.
- Wang, S., Ding, W., Li, J., Yuan, Y., Ouyang, L., & Wang, F. Y. (2019). Decentralized Autonomous Organizations: Concept, Model, and Applications. *IEEE Transactions on Computational Social Systems*, 6(5), 870–878. <https://doi.org/10.1109/TCSS.2019.2938190>
- Wiener, M., Saunders, C., & Marabelli, M. (2020). Big-data business models: A critical literature review and multiperspective research framework. *Journal of Information Technology*, 35(1), 66–91.