1 Introduction

1.1 Motivation

The rapid advancement and adoption of new digital technologies has already transformed numerous established industries and is expected to continue driving profound changes in the future (Cichosz et al., 2020, p. 209; Möller et al., 2020, p. 5379). In addition, it has created new industries, such as the digital platform economy (Evans & Gawer, 2016, p. 4; Tiwana, 2014, p. 4). Particularly, traditional industries, such as the automotive or logistics industry, face potential disruptions due to the accelerated pace of novel technologies (Steffen et al., 2024, pp. 1–2). Another threat comes from companies outside the sectors that are taking advantage of new business opportunities created by digital transformation. (Atasoy et al., 2020, p. 670). Thus, digital transformation and its implications for traditional industries are frequently discussed in research and practice (Hermann et al., 2016, p. 3928; Weking et al., 2018, p. 1). The vision of integrating the physical world (e.g., design, production, and maintenance of complex hardware products) and the digital world (e.g., software, data analytics, and digital services) serves as the overarching objective to secure national wealth and competitiveness (Bilgeri et al., 2017, p. 1; Weking et al., 2018, p. 1).

Despite the increasing pressures for over ten years, traditional companies (e.g., machinery manufacturers) still struggle to enter the digital economy successfully due to, e.g., the lack of cultural transformation, the lack of intra- and cross-company collaboration, the slow adoption of new technologies, and slow development cycles (Bilgeri et al., 2017, p. 5; Bitzer et al., 2021, p. 2).

The logistics industry is a prototypical example of a traditional industry struggling with digital transformation, having a reputation as a *"technology laggard"* (Fontecchio, 2023). However, the logistics sector is of high importance for the German industry, being the third-largest industry branch in Germany behind the automotive industry and commerce (BVL, 2024). According to the Supply Chain Network[1], the logistics industry is characterized by mostly small and medium-sized (SME) companies that have more than 3,35 million employees and generate annual revenues of 331 billion euros (BVL, 2024).

[1] German: Bundesvereinigung Logistik (BVL)

Compared to other industries, such as media, communication, or retail, logistics companies are behind the digital transformation curve (Cichosz et al., 2020, p. 210). A study from the German Federal Ministry for Economical Affairs and Energy[2] found the logistics sector lags due to several reasons: The logistics sector considers digitalization to be less important, highly digitized processes are less common, fewer logistics companies make revenue with digital offerings, and fewer logistics companies consider the degree of digitalization in their service offerings as high (BMWi, 2018, pp. 13–22). Furthermore, Cichosz et al. (2020, p. 238) discovered five major barriers to digital transformation in the logistics industry, focusing on logistics service providers:

1. Complexity of logistics networks and underlying processes
2. Lack of resources, including skilled resources
3. Technology adoption
4. Resistance to change
5. Data protection and security breach

The complexity of logistics networks and underlying processes results from two factors: First, logistics service providers act as intermediaries between shippers and customers of different sizes and locations, which require coordination across different companies, countries, locations, and departments (Cichosz et al., 2020, p. 219). Second, the companies struggle with the complexity of their existing IT infrastructure and processes, which often lack standardization (Cichosz et al., 2020, p. 219). Next, logistics service providers have a shortage of digitally skilled employees but also lack time and money to invest in digital transformation (Cichosz et al., 2020, p. 221). The third barrier describes the slow technology adoption observed in the logistics industry. Logistics service providers are often reluctant to adopt new technologies due to high up-front fees and entry barriers (Cichosz et al., 2020, p. 221).

Furthermore, the margins in the logistics industry are relatively low, so logistics companies have only a limited budget to adopt new technologies (Rotgang et al., 2023, p. 7). Resistance to change is a common barrier to digital transformation, as employees need to understand why daily routines and work patterns need to change (Cichosz et al., 2020, p. 221). Often, a disconnection between digital transformation strategies and existing

[2] German: Bundesministerium für Wirtschaft und Energie (BMWi)

corporate culture hinders the successful adoption of new technologies (Carroll et al., 2023, p. 515). Lastly, some logistics companies fear data infringement or security breaches when using external solutions (Cichosz et al., 2020, p. 221). As a result, they are critical of new and proprietary software solutions for fear of losing their digital sovereignty and becoming dependent on external providers (Rotgang et al., 2023, p. 6).

A promising approach seems to be the open-source concept, which has the potential to overcome these barriers due to its inherent characteristics. For example, Tesla open-sourced its patents to accelerate the digital transformation in the automotive industry toward electric mobility and sustainable energy through open innovation (Musk, 2014). The open-source concept allows people and companies to publish, use, adapt, and disseminate source code (Open Source Initiative, 2007). Today, open-source software has become an essential part of the economy, as more than 90% of software products are estimated to include open-source components (Harutyunyan, 2020, p. 77). The widespread use of open-source software is explained by its manifold potentials if done right: open-source software can be downloaded freely, reduces costs, increases software quality, and encourages the software's dissemination (AlMarzouq et al., 2005, p. 775; Chengalur-Smith et al., 2010, p. 719; Feller & Fitzgerald, 2000, p. 5).

In open-source communities, a large number of companies and individuals come together to form complex networks in order to work together on common goals and develop open-source software (Bagozzi & Dholakia, 2006, pp. 1099–1100; Bonaccorsi & Rossi, 2003a, p. 41). Open source brings entities from different backgrounds together, regardless of geographic location, nationalities, or time constraints, to form diverse communities (Culotta & Duparc, 2022, p. 19). Established open-source foundations, such as the Eclipse or Linux Foundation, provide the necessary infrastructure, such as a common developer platform, open-source licenses, and governance frameworks, to give guidance and make the complex networks and development processes manageable (e.g., see Eclipse Foundation, 2024 or Linux Foundation, 2024). Thus, the collaborative approach seems to naturally fit the first barrier to the digital transformation of the logistics industry. The open-source concept also supports the barrier's other aspect, the lack of standardization, as it is often used to establish de facto standards and common infrastructure (Harutyunyan et al., 2020, p. 5851).

Software companies often use open source to extend their internal resources to the open-source community. Thus, the open-source concept also addresses the second barrier, the lack of resources. For example, companies benefit from open innovation as open-source communities can contribute not only source code but also new and innovative ideas (AlMarzouq et al., 2005, p. 771; Eseryel, 2014). The development resources in open-source communities are almost endless, so popular open-source projects benefit from high software quality and fast development cycles (AlMarzouq et al., 2005, p. 768; Feller & Fitzgerald, 2000, p. 5). In the context of traditional industries, companies can use open source to share their resources to work on common solutions instead of developing silo solutions (ten Hompel et al., 2022, pp. 53–54).

Regarding the third barrier, technology adoption, open source poses fewer technological hurdles to the implementation of new software, resulting in quicker software dissemination (Chengalur-Smith et al., 2010, p. 719). As open-source software comes without license fees, individuals or small businesses can try out new technologies before making larger investments (Nagy et al., 2010, p. 148). However, users need to consider the total costs of ownership when adopting open-source software in the long term (Shaikh & Cornford, 2012, p. 5).

The open-source mindset is characterized by openness, a diverse culture, collaborative values (e.g., helping, sharing, cooperation), individual values (e.g., learning, technical knowledge, reputation), open-source process beliefs (e.g., bug fixing, code quality, status attaintment), and beliefs of freedom (e.g., free information, free software) (Stewart & Gosain, 2006, pp. 6-7). Thus, adopting an open-source mindset into the corporate culture can help to overcome cultural barriers to digital transformation (Aksulu & Wade, 2010, p. 589; Culotta & Duparc, 2022, p. 16). However, adopting open source in companies faces the same cultural barriers as digital transformation, as its potential is often difficult to quantify (AlMarzouq et al., 2005, p. 773; Nagy et al., 2010, p. 149). As a result, employees may be reluctant to the adoption of open source.

Open source supports securing data protection and security breaches, the last barrier. For example, the European Commission committed itself to an open-source strategy to ensure digital sovereignty:

> *"To ensure our digital sovereignty and guarantee a level playing-field, for all future IT developments the Commission will promote standards and specifications that are implemented and distributed through open-source software, and include this in its corporate governance approach."*
>
> ***The European Commission (2020, p. 10) on digital sovereignty and open source.***

In this context, open source is a central element of digital sovereignty as it is vendor-independent, discrimination-free, and technology-neutral (Nagy et al., 2010, p. 151; Open Source Initiative, 2007). Therefore, many public projects use open-source software in order to create shared and independent infrastructures. For example, Gaia-X[3] aims to establish an interoperable data infrastructure to ensure data protection and data sovereignty. Furthermore, the Federal Ministry for Economic Affairs and Climate Action[4] installed the *"Sovereign Tech Found"*[5] to ensure digital sovereignty through digital infrastructure and ecosystems by funding and promoting open-source projects.

Despite the growing importance of open source in the public domain (e.g., see European Commission, 2020 or Blind et al., 2021), it remains unclear which role open source could play as a strategic tool for digital transformation in traditional industries, specifically logistics. Previous studies show that industrial companies are open-minded toward open source but lack adequate strategies and expertise to enable its opportunities. For example, more than 66 % of the companies that were questioned did not have an open-source strategy (Bitkom e. V., 2023, p. 18).

While open source offers many potentials and benefits, it also comes with risks, e.g., the trustworthiness, quality, and reliability of open-source software and their documentation depends on the respective open-source community (Hoepman & Jacobs, 2007, p. 5; Silic & Back, 2015, p. 8). Therefore, it is essential to understand and analyze the specific cost-benefit ratio of open-source integration given the desired product's functionality and the company's IT expertise in comparison to its sole in-house development or the adoption of existing proprietary solutions (Steffen & Möller, 2022, p. 3).

[3] https://gaia-x-hub.de/en/

[4] German: Bundesministerium für Wirtschaft und Klimaschutz (BMWK)

[5] https://www.sovereigntechfund.de/

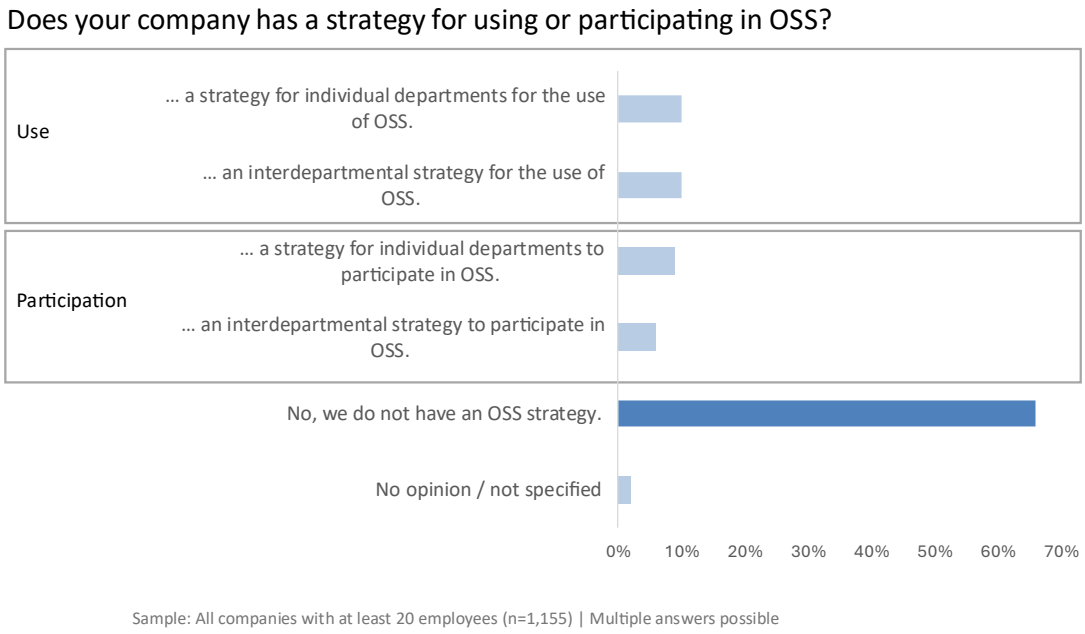

Figure 1: Open-source strategy by type. Adapted from Bitkom e. V. (2023, p. 18).

Open source by itself does not offer a standard level of quality nor any guarantees with regard to the open-source software functionalities and services, such as ongoing maintenance and updates (Petrov & Obwegeser, 2018, p. 4; Silic & Back, 2015, p. 8). Thus, companies need to carefully evaluate whether they are prepared to enter the corresponding open-source dependencies; for example, they should be able to overtake all tasks in-house or have the option for vendor-supported aid if the open-source community stops supporting the project (AlMarzouq et al., 2005, p. 770). Also, companies must not overestimate the benefits and underestimate the required in-house responsibilities and efforts to ensure the value of open-source integration in the long term. However, the existing literature mostly focuses on isolated aspects (e.g., technological or social aspects), which do not provide a full understanding of supporting traditional industries in grasping the strategic implications of open source. Furthermore, companies lack the understanding of how to develop an open-source strategy according to their needs. Therefore, this dissertation addresses this gap by answering the overarching research question:

"How to support logistics organizations with their open-source strategy?"

1.2 Research Questions

The overarching goal of this dissertation is to support industrial companies in adopting the open-source concept. By focusing on logistics, this work examines a prototypical traditional industry in which the open-source concept is rarely used strategically. Particularly, this dissertation seeks to guide researchers and practitioners through the strategic planning process for the adoption of open source.

Table 1: Summary of the research questions and the corresponding contributions.

#		Contribution	Section
RQ	How to support logistics organizations with their open-source strategy?	Specified for each research question (RQ)	-
1.	What are the strengths, weaknesses, opportunities, and threats associated with open source in traditional industries?	Influencing factors and SWOT analysis of open-source adoption in traditional industries.	4
2.	How can open-source business models be characterized and differentiated based on conceptually and empirically grounded characteristics?	Taxonomy of open-source business models.	5
3.	What are the archetypes of open-source business models?	Archetypes of open-source business models and examples of industrial open-source projects.	5
4.	How are logistics organizations adopting open source strategically?	Exploratory case studies in the context of logistics.	6
5.	Which action recommendations can support the strategic adoption of open source in logistics organizations?	Action recommendations for open-source adoption in logistics.	6

Based on the practical challenges and the existing research gap in this field, this work addresses these issues following the strategic planning process. The strategic planning