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Abstract:

Traditional industries, such as logistics, are facing the challenge of digital transformation. Barriers, such as the slow adoption of new technologies and the emergence of competitors from the software industry, increase the pressure on established firms. In this context, open source (OS) eases the collaboration among the stakeholders within traditional industries to solve common digital problems and leverage the innovation potentials of the OS community. However, research on the strategic use of OS software (OSS) is mainly limited to the software industry. Consequently, these potentials are left untapped for the more traditional industries based on physical assets. The paper starts at this point and reports on a systematic literature review and a comprehensive interview study. The results uncover influencing factors regarding the adoption of OSS, focusing on the logistics industry as a prototypical example of a traditional industry. The influencing factors are structured using the TOE framework and a SWOT analysis, allowing researchers to focus on how to avoid barriers or unlock specific potentials to drive digital transformation and innovation. In terms of practical contributions, practitioners can use the influencing factors to strategically incorporate OSS by focusing on non-technical aspects that hinder the adoption of OSS in traditional industries.

Keywords: Open Source, Opportunities, Threats, Digital Transformation, Digital Strategy, Toe Framework, Swot Analysis.

[Department statements, if appropriate, will be added by the editors. Teaching cases and panel reports will have a statement, which is also added by the editors.]

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This manuscript underwent [editorial/peer] review. It was received xx/xx/20xx and was with the authors for XX months for XX revisions. [firstname lastname] served as Associate Editor.] **or** The Associate Editor chose to remain anonymous.]

1 Introduction

The rapid development of digital technology has led to a fundamental transformation in many industries (Hein et al. 2020; Möller et al. 2020) and the generation of entirely new ones, such as the platform economy (Evans and Gawer 2016; Tiwana 2014). Traditional industry sectors, e.g., the automotive or logistics industry, particularly face potentials and barriers frequently discussed in research and practice (Hermann et al. 2016; Weking et al. 2018). In this context, we define traditional industries as industry sectors whose core offerings and competencies focus on physical goods and services, such as machinery or transportation services. 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; Weking et al. 2018). However, traditional firms (e.g., mechanical manufacturers) struggle to enter the digital economy due to several factors, such as the lack of cultural transformation, the lack of intra- and cross-company collaboration, the slow adoption of new technology, or slow development cycles (Bilgeri et al. 2017; Bitzer et al. 2021).

The software industry has already addressed the challenges accompanying digital transformation by using open source (OS) (Parker et al. 2016; Saebi and Foss 2015; Schlagwein et al. 2017). Under OS principles, people and firms can publish, use, adapt, and disseminate source code (Open Source Initiative 2007). Today, OS software (OSS) has become an essential part of the economy, as more than 90 % of software products are estimated to include OS components (Harutyunyan 2020). The widespread use of OSS can be explained by its manifold potentials: OSS can be downloaded freely, reduce costs, increase software quality, and encourage the software's dissemination (AlMarzouq et al. 2005; Chengalur-Smith et al. 2010; Feller and Fitzgerald 2000). From a technological perspective, IT experts favor the integration of OSS as peer review processes and external developer resources increase the software's quality and the pace of development cycles (AlMarzouq et al. 2005; Feller and Fitzgerald 2000). Furthermore, firms can benefit from open innovation as OSS communities can contribute not only source code but also new and innovative ideas (AlMarzouq et al. 2005; Eseryel 2014). For example, Tesla open-sourced their patents to accelerate the industrial transformation in the automotive industry towards electric mobility and sustainable energy through open innovation (Musk 2014; Wolff and Schlagwein 2021).

Both research and practice have widely recognized the potential of OSS for many years and have systematically analyzed the phenomenon in IS research. For example, Aksulu and Wade (2010) conducted a comprehensive literature review, presenting a holistic framework for OSS research, which highlights that most studies focus on the software industry as the primary application area for OSS. Nelson et al. (2006) analyzed OSS from a personal, technical, economic, and political perspective through its different development stages, encompassing the sole technological view of OSS. However, the studies do not provide an in-depth analysis of the presented aspects as they focus on giving an overarching classification framework.

Previous studies show that industrial firms have recognized the importance of OSS but lack adequate strategies to enable its potential or avoid its accompanying barriers (Gentermann and Termer 2019). For example, Steffen et al. (2024) propose leveraging OSS to drive industry transformation by using it as a foundation for establishing new standards. Also, Harutyunyan et al. (2023) aim at enabling the OSS potential by providing industry-inspired best practices. However, the overall role of OSS as a strategic tool for driving innovation and digital transformation in traditional industries remains unclear despite its growing strategic importance in these sectors in recent years. Translating existing OSS opportunities and threats into the context of traditional industries is complicated because most literature analyzes OSS in the software industry (e.g., see Aksulu and Wade 2010 or Bagozzi et al. 2006). Thus, we assume that traditional industries, due to their initial situation, have a different perspective on the aspects associated with OSS compared to the software industry. Therefore, we aim to systematically gather existing influencing aspects related to OSS through a structured literature review to address the research gap and to complement theoretical knowledge with practical insights from traditional industries. Our goal is to synthesize findings from previous research and place them in the context of traditional industries. The literature findings serve as a coding sheet for conducting semi-structured interviews with research, industry, and political experts to identify relevant factors influencing strategic OSS adoption in traditional industries. Thus, we want to systematically assess and identify influencing factors regarding OSS in the context of traditional industries, which leads to the following research question:

RQ1: Which influencing factors are relevant in the adoption of OSS as a strategic tool in traditional industries?

RQ2: Which of these factors do practitioners perceive as strengths, weaknesses, opportunities, or threats?

Our paper is structured as follows: After the introduction, we outline the background of OS. Then, the research design details our approach to conceptualizing the coding sheet and our means of data collection based on a workshop and an interview study. Section 4 gives an overview of our identified potential and barrier factors in the context of traditional industries structured with the TOE framework. In section 5, the influencing factors are structured and discussed using a SWOT analysis. Finally, we explain the contributions, describe the limitations, and illustrate further research avenues.

2 Open-Source Software

The terminology of openness and its underlying concepts, such as open innovation, open strategy, or OS, has been a significant driver for innovative information technology (IT) (Schoder et al. 2019). Openness is characterized by transparency, access, participation, and democracy (Schlagwein et al. 2017). For example, opening specific features of a platform is a common strategy to spur network effects and participation (open strategy) (O'Mahony and Karp 2020; Pellizzoni et al. 2019; Rotgang et al. 2023). In the context of IS research, OSS is reported as the earliest and most striking case of "openness with IT" (Schlagwein et al. 2017). Therefore, we focus our research on OSS as it can be seen as a facilitator for further open concepts and open technology (Eseryel 2014; Saebi and Foss 2015).

Fundamentally, OSS describes source code that is made freely available for third parties under distinct distribution terms that describe, for example, how modified forms of the licensed source code may be distributed (by indicating the original source code as well as the changes) or how the software needs to be handled (non-discriminatory towards persons or field of use). Also, the licensing issue is highly significant as it should not only be technologically neutral but must also apply to all who further distribute the product (Raymond and Perens 1998). The terminology was introduced by the foundation of the "OS Initiative" in February 1998 to create a pragmatic approach to freely available source code and to detach from the ethically-driven concept of "Free Software," which was strongly associated with the misconception of source code for a zero price (Fitzgerald 2006; Raymond 2001; Raymond and Perens 2018). The main goal of the OS Initiative was to spread the idea of OSS and to popularize distribution terms that were more adaptable for commercial use than the former "Free Software" definition (Stallmann 2006; Rajala et al. 2006). In summary, Stallmann (2006) explains the difference as follows*:"Open source is a development methodology; free software is a social movement (p. 32)."*

Morgan and Finnegan (2014) introduce the notion of "strategic OS" to describe an approach in which OSS is used as a strategic tool to achieve competitive advantages, such as gaining first-mover advantages, commoditizing software that supports or increases the demand for core products, attracting IT personnel, or creating new ventures (Nelson et al. 2006). In contrast to the sole use of OSS as a low-cost alternative to proprietary software (operational), strategic OS also focuses on identifying and enabling long-term potentials to create business value based on OSS (strategic) (Morgan and Finnegan 2014). For example, Google Android made its operating system's core OS to increase its market share using advertisements and other services as a source of revenue (Karhu et al. 2020; Soto Setzke et al. 2017). MySQL provides another example of strategic OS: the OS relational database management system has become the quasi-standard in the industry as they reached a rapid adoption and market penetration through OSS (Fitzgerald 2006; Rajala et al. 2012). In recent years, aspects of strategic OS have gained attention in research by focusing, for example, on OS business models (e.g., see Duparc et al. 2022), best practices in industry (e.g., see Harutyunyan et al. 2023), or open innovation through OSS (e.g., see Ahuja et al. 2022). Especially in traditional industries, competitors start to form OS communities, such as the Silicon Economy or the Automotive Grade Linux to develop OSS together (Author et al. 2024, Apolinario 2023). Companies engage in open coopetition to establish common standards, leverage external funding opportunities, pool resources, improve software, and boost developer motivation with the overarching goal of accelerating digital transformation in the respective industry (Yavuz and Riehle 2025, Author et al. 2024). In this study, we include the aspect of strategic OS to encompass the purely technological view of OSS and enable long-term potentials for organizations.

3 Research Design

3.1 Research Design Overview

This study applies Grounded Theory, which aims to generate theory based on empirical data (Glaser and Strauss 2009). The research design follows a two-phase research approach consisting of a theoretical and an empirical phase. In the theoretical phase, we conduct a structured literature review following vom Brocke et al. (2009) and Webster and Watson (2002) to synthesize the existing knowledge base. In the empirical phase, we conduct an interview study proposed by King (2004) to enrich and refine the theoretical insights. Involving practitioners in this phase not only strengthens the empirical grounding of the study but also enhances the practical relevance and validity of the emerging theoretical concept (Glaser and Strauss 2006).

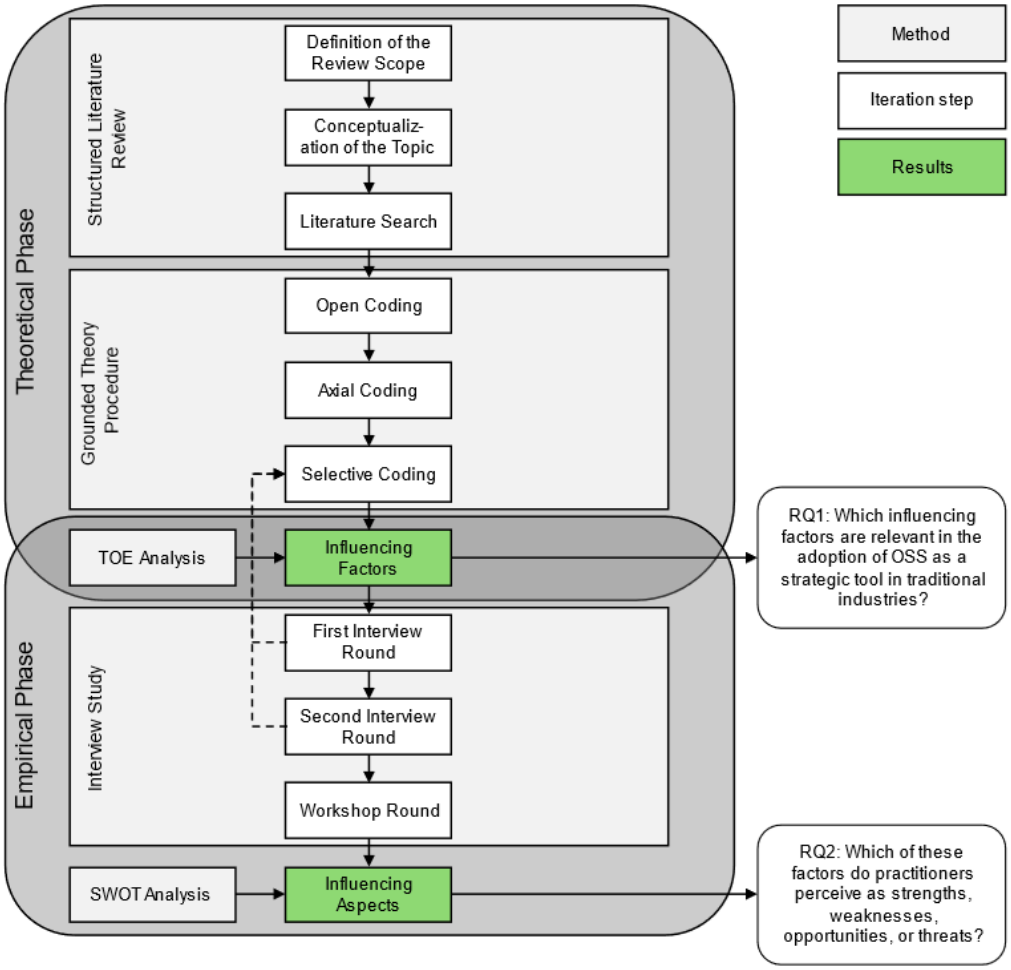

Figure 1. Research Design Overview

The theoretical phase focuses on identifying relevant influencing factors through a structured literature review and qualitative data analysis following the grounded theory procedure after Strauss and Corbin (1990). The outcome of this phase is a set of influencing factors that are structured using the TOE framework.

The empirical phase aims to assess how practitioners perceive these influencing factors in terms of their strategic impact on OSS adoption in traditional industries. The phase is conducted through an interview study with two iterations. During the interview study, we detailed the factors that influenced the aspects of the interviews. As we reached theoretical saturation during the interviews, we decided to end the conceptualization of the influencing factors. Finally, we structure the identified influencing aspects in a workshop using the method of SWOT analysis and categorizing the aspects as strengths, weaknesses, opportunities, or threats.

3.2 Structured Literature Review

The structured literature review follows the guidelines of vom Brocke et al. (2009) and Webster and Watson (2002). During the definition of the review scope, we establish the boundaries and define the focus of the literature review to ensure relevance by determining our research questions, inclusion criteria, and the scope of the industries considered. Consequently, we focus our search on top-ranked AIS journals and conferences as well as top-tier outlets of the IS community. Additionally, we include other journals that follow standard peer-review processes and that were listed in the VHB ranking, a widely used journal ranking system for IS and business research.

Next, we conceptualized the topic by defining key concepts and themes related to OSS adoption and specifying relevant keywords for the search. We use the search strings "open source" AND ("opportunities" OR "potentials") OR ("threats" OR "barriers") in the title and abstract fields within the AISeL and Scopus databases. We then conducted a systematic search of academic literature to identify relevant studies. Each paper was scanned to determine potential influencing factors on OSS. Furthermore, 16 additional publications were included after a forward and backward search. For the analysis, we removed duplicates, non-English literature, and irrelevant publications (e.g., those only presenting specific use cases). Ultimately, 85 papers were included in the full-text analysis.

Table 1. Structured Literature Review

Outlet		Search	Hits	Selected
Top journals	MISQ	Search in title and abstract for *"open source"* AND (*"opportunities" OR "potentials"* OR "strengths" OR *"threats"* OR *"barriers"* OR *"weaknesses")*	9	3
	JAIS		7	2
	JMIS		6	5
	ISJ		1	0
Top conferences	ICIS		31	13
	ECIS		16	4
	AMCIS		33	9
	PACIS		19	3
	HICSS		19	4
Others	Other Journals		125	18
	Other Conferences		38	8
	Others		11	0
	Forward and backward search		0	16
		Total	315	85

3.3 Grounded Theory Procedure

During the coding procedure, we distinguished between open, axial, and selective coding as outlined by Strauss and Corbin (1990). The papers from the literature review were equally distributed between the authors. Three authors were involved in the coding process to ensure rigor and reliability and mitigate criticisms of subjectivity, hermeneutics, and value-load (Sinkovics et al. 2005). The coded text was structured into three hierarchical levels, a common approach in qualitative data analysis (Robson and McCartan 2015; Rohmann et al. 2015).

Open Coding: Each factor mentioned in the publications was noted in its original terminology to ensure an objective approach, allowing later codes to emerge independently. Thus, individual codes were classified and grouped into influencing factors, serving as precursors for the SWOT analysis. The open coding aimed to break down the data into smaller units.

Axial Coding: Next, we condiuted axial coding to systematically group the initial codes into broader categories by identifying relationships and clustering them into higher-order dimensions. The step focuesd on deriving categories to summarize and connect the codes. The influencing factors from the open coding process were further clustered into overarching dimensions, such as culture or business.

Selective Coding: During the selective coding, the inductively derived categories were tested, modified, enhanced, or consolidated based on additional textual material from the interviews. Finally, the dimensions were sorted into meta-dimensions using the TOE framework, integrating the findings into an

overaching theoretical model.

An illustrative example of this process is provided in Figure 2, focusing on factors related to costs and efficiency. The raw data, consisting of direct quotes from the literature, is displayed on the far left. The first-order codes (second-left column) capture the individual factors. Notably, a single raw data factor can be associated with multiple first-order codes—for instance, resource constraints relate to both cost handicaps and efficiency.

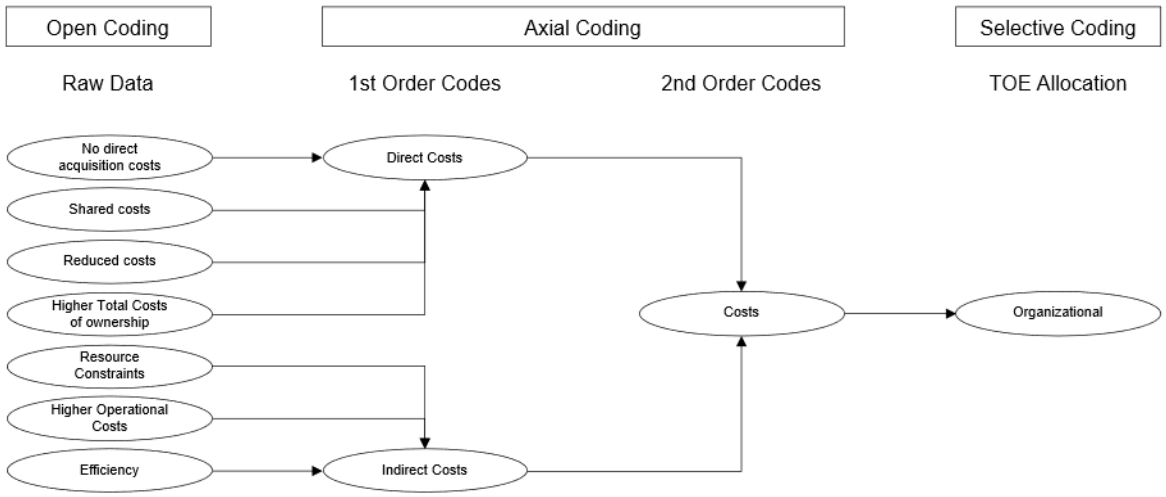

Figure 2. Raw Data Coding Example

In the second step, the interpretive coding, we synthesized and enhanced the first set of codes iteratively. This provided the second-order codes (second-from right column). Here, there should be no interdependencies, i.e., every first-order code only relates to one second-order code. For instance, cost benefits and handicaps are summarized into direct economic effects. The second-order codes then relate to one of the TOE categories, in this example, to the organizational category. All raw data sets are synthesized analogously.

During the second phase of interpretive coding, we systematically refined and amalgamated the initial set of codes iteratively. This process yielded the emergence of second-order codes, which are showcased in the column situated second from the right. It is imperative to note that within this framework, each first-order code exclusively corresponds to a singular second-order code devoid of any interdependence. To illustrate, concepts such as cost benefits and handicaps are succinctly consolidated under the umbrella of direct economic effects. Subsequently, these second-order codes are consolidated in third-order codes (the influencing factors) and linked to one of the categories within the TOE (Technological, Organizational, and Environmental) framework. This linkage is exemplified in the provided instance, wherein the second-order codes are associated with the organizational category. The synthesis of all raw data sets follows a similar analogous approach.

After sorting the codes within the TOE framework, we validated them through an interview study after Iivari et al. (2020). Following the qualitative research approach after Sarker and Sarker (2009), we structure the empirical phase iteratively: in the first phase, we conducted interviews with experts having an academic and practical background in the strategic use of OS (interviewees 1-10). The participants focused their everyday work on the topic of OS and were seen as fundamental experts in the field due to their leading roles in OS projects or publications. During the second phase, we focused on experts (interviewees 11-20) from the logistics industry to gain a deeper understanding of a prototypical traditional industry.

Each interview was structured as follows: first, we conducted the interviews following the semi-structured interview guidelines. Then, we asked the interviewees to brainstorm further aspects alongside the TOE framework on an online board. Lastly, we provided the interviewees with an overview of the gathered factors from the literature. In summary, the interviewee agreed with the findings from the literature and added new aspects to the existing codes. In total, three new factors, digital transformation, public funding, and legislation and regulation, were added based on the interviews.

3.4 Interview Study

The study follows the standard process of constructing an interview study (King 2004). After formulating the research question, the interview guide was created based on the insights of the structured literature review. The qualitative data was collected based on semi-structured expert interviews. We searched for experts from traditional industries, such as logistics or automotive, meeting the definition of a typical expert as *"a carrier of practice experience and an explicit expert in the studied sphere"* (Libakova and Sertakova 2015). Our sampling logic followed a purposive approach aiming for interviewees with several decades of experience and work in multiple international firms in the mechanical engineering, automotive, logistics, and software industries. Furthermore, we searched for interviewees in strategic IT positions and with a profound knowledge of OS projects and digital transformation.

The interview study was iteratively conducted in two rounds with experts from diverse traditional industries (experts 1-10) and experts from the logistics industry (11-20). We identified a total of 20 experts to conduct the study. As the interview study proceeded, we focused on experts from the logistics industry to enhance the insights from the first interview round. This was necessary as the results lacked deeper industry-specific aspects, so we decided to focus on the logistics industry to gain insights from one prototypical traditional industry. Each interview was conducted with two interviewers. In case the interviewees agreed, the interviews were recorded and transcribed. Otherwise, one interviewer focused on protocolling the interview while the other conducted the interview. The results for the evaluation are gathered through the grounded theory approach (Lapadat and Lindsay 1999; Ochs 1979). We reached theoretical saturation after 20 interviews as the last four interviews only confirmed the previously mentioned aspects not giving new insights into the phenomenon. Lastly, we can derive a profound overview of the influencing factors of OS.

Table 2. Overview Interview Study

ID	Domain	Organization	Position	Duration
1	Data Spaces	Association	CTO	59 min
2	Production and Automation	SME	Head of Sales	55 min
3	Software Development for Industrial Applications	Research Organization	Technical Steering Committee OSS Projects	59 min
4	OSS Development	OSS Association	CEO	54 min
5	Mechanical Engineering	SME	Head of R&D	59 min
6	Innovation Research in Industry	Association	CEO	39 min
7	Information and Communication	Association	Head of Software Development	52 min
8	Software Development for Industrial Applications	OSS Association	CEO	55 min
9	Software Development for Industrial Applications	Start-up	Founder/CEO	62 min
10	Automotive	Large Enterprise	IT Director	47 min
11	Logistics	Start-up	Founder/CEO	41 min
12	Logistics	Large Enterprise	Technology Architect	57 min
13	Logistics	Foundation	CEO	73 min
14	Logistics	Association	Head of International Road Haulage	86 min
15	Logistics	Logistics Service Provider	CIO / CDO	89 min
16	Logistics	Large Enterprise	Department Head of Prototyping & Testing	87 min
17	Logistics	SME Carrier	Managing Director	55 min
18	Software Development for Logistics Application	Start-up	Product Manager	75 min
19			Head of Technology and Engineering	
20	Logistics	Large Enterprise	Software Developer	57 min

3.5 TOE Framework

The TOE framework introduced by Depietro et al. (1990) is a standard tool to analyze technology adoption in organizations. Coming from organizational theory, the framework allows researchers to analyze a given domain along the three categories of technology, organization, and environment (Baker 2012). The framework is a widely used tool in IT adoption studies as it is a useful analytical tool for studying organizational adoption of technologies (Dedrick and West 2004). In the context of open source, Dedrick and West (2004) conducted an exploratory study into the adoption of open-source platforms using the TOE framework to structure the identified factors. Similarly, we used the TOE categories as an overarching framework to code our data.

According to Baker (2012), the TOE categories are defined as follows: The technological category includes all technologies that are relevant to the firm. It analyzes technologies that are already in use as well as technologies that are available in the marketplace (Baker 2012). The analysis includes, for example, the technology's reliability and comparability (Dedrick and West 2004). The organizational category refers to the resources and capabilities of the organization, such as the corporate culture, existing business models, or communication processes (Baker 2012). Knowledge about the organizational context allows one to align the processes with demands from the environment. Lastly, environmental aspects analyze the external factors that might influence an organization's technology adoption. The environmental analysis includes aspects such as the industry structure, the presence or absence of technology service providers, legal aspects, and public incentives (Baker 2012).

3.6 SWOT Analysis

The SWOT analysis is a key strategic tool for identifying internal and external factors that influence a company's strategy (Pickton and Wright, 1998). It consists of four elements:

- Strengths: Internal advantages, such as strong competencies or resources (Andrews 1987; Dyson 2004).
- Weaknesses: Internal disadvantages, like inflexibility or outdated mindsets (Johnson et al. 2006; Piercy and Giles 1989).
- Opportunities: External factors that offer potential benefits, e.g., market growth (Andrews 1987; Pickton and Wright 1998).
- Threats: External risks, such as increasing competition (Andrews 1987).

The analysis helps formulate strategies by leveraging strengths, addressing weaknesses, seizing opportunities, and mitigating threats (Dyson 2004). It involves gathering internal data on competencies, resources, and corporate culture alongside external insights on market trends, customer needs, and regulatory conditions (Pickton and Wright 1998; Weihrich 1982). Due to its simplicity and effectiveness, SWOT is a widely used tool for strategic decision-making, including market entry and product policy (Piercy and Giles 1989). Also in research, the SWOT analysis is widely used for supporting researchers in the strategy formulation based on the structured analysis of external and internal factors (Dyson 2004). Thus, we apply the SWOT analysis to engage with industry expersts to faciliate structured feedback and ensure alignment with the theoretical data.

4 Influencing Factors Regarding Strategic Open Source in Traditional industries

4.1 Final Influencing Factors

We identified 14 influencing factors organized into three categories based on the TOE framework through specific iterations. Table 3 briefly describes each factor and summarizes their theoretical and empirical hits. Each influencing factor encompasses underlying aspects, providing a more detailed granularity to explain their impact on the strategic adoption of OS. The individual aspects are detailed in Table 4, Table 5, and Table 6. Additionally, new aspects or those particularly emphasized by the interviewees are highlighted in green.

Table 3 . Influencing Factors Overview

M	Factors	Literature	Interviews	Description
Environmental	Licensing	31	24	Licensing aspects and issues that are addressed explicitly in the context of OS, for example, missing guarantee rights or the risk of stealing intellectual property.
	Market	19	39	Environmental and external factors influencing an organization's OSS project, such as the overall perception of OSS in the market.
	Digital Transformation	16	19	The factor describes the role of OSS regarding digital transformation in traditional industries.
	Public Funding	11	11	Public funding includes potentials and barriers enabled by (European) initiatives that support OSS.
	Legislation and Regulation	10	28	The factor describes the possible impact of legislation and regulation on OSS projects and vice versa, such as legislation, data protection, or tax regulation.
Organizational	External Community	79	76	The external community includes actors outside an organization, such as third-party developers or customers, and accompanying phenomena.
	Culture	55	51	The factor treats cultural aspects regarding OS, such as the OSS ideology or the corporate culture.
	Costs	78	38	Costs that are (in-)directly tied to the OSS, such as higher operational costs, no licensing fees, reduced or increased time and effort.
	Internal Community	44	30	The internal community comprises the actors, e.g., employees, of an organization and the accompanying potentials and barriers for them.
	Business	48	36	Business-related aspects of OSS for an organization include new business models, competitive advantages, and disadvantages.
	Marketing	33	19	The factor describes the potentials and barriers for companies and individuals to release software code for self-marketing purposes.
Technological	Technology	62	53	The technology factor includes architectural aspects of OSS, e.g., interoperability, modularity, security, and standardization.
	Development Process	46	16	The factor outlines typical characteristics of the OSS development process, for example, peer review and forking.
	Usability	23	13	The usability describes potentials and barriers regarding the user-(un)friendliness of OS.
	Sum hits	555	433	

4.2 Environmental Influencing Factors

Licensing: The license is one of the main characteristics of OSS as it defines the software's distribution terms and has mainly contributed to the success of OSS (Fitzgerald 2006). In the traditional industry, the multitude of licenses represents a barrier to using OSS in SMEs. Interviewee 1 described the aspect as follows: "*If you look at the larger ones, you have a catalog that clearly states that the organizations are okay and the licenses are okay […]. And SMEs often have to consult lawyers, […], who may not be familiar with the issues, because these are special topics, and that's a risky business*." Especially the software's reuse and distribution are influenced by the right license choice, so firms perceive incorporating OSS in their products or making their software available under an OSS license as a threat. Furthermore, the interviewees highlighted the threat of legal issues, such as unclear taxation or ownership rights. Interviewee 3 reflects the general mood in the traditional industry as follows: *"I have often been told that there is still a very, very great uncertainty about the law."* Thus, firms are hesitant to participate in OSS projects due to the perceived threat from legal issues.

Another aspect is the risk of stolen intellectual property, which traditional firms fear. Interviewee 8 describes the preconception as follows: "*So classic manufacturing industry [...] they don't understand that, they say, they could have sold all that as products as well. Yes, then nobody would use it today*." However, the tendency towards traditional licensing models represents a cultural issue rather than a licensing aspect. An overview of licensing aspects is given in Table 4.

Market: This influencing factor describes the market environment in which a firm uses or releases OSS, as well as the potential that the concept of OSS holds for a specific local market (see Table 4). For example, OSS allows accelerating digital transformation in developing countries as large proprietary software firms have little interest in adapting their products to local markets (Berquist et al. 2005). An interviewee said that many firms are open-minded toward OSS and support OSS communities (Gentermann and Termer 2019). Also, OSS has already been used in the traditional industry for many years. Interviewee 6 explained: "*The importance is enormous, even if this is sometimes not transparent to everyone. The entire software landscape of our company is now massively based on OSS*." However, a new OS provider of industrial OSS could face difficulties in entering the market as many industrial firms already have established OSS as well as proprietary software, such as Linux or SAP, so high efforts would accompany a change.

Digital Transformation: This factor comprises all aspects of digital transformation in traditional industries. The factor evolved during the interviews and comprised aspects such as digital transformation and digital innovation. The interviewees described OSS as a driver for both: "*Because everything we see in terms of technological developments, in terms of new ideas that are coming onto the market, is experiencing a massive acceleration and a real boost in innovation as a result of OS."* The statement is underlined by interviewee 2, who described OSS as an accelerator of digital transformation and proprietary development as a barrier. The interviewees argued that many basic libraries and projects regarding digital technologies that are important for innovative technologies in traditional industries are OSS, such as the projects ROS, FIWARE, IndustryFusion, or Apache IoT projects. Also, OSS can act as a means to drive commodity services to create a common industrial infrastructure. Interviewee 9 concluded: *"OSS has a very, very high position in the area of digital transformation and Industry 4.0."*

Public Funding: The potential of public funding was first addressed in the interviews. For example, many European initiatives, such as Gaia-X or the Silicon Economy, are based on OSS infrastructure. Furthermore, firms can apply for public tenders to receive public funding for OSS projects. Thus, an OS-friendly environment is promoted and supported by diverse public initiatives. The interviewees also positively mentioned the initiatives as they promoted OSS. The interviewees emphasized the need for governments to promote OSS and to link sponsored projects to it, which was described as "*public money, public code*." However, interviewee 11 described his experiences as follows: "*I had the experience that many companies only do it primarily for funding. That they say, I'll write something in the proposal, just to get the funding."* As a risk, projects may not succeed due to project burnout after the funding period ends. However, the interviewees saw potential in supporting successful lighthouse projects that could encourage other firms to participate in OSS projects.

Legislation and Regulation: The legislation and regulation factor was derived from the interviews. The factor includes aspects such as challenges for current legislation regarding OSS and the potential for digital sovereignty (see Table 4). Interviewee 12 pointed out that (national) legislation needs to be adapted to OSS by using the following example: *"the law has to do something [...] if I now use software that the other company also uses, and now both work together on the software, who owns the right and who has, the tax advantage through it?"* Thus, firms risk legal issues, such as tax fraud, if the legal situation is unclear. Besides the need for adapted legislation, interviewee 1 emphasizes the need for politics to strengthen the national and European competitiveness of OSS: *"the second thing is to make OSS much more feasible by really strengthening the national or European infrastructure for it, because where do you end up when you do something like that? For example, you end up at GitHub, which is Microsoft, so it's not European."* In summary, the interviewees agreed that OSS is an opportunity to secure digital sovereignty regarding freedom of choice, transparency, and openness worldwide.

Table 4. Environmental Influencing Factors and Aspects

Factors	Aspects	Literature
Licensing	Less accountability, flexible licensing, legal issues, intellectual property, no warranty rights, complicated licensing	(AlMarzouq et al. 2005; Del Nagy et al. 2010; Germonprez et al. 2021; Haider and Koronios 2009; Watson et al. 2008)
Market	Strengthen local competitiveness, positive perception of OSS in the market, proprietary software landscape in industry, local and global competition	(Berquist et al. 2005; Haider and Koronios 2009)
Digital transformation	Digital transformation in traditional industries, industrial OSS libraries	Empirically collected
Public Funding	Many initiatives based on OSS, public funding, project burnout	Empirically collected
Legislation and Regulation	Digital sovereignty Unclear legislation regarding OSS, antitrust, compliance	Empirically collected

4.3 Organizational Influencing Factors

External Community: The external community, consisting of external developers and third parties, is an essential part of OSS as it is the key to a successful project (AlMarzouq et al. 2005). The interviewees cited similar potentials and barriers for the industry as found in the literature, such as trust, high motivation in communities, open innovation, community support, and network effects (see Table 5). For example, one interviewee described OSS as a fundamental basis for blockchain technology to create trust based on transparency and to motivate people's participation. On the other hand, the workshop participants addressed the aspect of untrustworthiness as the initiator of the OSS project could be considered "*untrustworthy*" due to his background, causing a potential risk for others to become dependent on his software product. The aspect of OSS communities was addressed several times: "*It is important to look closely at these ecosystems, not just the technology, but to look at the ecosystems."* (interviewee 8). Thus, firms should consider the surrounding ecosystem when evaluating OSS.

Furthermore, community building was mentioned as an essential aspect of enabling the potential of OSS communities. For example, interviewee 9 mentioned the missing awareness for community building in the industry: "*So the topic of community building is not that simple. Many are aware of the need for it […], but no one really knows how it actually works."* Another interviewee reported on a case in which the firm that mainly received in-house contributions to its OSS due to missing community building. Even if developers use the product, their contributions are not assured. However, the interviewees found OSS to be an excellent means of collaboration to work on joint projects and onboard partners, such as their original equipment manufacturer. Particularly in highly networked industries, such as logistics, the interviewee found the joint development of OSS to be a great means of collaboration. The interviewees criticized the uncertain support as a potential barrier to adopting OSS in a professional context from a user's perspective. Therefore, one interviewee proposed service-level agreements as a possible countermeasure. In summary, the external community is the most mentioned factor as it forms the backbone of every OSS project to succeed.

Culture: This factor includes social aspects related to OSS and is displayed in Table 5. The OSS ideology manifests itself through OSS distribution terms, such as the free redistribution of software, diversity, integrity, and technology neutrality (Open Source Initiative 2007). The interviewees thematized possible misconceptions and a missing understanding of the OS ideology in industrial firms as cultural barriers: *"This has not yet been fully understood, especially by small and medium-sized production companies."* One interviewee reported that many firms want to patent and license as much as possible as the product or software could generate income, without considering that open sourcing would have brought more strategic benefits in some cases. Also, in management, cultural barriers can occur as the controller is described as the "*biggest enemy*" regarding OSS due to missing KPIs to assess the value of OSS. This results in the unwillingness to invest in "*free software*," hindering further involvement in OSS projects. Interviewee 1 describes another mindset barrier he experienced in the industry: *"If I didn't do it myself, it can't be good."* The last aspects highlight the need for firms to understand the ideological motivation that drives many communities. Therefore, to grasp the OSS mindset, adapting the corporate culture to OS is often necessary. Some interviewees reported on OS program offices that were established in their firms to

drive an OS-friendly mindset and enhance their competencies to enter the OSS world successfully. In total, culture marks the second most mentioned factor, as industrial firms often encounter cultural barriers characterized by closed structures and misconceptions that need to be adapted to the OSS mindset.

Costs: The category costs include direct and indirect costs regarding OSS. In the logistics industry, the use of OSS can significantly reduce direct costs, which is explained by interviewee 9 as follows: "*because the cost savings for a big logistics enterprise are quite different in absolute numbers than for smaller companies*." For example, the Linux operating system experiences wide acceptance as it comes without license fees. Furthermore, interviewee 7 highlighted the increased efficiency of reusing OSS code in the industry: *"Reuse, you don't have to rewrite or reinvent things that someone has already done […] there is a library, a component, you can use it without hesitation, that's great."* However, firms need to be aware that if skills or resources are lacking, IT service providers need to be paid to integrate the OSS. Similarly, firms sometimes underestimate the total cost of ownership. Thus, the effort for integration might surpass the benefits of using OSS.

To lower indirect costs, firms can decide to contribute to OSS projects instead of developing isolated solutions. Interviewee 15 described the benefit of shared resources with the example of creating a shared slot system for transportation:*" […] I invest […] five developers for a year, then they develop it for me. But I can probably do it with one developer in an OS context like this, if five other companies put one in, it's only a fifth of the effort for each in a year".* Thus, firms could save costs and share risks by efficiently sharing their developer resources. However, it is difficult to free up developer capacity to provide some developers dedicated fully to an OSS community *"not because we don't want to, but rather because we are a logistics service provider and not a software company."* as argued by interviewee 15.

Furthermore, firms can benefit from the community as an extended resource base to get support for their software development and use OSS in combination with individual code to serve individual use cases quickly. Especially in the field of commodity services, the interviewees saw great potential to share risks and costs to develop needed software or infrastructure that adds little financial value or competitive advantages in the industry. However, interviewee 10 described the increased indirect costs caused by the need for community management that his enterprise underestimated. The aspect was also mentioned by interviewee 8: "*Communication is important first. That's why almost half of our team consists of marketing and communication, i.e., active community management, offering a platform for exchange.* Overall, the interviewees agreed that OSS could reduce costs by collaboratively developing commodity software for entire industries, such as logistics and the automotive industry.

Internal Community: The internal community comprises all aspects related to the firm's employees who are involved in OSS communities, as shown in Table 5. For example, employees need to have an appropriate level of absorptive capacity to recognize the value of external information and to benefit from know-how transfer (Haider and Koronios 2009). Interviewee 13 mentioned the barrier of missing IT competencies in industrial firms to actively participate: *"even if the source code is freely available, nevertheless, many enterprises cannot do anything with it per se, they need someone to help them."* However, the interviewees also highlighted the potential of an extended knowledge base and know-how transfer in an industrial context. For example, engineers might access design blueprints for physical objects in the context of OS hardware. Furthermore, industrial firms can use OSS communities to search for new employees and to increase their attractiveness to IT personnel. Interviewee 7 described this as a chance for SMEs: *"A developer might not initially think of going to a medium-sized mechanical engineering company. […] he sees those interesting projects, OSS projects, are also being driven there, and that he might even have more creative freedom than if he went to one of those big companies."* Furthermore, firms that participate in OSS communities need to be aware of their behavior to avoid goal conflicts and a negative reputation. In summary, the internal community needs to invest in community building and respect the code of conduct to enable the potential of industrial firms, such as recruiting new IT personnel or extending the internal knowledge base.

Business: The business represents the firm's internal perspective of economic influencing factors regarding OSS (see Table 5). Interviewee 10 mentioned a missing OSS strategy as a risk of giving away intellectual property that could serve competitors and decrease revenue. While the competitor might use the OSS to improve its code for proprietary purposes, the true intangible asset often lies in the OSS community. Thus, the competitive advantage remains in the form of the OSS ecosystem (AlMarzouq et al. 2005). Also, in traditional industries, the firm's core competencies are mostly based on physical assets. Firms have, for example, high competencies and know-how in the industrial production of physical goods. Therefore, the barrier of losing intellectual property due to open sourcing is comparatively low as "*there*

will always be hardware and software," which can be compared to the analogy of printers: the seller releases its driver software under an OSS license to increase the sale of hardware.

Furthermore, OSS provides chances to create new digital business models (Duparc et al. 2022). For example, firms can choose to release OSS that is not relevant to their business but has the potential to develop shared infrastructure and set standards. In addition, business models could revolve around the OSS, such as professional services or software (Hecker 1999). However, the interviewees emphasized the need for a business model strategy, stating that simply deciding to open-source is not sufficient; a clear strategy is required, along with the ability to justify it when challenged. Also, firms need to be aware of the low willingness to pay for the OSS and that additional work may be required for maintenance. However, the potential to gain competitive advantages by setting de facto standards is high. Every physical product will somehow be part of digital infrastructures, such as digital twins in a smart factory. Interviewee 8 underlined the need for open sourcing to prevent external competitors from entering the pre-digital market. "*If we don't OS and standardize all this factory floor automation, Google or someone else will do it, right?"* Also, firms could benefit from the first-mover advantage and build a community as an asset. Another potential, from the user's perspective, is the vendor independence and flexibility that a firm experiences in choosing OSS. The interviewees emphasized the freedom of adopting different software functionalities for their industrial environment without being dependent on proprietary vendors. To summarize, OSS holds great potential for industrial firms to create new business models around their physical core competencies.

Marketing: This dimension comprises aspects of the software's dissemination, signaling, and corporate marketing (see Table 5). Due to the digital transformation in traditional industries, firms struggle to satisfy their need for skilled IT workers, as "*the industry is totally unsexy*" (interviewee 4). To increase their attractiveness to developers, traditional firms can use the previously mentioned signaling method to communicate their participation in OSS projects and to achieve greater outreach (Li et al. 2024). However, one interviewee mentions that firms must properly publish high-quality software code and adhere to the code of conduct to prevent reputational damage. Consequently, firms that actively engage in OSS communities invest in marketing and communication to support community management and enhance their reputation within OSS communities. This also has the advantage "*that it is always an indication of a bit of professionalization of OSS in this company*," as described by interviewee 9. Furthermore, firms that actively provide OSS can argue for vendor independence, customizability, and security, which may influence the decision to buy the underlying physical product. Other interviewees emphasized the potential of high scalability through dissemination demonstrated by the digital industry. "*They've gone completely OS. Google, Amazon, Facebook, Twitter, [...] it's all based entirely on OSS. And they have demonstrated to the world how you can build highly scalable, highly secure, highly innovative systems with OSS*" (interviewee 11). One interviewee mentioned the example of RAMI, a reference architecture model for digitalization in the industry that would benefit from OSS reference implementations to drive standardization. Finally, OSS can "*act as a vehicle to ensure a certain dissemination, quite a common means, to build a bridge for some technologies.*" (interviewee 7).

Table 5. Organizational Influencing Factors

Factors	Aspects	Literature
External Community	Meritocracy, increased customer relationship, community support, network effects, open innovation, collaboration, networking, trust, community ecosystem, distrust, free riding, no support, community building, community management	(AlMarzouq et al. 2005; Hoepman and Jacobs 2007; Li et al. 2025; Nelson et al. 2006; Peng et al. 2011; Petrov and Obwegeser 2018)
Culture	OSS mindset, OS program offices, motivation, corporate culture, preconceptions	(Aksulu and Wade 2010; AlMarzouq et al. 2005; Del Nagy et al. 2010; Sharma et al. 2022)
Costs	Efficiency, extended resources, reduced effort, reduced costs, resource constraints, increased effort, increased costs	(AlMarzouq et al. 2005; Fitzgerald 2006; Harutyunyan et al. 2020; Li et al. 2025; Sen et al. 2015; Shaikh and Cornford 2012; Sharma et al. 2022; Silic and Back 2015; Stewart and Gosain 2006)

Internal Community	Extended knowledge base, know-how transfer, talent recruiting, goal conflict, skill and staff shortage, learning effort	(Berquist et al. 2005; Del Nagy et al. 2010; Haider and Koronios 2009; Mehra and Mookerjee 2012; Teigland et al. 2014; Watson et al. 2008)
Business	New business models, competitive advantage, vendor independence, community as an asset, missing OSS strategy, missing KPIs	(AlMarzouq et al. 2005; Harutyunyan et al. 2020; Sen et al. 2015; Shaikh and Cornford 2012)
Marketing	Signaling, dissemination, increased attractiveness, image damage	(Fitzgerald 2006; Harutyunyan et al. 2020; Nelson et al. 2006; Sen et al. 2015)

4.4 Technological Influencing Factors

Technology: This factor includes architectural aspects that are associated with OSS (see Table 6). OSS is characterized by its modular architecture so that developers can work on the software independently from each other to a certain extent, which positively influences the development process (Peng et al. 2011). The interviewees highlighted the potential of OSS to set *de-facto* standards and to promote interoperability in traditional industries. Interviewee 1 described his observations as follows: "*in general, I notice that it is becoming more and more common to say that we want to join forces, we write down the de-facto standard, and we don't write it in text, but the code is the standard*." This has the advantage that long-lasting standardization processes can be bypassed to set industry-accepted standards. However, one interviewee highlighted that simply developing OSS is not sufficient as *"OSS does not guarantee that I will get really interoperable and functional solutions."* Instead, firms must ensure that open standards, open interfaces, and standard models are used in their OSS projects to create modular products that "*can be put together like Lego bricks*". Opinions on the security aspect were ambivalent: Some interviewees described OSS as having the potential to discover and fix vulnerabilities and bugs faster, as many actors can check the code. On the other hand, interviewee 11 explained the following example of a false sense of security: "*So we've had quite massive security gaps with Open SSL […] with Heartbleed et cetera, that no one would have thought would be in there, because everyone always thought, oh, its OSS, lots of people are looking at it, and there won't be any big bugs or obvious bugs in there."* Therefore, some interviewees argued not to open security-critical software; however, the counterargument arose that potential security gaps or bugs would longer remain undetected. The new potential of durability was introduced by interviewee 9, who described the following case: "*If you take a look at airplanes or in the automotive industry, where some manufacturers demand for decades that software must be updatable, that certain maintainability must be guaranteed, etc., where some companies don't even know if they will still exist in ten or twenty years, then they only have one chance to guarantee that and to say that we will make it OSS*". Lastly, OSS is seen as having great potential to enforce standards and commonly develop commodity software in traditional industries, which are often highly fragmented because of historical growth.

Development Process: The development process describes all potential and barrier factors related to the OSS development process, as displayed in Table 6. The potentials, such as peer review or shorter development cycles (Fitzgerald 2006), and barriers, such as the dependence on voluntary work and forking (Nelson et al. 2006; Stewart and Gosain 2006), mentioned in the interviews were primarily congruent to the ones in the literature. For example, the interviewees highlighted the potential for peer review and higher software quality. However, firms need to be aware of the underlying community and the project's owner background, as the potential does not generally apply to every OSS. One interviewee reported on internal barriers, such as process guidelines, that hinder active participation in OSS communities. Finally, one interviewee explained that firms that want to initiate an OSS project need to consider the problem of forking, as mentioned in the literature as well. In traditional firms, forking could hinder the development of a prosperous community.

Usability: The last factor describes aspects regarding the user experience in connection with OSS (see Table 6). In the context of traditional industries, OSS is perceived as having the potential to enable firms

to enter the digital economy. Interviewee 9 highlighted the potential as follows: "*there are many companies that, let's say, are not as economically flexible as large companies, and they also need a way to participate in the digital world, and that's why I like these OSS approaches very much."* Especially for SMEs, OSS was described as "*door opener*" and the possibility to try out new technologies without needing to invest much. The high adaptability and flexibility of OSS are further positive influencing factors, as industrial firms often need customized solutions for their individual use cases. The barriers mentioned in connection with usability were mainly related to cultural aspects, such as suspicion towards OSS solutions.

Table 6. Technological Influencing Factors

Factors	Aspects	Literature
Technology	Standardization, security, quality, durability, wide range of usage, software architecture, software complexity, lower security	(Germonprez et al. 2021; Li et al. 2024, Petrov and Obwegeser 2018; Silic and Back 2015; West 2003)
Development Process	Peer review, shorter development cycles, lack of professionalism, forking, unfitting corporate processes	(AlMarzouq et al. 2005; Boudreau 2010; Del Nagy et al. 2010; Feller and Fitzgerald 2000)
Usability	Flexibility, customization, lower entry barriers, higher barriers for non-technical users	(Chengalur-Smith et al. 2010; Haider and Koronios 2009; Sharma et al. 2022; Steffen and Möller 2022)

5 SWOT Analysis of Strategic Open Source in Traditional Industries

5.1 SWOT Analysis Procedure

After gathering the influencing factors, the goal was to develop a SWOT analysis to identify strengths, weaknesses, opportunities, and threats related to open source in traditional industries. However, for a more detailed analysis, influencing aspects were used instead of broad factors. Additionally, the TOE framework was applied to structure these influencing factors within the four dimensions of the SWOT analysis.

To conceptualize the SWOT analysis, we invited participants with both scientific and practical expertise in open source, all working in an eponymous competence field in their organization. The participants were not interviewed during the interview study to prevent biases. Instead of conducting interviews, we decided to use workshops to enable the development of the SWOT analysis through discussions between experts. Therefore, the SWOT analysis was developed through two workshop iterations. In the first workshop, participants evaluated and refined the influencing factors. Before the second workshop, the author team drafted a SWOT analysis to provide a comparative reference. Finally, in the second workshop, the participants collaboratively developed the final SWOT analysis.

5.2 Workshop Execution

Workshop kick-off: The kick-off workshop's aim was to create a common understanding of the influencing factors and the perspective for conducting the SWOT analysis. The participants actively engaged in discussing the identified factors and complemented missing aspects. While most influencing factors were already derived from the literature review and during the interviews, the workshop participants added some new aspects to the SWOT analysis. The focus was to evaluate the existing factors before starting the SWOT analysis. Also, the participants discussed the potential perspective from which to conduct the analysis. In the end, the participants agreed on conducting the SWOT analysis from a firm's perspective that wants to actively provide an OSS project, whether by publishing software previously used internally as open source or by developing new software directly as open source. The perspective was selected as it encompasses aspects relevant to other categories, such as users and contributors. Additionally, the workshop participants' experience in consulting and collaborating with various industrial firms gives them a broad knowledge base, making the chosen perspective highly applicable in the workshop setting.

Table 7. Overview Workshops

No.	Domain	Organization	Topic	Participants	Duration
1	Software Development for Industrial Applications, strategic consulting	Research Organization	Influencing Factors	4	60 min
2	Software Development for Industrial Applications, strategic consulting	Research Organization	SWOT Analysis	4	120 min

Workshop conceptualization: At the beginning of the second workshop, the aspects of the first workshop were briefly summarized. Then, the participants started to conduct the SWOT analysis, sorting the influencing factors into strengths, weaknesses, opportunities, and threats. In case of disagreements, the participants used scientific and practical sources, such as scientific papers, whitepapers, or reports, for the argumentation instead of *"deciding from the gut."* One of the authors moderated the workshop without actively intervening in the sorting process.

Workshop evaluation: After conducting the workshops, the author team compared the results from the workshop and the internally defined solution. The following factors needed further discussion in the author team due to inconsistency with the workshop results:

Durability (strengths vs. opportunity): The participants perceived the durability of OSS as a firm's internal strength, while the author team saw it as an external opportunity. As external communities or individuals ensure the continuation of abandoned software rather than a firm's internal strengths to provide durable software, we opted to classify durability as an opportunity.

Network effects (strengths vs. opportunity): The participants perceived network effects as a firm's internal strengths. However, network effects are caused by the external community and not by internal capability. Therefore, we decided to categorize network effects as opportunities.

Meritocracy (strengths vs. opportunity): OSS projects often have meritocratic structures to govern their projects. Thus, participants can gain a reputation and influence through active participation and good skills. The participants classified the aspect of meritocracy as an internal strength. However, the authors decided to leave this influencing factor in the opportunity category as it is rather an opportunity as an internal skill that a firm possesses.

Project burnout (weakness vs. risk): The participants see project burnout as a firm's weakness. The authors agree that poor OSS skills and project management can lead to project burnout. However, project burnout is rather a risk than a weakness as firms cannot influence external actors' adaptation and continuation of the project.

Competitive advantage (opportunity vs. strengths): OSS holds the potential to gain a competitive advantage over other firms, for example, by easier adopting technological advancements, as explained by the workshop participants. Initially, the author team classified the competitive advantage factor into strengths. However, after the participant's discussion, the author decided to place the competitive advantage factor into the opportunity category.

Lack of professionalism (risk vs. weakness): The participants described the lack of professionalism as a risk that might occur in OSS projects. The authors agreed with the participants that a lack of professionalism might be a risk for firms. However, the factor is a risk if a firm wants to participate in external OSS projects. If a firm wants to initiate an OSS project, the lack of professionalism is attributable to the firm's internal capabilities and is, therefore, a weakness.

Missing OSS strategy (risk vs. weakness): The workshop participants saw a missing OSS strategy as a risk for a project's failure. While the authors agree that an OSS strategy is a risk for starting OSS projects, they did not agree on placing the OS strategy into the risk category. Rather, the OS strategy is seen as an internal capability that the firm can influence.

Missing know-how (risk vs. weakness): As the participants described, missing know-how can be a major risk during the initiation of an OSS project. However, similar to the missing OSS strategy, the missing know-how is an internal capability determined by a firm, so the factor was placed into the weakness category.

In total, most of the categorized influencing factors from the workshop participants were in line with the predefined results from the author team. The additional aspects, such as "deep industry knowledge" or "no

active participation," did not change the influencing factors (see Table 3). Therefore, no further evaluation round was conducted.

5.3 Outcome of the SWOT Analysis

The transformation of traditional industries poses several opportunities and risks to traditional firms. In particular, firms need to adapt their internal capabilities and resources to enable external OSS opportunities and overcome internal weaknesses as well as external risks. Building on findings from the literature, the SWOT analysis focuses on the strategic analysis of OSS in an industrial context:

Strengths: Starting from the environmental perspective, many traditional firms already have a positive perception of OSS in the market. Especially, the increased professionalization of OSS drives the adoption of OSS in traditional industries. On an organizational level, traditional firms are often "hidden champions" in the market and have been established for many years. Consequently, they have a deep industry knowledge, a large network, and established structures. It is, therefore, easier for established firms to collaborate and network in order to build successful OS communities than it is for new entrants from the software industry, who are often met with skepticism. Furthermore, traditional firms rely on physical assets as their core competence. Trying out new business models or strategies based on OSS is, therefore, less risky, as these have little impact on the core business. Similarly to the potentials from the literature, firms can benefit from increased attractiveness and signaling effects. This is especially important in the context of increased staff shortage, as traditional industries are not typical employers of IT personnel. On a technological level, firms have the advantage of being able to draw on a large number of existing projects focusing on digital transformation and OSS in an industrial context.

Weaknesses: On an environmental level, European laws and regulations often do not contemplate or are not compatible with OS licenses. For example, some common OS licenses do not comply with European law requirements as most are based on US legal standards. Thus, European firms often face legal issues, such as compliance or licensing difficulties. In general, many industrial firms lack needed skills, such as community building or management, so relatively few participate actively in OSS projects, slowing down the OSS adoption in traditional industries. This weakness is rooted both in the effort these activities require and in the misalignment between the informal, collaborative nature of OS communities and the more hierarchical, structured culture of traditional firms. Contrary to commonly assumed beliefs, this can be attributed more to cultural issues than technological shortcomings. Especially in traditional firms, preconceptions, and a rigid corporate culture lead to barriers to the adoption of OSS. In such cases, the absence of effective community management or cultural adaptability further reinforces these barriers. In this context, organizational weaknesses often lead to technological weaknesses. For example, the lack of OS skills leads to increased efforts, a lack of professionalism, or increased costs. Therefore, industrial firms often face higher entry barriers than software firms, which are more familiar with the OS principles. Lastly, corporate processes cause a high barrier to efficiently participating in OS communities, which are often characterized by informal and agile processes.

Opportunities: OSS holds manifold opportunities for traditional industries. Most identified opportunities are in line with the opportunities from the literature. On an environmental level, digital sovereignty and digital transformation are the most important opportunities that the interviewees saw within incorporating OS principles. Traditional firms especially risk becoming dependent on new entrants from the software industry or missing out on digital transformation. Therefore, OS program offices and public initiatives hold the opportunity to ease digital transformation and strengthen the local competitiveness of traditional firms based on OSS. Also, on an organizational level, firms can enable various opportunities, such as benefitting from network effects or open innovation. Both concepts are fundamental in the digital economy and are fueled by OSS. Thus, a firm's participation in communities and the quality of the provided source code could be an important indicator of a firm's innovation power. Also, firms that cannot actively provide OS projects or participate in OS communities can benefit from opportunities such as vendor independence. Regarding the technological opportunities, the aspects from the literature were in line with the interviewees' and workshop participants' statements. However, in traditional industries, the potential for standardization is one of the most important drivers for adopting and providing OSS. Rather than developing new business models or enabling network effects, actors from traditional industries focus on developing commodity services together. Thus, even in highly competitive industries like logistics, OSS serves as a bridge for collaboration among competitors to drive the digital transformation of entire industries.

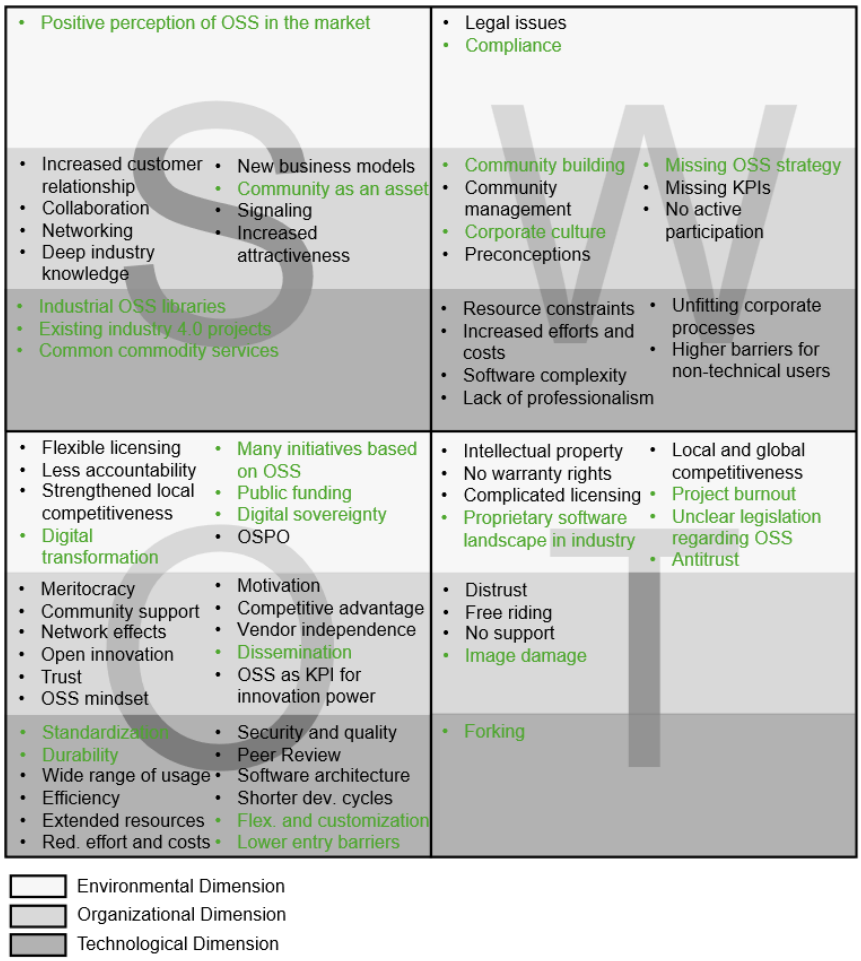

Figure 3. Outcome of the SWOT Analysis

Threats: Some threats, such as the fear of losing intellectual property or legal issues, pose major barriers to adopting OS practices, especially on an environmental level. In comparison to the other categories, we identified a few threats on an organizational (e.g., distrust, free riding, no support, or image damage) or technological level (e.g., forking). However, most negative influence factors were located in weaknesses.

Most barriers regarding the strategic adoption of OSS in traditional industries are attributable to internal weaknesses. However, traditional firms build on certain strengths that could ease the adoption process. Thus, firms could actively target those weaknesses by acquiring specific capabilities or resources. In addition, most influencing factors are located on environmental and organizational levels rather than on a purely technological level, which could be assumed based on past OS research.

In total, the observed opportunities outweigh the risks of OSS. Therefore, traditional firms should focus on how to adopt suitable OS strategies rather than whether they should do so. Even the sole usage of OSS provided by industry consortia or non-profit organizations can help ensure that industry standards based on OSS are established, thereby guaranteeing digital sovereignty and digital transformation in traditional industries.

6 Implications, Limitations, and Future Research

This paper provides a comprehensive approach, giving an overview of the influencing factors regarding OSS as a strategic tool in traditional industries, such as logistics or automotive. We identified 14 dimensions based on theoretical and empirical findings as key factors regarding OS in the context of traditional industries. To answer the research question, we synthesized the influencing factors based on a structured literature review. We first derived influencing factors (e.g., external community, technology, business, and licensing) and aspects through a systematic data coding process. Using the TOE

framework as the coding lens, we aimed to create a structured view of the theoretical findings. These findings were then complemented by empirical insights gained from an interview study embedding OSS in the context of traditional industries. Finally, the results from both inductive and deductive research were structured in an expert workshop, using the SWOT analysis as an overarching framework. This SWOT analysis of strategic OSS in traditional industries presents several scientific and practical contributions.

In terms of **scientific contributions**, we extend earlier OS research by identifying 14 influencing factors sorting barriers and potentials of OSS. By using the TOE framework as the overarching lens, we provide a conceptualization of OSS in an environmental, organizational, and technological context. While existing literature provides extensive insights into OSS factors (e.g., Dahlander & Magnusson, 2008; Peng, 2011) and holistic frameworks (e.g., Nelson et al., 2006; Aksulu & Wade, 2010), there remains a gap in research offering a comprehensive framework that both integrates these insights and provides a detailed view of OSS influencing factors in traditional industries. In contrast to previous research that mostly focuses on isolated aspects regarding the strategic use of OSS, this study presents a comprehensive and structured approach to capture and classify influencing factors relevant for industrial organizations that wish to incorporate OS practices on a strategic level. We also synthesize the findings of previous work, combining both overarching factors and detailed aspects, extending and validating the results through empirical insights. This integrated approach echoes the call for a holistic perspective, as highlighted by Leidner (2020), who emphasizes the importance of validating theoretical statements through empirical observations.

Moreover, our work contributes to the growing literature on the digital transformation of traditional industries, adding new aspects for further research regarding the topic. The main barriers to digital transformation in traditional industries are the slow cultural transformation, outdated business models, lack of collaboration, missing interoperability, the slow adoption of new technology, missing digital skills, and slow development cycles (Bilgeri et al. 2017; Bitzer et al. 2021). Particularly, the final SWOT analysis captures and classifies these aspects, enabling further research to bridge the gap between traditional industries and the software industry. For example, researchers could focus on how to raise specific potential or avoid barriers respectively to drive digital transformation and innovation. The workshop and interview study provide up-to-date insights that extend the existing body of knowledge. Furthermore, the practical insights put the spotlight on non-technical aspects of OS research, such as cultural and political factors that could facilitate or hinder digital transformation. In summary, the SWOT analysis integrates insights from both literature and practice into a comprehensive framework, providing a structured yet in-depth perspective on OSS adoption in traditional industries.

Regarding **practical contributions**, we illustrate the current influencing factors of OSS that can give guidance to practitioners to enable digital transformation in their respective industry sectors. The structured factors in the TOE framework can act as an evaluation sheet for firms to identify internal barriers and untapped potential to challenge existing strategies and structures. In addition, the TOE framework promotes awareness of OSS in an organizational context, which encompasses the purely technical perspective on OSS. We encourage practitioners to incorporate OS practices to, for example, facilitate digital transformation and new business models. At the same time, firms should consider and mitigate accompanying OS threats through early countermeasures. In this regard, our overview guides the early identification and awareness of potential OS-influencing factors. Furthermore, the SWOT analysis allows practitioners to concentrate on specific aspects, e.g., the prevention of free riding or coordination overhead. The interview study provides practical insights into which firms may recognize similar threats and opportunities that occur in their industry. Thus, firms can use practical insights as the starting point for developing action guides regarding the use of OSS in their respective industry or firms.

Naturally, **limitations** arise while conducting research. We report on the current state of research at the point of submission, acknowledging that the rapidly evolving nature of OSS adoption may lead to shifts in influencing factors over time. The selection of literature and interview partners provides only a snapshot of the OSS landscape, with a focus on Germany and the logistics industry. Thus, limiting our literature and interviews in English and German may limit the generalizability of findings, as trends and challenges in other countries or sectors could differ. Nevertheless, we aimed for theoretical saturation by incorporating a diverse body of work.

While the study centers on traditional industries, particularly logistics, the analysis remains broad rather than highly granular regarding industry-specific aspects. The overarching perspective enables a structured understanding of OSS adoption. Still, it may not fully capture sector-specific nuances, as the SWOT analysis was conceptualized by industry experts with strong IT competencies. Participants from SMEs or

industries with less OSS experience may identify additional or alternative influencing factors. Thus, future research could focus on the perspective of SMEs by analyzing specific use cases to gain a higher level of detail and industry-specific applicability.

The composition of workshop participants and interviewees strengthens the empirical foundation, as all had expertise in OSS and IT. However, this focus introduces a potential bias, as most participants had a positive perception of OSS adoption. Although we included questions about the challenges of OSS, the opinions of companies that are skeptical or hesitant to adopt OSS might not be fully represented. Also, we focused on traditional industries, which might affect the generalizability of the results to other industries, such as the finance, insurance, or medical sectors. Despite these limitations, our findings provide a valuable foundation for further research, particularly in exploring industry-specific OSS adoption strategies and digital transformation processes.

In terms of **future research**, the influencing factors need to be explored in more depth in the specific units. For example, the correlations of the factors amongst each other are research-worthy, as some opportunities could foster threats and the other way around. From the overall result, other artifacts are derivable. While we concentrate on descriptive work, prescriptive artifacts, e.g., design principles, business models, or reference architectures, can be developed that adhere to the influencing factors of OSS. For example, action guides for research, industry, and politics can be derived from the interview study to leverage the strategic use of OSS as a driver for digital transformation and innovation in traditional industries.

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