Technological innovations by logistics service providers: an empirical analysis of selected adoption activities

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Vorwort

Mit dieser Dissertation geht ein lang gehegter Wunsch in Erfüllung. Obgleich ich in einem ebenso unternehmerischen wie praxisnahen Umfeld aufgewachsen bin, habe ich im Studienverlauf grossen Gefallen am wissenschaftlichen Arbeiten gefunden. Jene anregende Kombination aus Praxisorientierung und wissenschaftlicher Fundierung ist auch charakteristisch für das Institut für Supply Chain Management (ISCM-HSG) der Universität St.Gallen, an welchem die vorliegende Arbeit im Rahmen meiner rund dreijährigen Forschungstätigkeit von März 2017 bis April 2020 entstanden ist. Das Interesse für technologische Innovationen bei Logistikdienstleistern hat sich aber nicht erst durch den wertvollen Austausch mit Branchenvertretern ergeben. Stattdessen war ich stets von der Aussicht getrieben, nach meiner Promotion ins heimische Logistikunternehmen eintreten und dort eine gestaltende Rolle wahrnehmen zu können.

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VS-Villingen, im Juni 2020 Mathias Mathauer

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List of abbreviations

ABV	Attention-based view
AT	Agency theory
B2B	Business to business
cp.	Compare
ICT	Information and communications technology
IDT	Innovation diffusion theory
MC	Managerial challenge
RFID	Radio-frequency identification
RO	Research objective
RQ	Research question
SCM	Supply chain management
TAM	Technology acceptance model
TS	Theoretical shortcoming
2PL	Second-party logistics provider
3PL	Third-party logistics provider
4PL	Fourth-party logistics provider

Summary

The emergence of technological innovations at ever-shorter intervals in combination with increasing customer demands and global competition have made technology adoption a top strategic priority for many firms in recent years. However, not all companies can cope with this development to the same extent. Some service firms are facing severe issues, as the incorporation of technologies into their service provision has not been at the core of their business activities in the past. Logistics service providers (LSPs) are currently under unprecedented pressure to introduce technological innovations but have a hard time in doing so. Peculiarities such as the asset intensity of logistics services or the regular use of subcontractors hamper LSPs' efforts to adopt technologies. While research on technology adoption is proliferating, specific technology adoption activities have been insufficiently addressed, thus the lack of an LSP perspective on the topic.

Consequently, the present research aims to explain why some LSPs struggle less than others do with technology adoption by examining three selected adoption activities: (1) searching, (2) accessing, and (3) diffusing. Innovation diffusion theory (IDT), absorptive capacity theory, agency theory (AT), and an attention-based view (ABV) are applied as theoretical lenses for the investigations. The research comprises three qualitative studies devoted to one technology adoption activity each. The first study on the external antecedents of LSP search behavior draws on a comparative case study design including seven cases. The second study on the effects of technology access mode choice on integration success is based on ten case studies. The third study on the information distribution in vertical interorganizational technology diffusions incorporates a multi-level case study design and includes four cases.

The results indicate that (1) firm size impacts the effect of external search drivers on LSP search behavior, (2) technology access mode choice prejudges integration success, and (3) service chain constellations imply certain information asymmetry types during technology diffusion. These specific findings not only help decision-makers at LSPs to better manage the studied adoption activities, but also allow conclusions about other technology adoption activities to be drawn. Thereby, this dissertation contributes to overcoming the general lack of empirical research on specific technology adoption activities and guides technology adoption by LSPs. Furthermore, it calls for transferring the notion of principal–agent hierarchies to interorganizational settings for the application of AT in logistics research.

Zusammenfassung

Die Schnelllebigkeit technologischer Innovationen, steigende Kundenanforderungen und verstärkter globaler Wettbewerb haben der Technology Adoption in vielen Unternehmen zuletzt höchste strategische Priorität verliehen – doch nicht alle kommen damit gleichermassen zurecht. Einige Dienstleister sind mit grossen Herausforderungen konfrontiert, da die Einbindung von Technologien in die Leistungserbringung lange nicht zum Kern ihrer Geschäftstätigkeit gehörte. Logistikdienstleister (LDLs) etwa haben Probleme mit dem derzeitigen Druck zur Technology Adoption. Besonderheiten wie die Asset-Intensität von Logistikleistungen oder der regelmässige Einsatz von Subunternehmern erschweren die Einführung von Technologien. Während die Forschung zu Technology Adoption im Allgemeinen stark zunimmt, wurden spezifische Aktivitäten der Adoption bisher nur unzureichend behandelt – gerade aus der Perspektive von LDLs.

Die vorliegende Dissertation strebt nach Erklärungen, warum einige LDLs weniger Schwierigkeiten als andere mit der Technology Adoption haben und untersucht drei dazugehörige Aktivitäten: (1) die Suche, (2) den Zugang und (3) die Diffusion. Als theoretisches Fundament der Untersuchungen dienen Diffusionstheorie, Absorptionstheorie, Prinzipal-Agent Theorie sowie die aufmerksamkeitsbezogene Sicht. Die Forschung umfasst drei qualitative Beiträge. Eine erste Studie zu externen Treibern des Suchverhaltens stützt sich auf ein vergleichendes Fallstudiendesign mit sieben Fällen. Eine zweite Studie zu den Auswirkungen des Technologiezugangs auf den Integrationserfolg basiert auf zehn Fallstudien. Eine dritte Studie über die Informationsverteilung bei vertikalen, interorganisationalen Technologiediffusionen verfolgt ein mehrstufiges Fallstudiendesign mit vier Fällen.

Die Ergebnisse weisen darauf hin, dass (1) die Unternehmensgrösse die Wirkung externer Treiber auf das Suchverhalten von LDLs beeinflusst, (2) die Wahl des Technologiezugangs den Integrationserfolg präjudiziert und (3) gewisse Konstellationen in Dienstleistungsketten zu Informationsasymmetrien führen. Diese Ergebnisse helfen Entscheidungsträgern nicht nur beim Management der untersuchten Aktivitäten, sondern lassen auch Rückschlüsse auf andere Aspekte der Technology Adoption zu. Damit trägt diese Dissertation dazu bei, den allgemeinen Mangel an empirischen Untersuchungen zu spezifischen Aktivitäten der Technology Adoption zu überwinden. Ferner wird die Übertragung von Prinzipal-Agent Hierarchien auf interorganisationale Konstellationen in der Logistikforschung vorgeschlagen.

1 Introduction to the research on the adoption of technological innovations by logistics service providers

The present research empirically examines the adoption of technological innovations by LSPs. In this first chapter, the relevance of the topic is narrowed down from technology adoption in general to selected technology adoption activities at LSPs. While Section 1.1 takes a managerial perspective, Section 1.2 presents the relevance of this topic from a theoretical perspective. Departing from the depicted managerial challenges and theoretical shortcomings, research objectives are derived in Section 1.3. Section 1.4 provides an outline of the structure of this dissertation.

1.1 Managerial relevance

Technological innovations imply changes in the way of doing business and can even yield entirely new business models. The trigger for innovation activities is either the occurrence of a promising technology ("technology push") or the need to close a performance gap ("need pull") (Yu, Minniti, & Nason, 2019; Zmud, 1984). Due to the rapidly increasing rate of technological progress (Funk & Owen-Smith, 2017), ever-shorter technology life cycles (Eckstein, Goellner, Blome, & Henke, 2015), and the ongoing interlinking of technological solutions (Zhu, Kraemer, & Xu, 2006), an unprecedented "technology push" dynamic is currently affecting all sectors. At the same time, rising global competition and customer requirements amplify the "need pull," which forces firms to access technological innovations to maintain or achieve a competitive advantage (Lengnick-Hall, 1992; Madsen & Leiblein, 2015).

Logistics service providers (LSPs) are a typical example of a company type that has long been characterized by low levels of technology use in its service provision (Goldsby & Zinn, 2016), but LSPs are now more than ever affected by a significant technology push (Hofmann & Osterwalder, 2017). The simultaneously observable need pull is closely linked to the industry's structure. Key characteristics of the logistics market are high levels of competitive pressure (C. König, Caldwell, & Ghadge, 2019) and—related to this—low profit margins (Nilsson, Sternberg, & Klaas-Wissing, 2017). The world's largest LSPs generated an average earnings before interest and taxes margin of approximately 4% in 2018 (Paulsen, 2019). Against this backdrop, the results of a branch survey by Pflaum and colleagues (2017) on the antecedents of technology adoption in the context of logistics are hardly surprising: the undisputed main driver (stated by two-thirds of the participants) is the pressure on margins, followed by increased customer expectations (stated by 56% of the participants). Besides, new competitors from outside the industry are continuously entering the market and are threatening existing business models based on new technologies (Hofmann & Osterwalder, 2017). Reflecting these developments, three-quarters of the participants in a recently conducted survey on the logistics market in Switzerland view a technologically pioneering role as important for the future ability of the market players (Mathauer & Hofmann, 2020). In sum, the adoption of technological innovations can be considered as one key for LSPs' competitiveness in the future.

However, service firms from sectors with previously little affinity to technology are typically experiencing the greatest challenges in the prescribed "technologization" of the business environment (Barrett, Davidson, Prabhu, & Vargo, 2015). In logistics-specific studies, the frequently mentioned inhibitors of technological innovations are a lack of knowhow and the limited availability of financial resources (e.g. Huth, Knauer, & Ruf, 2019; Stölzle, Hofmann, & Oettmeier, 2017). It is therefore not surprising that some LSPs are struggling with technology adoption. Scholars have shown that LSPs are significantly less innovative than other service firms are (Busse, 2010) and are among the least innovative service companies of all (Busse & Wallenburg, 2014; Wagner, 2008). At the same time, some LSPs have found ways to deal with the adoption of technological innovations and are recently gaining increased media attention (e.g. FedEx, 2020; SwissPost, 2020).[1] Nevertheless, these examples cannot hide the fact that there are aspects of technology adoption that pose particular challenges to the majority of LSPs. In the following, three particular technology adoption activities and the associated challenges are further elaborated.

For a long time, it may have been sufficient for LSPs merely to adopt technologies that were suggested to them by their customers or that had gradually become established as an industry standard (Flint, Larsson, Gammelgaard, & Mentzer, 2005). However, the number of available technologies has increased tremendously in times of digitalization

[1] The presented sources were only selected on the basis of their media presence and are not intended to suggest that the innovation projects that were launched were also successful from an economic perspective.

and industry 4.0, requiring LSPs to select appropriate technologies out of a hugely unmanageable number of them (Mathauer & Hofmann, 2019b; Scheiner, Baccarella, Bessant, & Voigt, 2015). Studies instead show that the customer still dominates the technology searches by LSPs (Wagner & Sutter, 2012). In consequence, technological adoptions are regularly not the result of planned behavior, but are an ad hoc response to customer needs (Busse, 2010; Cui, Su, & Hertz, 2012). While the goal should still be to adopt technologies that create customer value, relying on the customer alone is no longer sufficient to cope with the number of available technologies; especially not if those technologies aim at improving internal processes (Bellingkrodt & Wallenburg, 2015; da Mota Pedrosa, Blazevic, & Jasmand, 2015). But many LSPs have failed to build up their knowhow for a structured examination of technologies (Cichosz, Goldsby, Knemeyer, & Taylor, 2017). Instead, they search opportunistically and are subject to the selective attention of their decision-makers (Monteiro, 2015). Major market players are now trying to make up for lost ground. DHL, for example, established the world's first LSP trend research team in 2015 (DHL, 2015). Adding to that, there is a proliferation of trend radars issued by LSPs that should help to make searches more effective (Chung, Gesing, Chaturvedi, & Bodenbenner, 2019; Klare, 2018). Such approaches might be appropriate for large companies with high R&D budgets (J. Choi & Lee, 2018; Rohrbeck, Heuer, & Arnold, 2006), but not for small- and medium-sized firms that represent the majority of all LSPs (Evangelista, McKinnon, & Sweeney, 2013). Therefore, the effective allocation of resources during searches for adoptable technologies is a critical issue for logistics professionals and calls for a better understanding of the underlying attentional processes when accounting for firm size.

Moreover, the character of technological innovations has changed, confronting LSPs' decision-makers with further adoption challenges. Technological innovations in logistics have long been limited to hardware (e.g. new charge carriers or transport vehicles) and stand-alone software solutions (e.g. enterprise resource planning and advanced planning systems) from a few dominant suppliers (Mathauer, Stölzle, & Hofmann, 2018). Therefore, the way to make these standardized solutions accessible was quasi-predetermined. In the meantime, hard- and software solutions are melting into more complex hybrid innovations (Daugherty, Chen, & Ferrin, 2011; Schmidt et al., 2015). LSPs have to choose between combined standardized components and comprehensive customized solutions, which are both provided by many different suppliers (da Mota Pedrosa et al., 2015). Some LSPs have even started to develop technologies on their own (Cichosz et al., 2017). Managers must select a suitable technology access mode that matches the individual case's integration requirements, for example, low costs (Devaraj, Krajewski, & Wei, 2007), or a high implementation speed (Busse & Wallenburg, 2011). This can be very challenging, considering the limited knowhow and financial resources stated above. Adding to that, manufacturing firms from high-tech sectors naturally have a greater proximity to startups and innovative suppliers than LSPs do (Rohrbeck & Gemünden, 2011). LSPs such as DB Schenker and Dachser thus initiated close cooperation with research institutes and launched platforms to come into contact with startups (Dachser, 2017; Schenker, 2016). However, even if LSPs can create different ways to access technological innovations, the question arises as to which particular one should be chosen.

Furthermore, the structure of LSPs' service chains poses further issues in terms of technology adoption. Due to the required physical proximity of LSPs to their customers, employees are typically geographically dispersed across different sites or decentrally drive in their vehicles (Andersson & Norrman, 2002). As a result, both information diffusion and coordination are particularly difficult (Grawe & Ralston, 2019). The loss of control becomes even more acute if subcontractors are used as well (Brahm & Tarziján, 2016). More than half of the sales revenues of the general cargo and courier, express and parcel (CEP) networks in Germany are accounted for by subcontractors, with this tendency increasing (Klaus & Otto, 2017). Many of the abovementioned hybrid innovations such as handheld devices or smart charge carriers thus have to be vertically diffused across different organizations down the service chain. For this reason, the branch survey by Pflaum and colleagues (2017) found interorganizational process alignment as the second-largest challenge of technology adoption in logistics, just behind the related problem of missing standards. To increase the rate of successful technology adoptions, decision-makers need an in-depth understanding of the challenges in interorganizational technology adoption contexts as well as appropriate governance mechanisms to overcome these challenges.

The overview of the managerial challenges related to technology adoption by LSPs shows that some are predominantly struggling with searching for, accessing, and diffusing technological innovations, as explained hereafter:

- *Managerial challenge 1 (MC1)—Searching for technological innovations*: Due to the ever-increasing number of available technological innovations, LSPs need a better understanding of the attentional processes underlying their search behavior to allocate resources more effectively.
- *Managerial challenge 2 (MC2)—Accessing technological innovations*: The development toward more customized technological innovations that combine software and hardware elements complicates accessing technological innovations. LSPs lack guidance for choosing an appropriate technology access mode that meets the requirements for implementation.
- *Managerial challenge 3 (MC3)—Diffusing technological innovations:* LSPs increasingly use subcontractors, but struggle with technology adoptions that comprise several vertical levels of the service chain. Governance mechanisms are required that will help to ensure the intended technology use beyond company boundaries.

Thus, the present study's *unit of analysis* includes these *selected technology adoption activities* of LSPs.[2]

1.2 Theoretical relevance

To examine technology adoption by LSPs, this dissertation builds on different research streams and can be considered as cross-sectional. While it is predominantly anchored in innovation management, general and logistics-related insights from operations management, service management, and strategic management are also touched upon (cp. Section 2.3).

Although research on the adoption and diffusion of technological innovations has been conducted for decades (Bass, 1969; Cooper & Zmud, 1990; Norton & Bass, 1987; Rogers, 1962), academic interest has not waned to date. On the contrary, both general (Forman & van Zeebroeck, 2019; Souder, Zaheer, Sapienza, & Ranucci, 2017) and LSP-specific studies show an upward tendency (Chu, Feng, & Lai, 2018; Y. Lai, Sun, & Ren, 2018). It has been shown that LSPs' innovation activities differ considerably from man-

[2] The unit of analysis is comprehensively derived in Sections 2.1 and 5.1.

ufacturing or other service firms due to the innovation-related peculiarities of this company type (Busse & Wallenburg, 2011; Wagner, 2008).[3] For instance, very pronounced financial restrictions lead to fear around radical innovations (Busse & Wallenburg, 2014). Besides, structured innovation efforts are less frequently encountered than opportunistic adoption behaviors (Busse, 2010; Cui et al., 2012). To overcome their struggles with technology adoption described in Section 1.1, more industry-specific research on technology adoption by LSPs is required. To date, the efforts to study technology adoption from the perspective of LSPs have remained in their infancy (Busse & Wallenburg, 2011; Chu et al., 2018; Grawe, 2009).

Initial efforts have approached the phenomenon from different angles, and have examined, for example, the antecedents, moderators, and consequences of LSP technology adoption. Drawing on insights from innovation management (Tornatzky, Fleischer, & Chakrabarti, 1990), Lin (2008) assigned relevant antecedents of LSP technology adoption to the categories of technology, organization, and environment. Subsequent research efforts strengthened the influence of environmental factors—both as antecedents and as moderators (Bellingkrodt & Wallenburg, 2013; Y. Lai et al., 2018). Above all, the customer was found to play a decisive role in triggering LSPs' adoption activities (Wagner, 2013). Researchers have further tried to grasp the consequences of technology adoption. Panayides and So (2005) have shown that innovation adoption is associated with increased supply chain effectiveness, which in turn positively impacts supply chain performance. Others found evidence for improved customer loyalty (Wallenburg, 2009), financial performance (Bellingkrodt & Wallenburg, 2013; Flint, Larsson, & Gammelgaard, 2008), and for achieving a competitive advantage (Grawe, 2009). The common thread to most existing research efforts, however, is that technology adoption has remained a black box, as researchers tend to frame adoption as a dichotomous choice (Yang, Kankanhalli, Ng, & Lim, 2015). Only gradually have scholars from innovation management started to realize that adoption at the firm level includes a wide variety of activities such as searching for technological innovations during initiation or diffusing technological innovations during implementation (Geroski, 2000; Hazen, Overstreet, & Cegielski, 2012; Makkonen, Johnston, & Javalgi, 2016). To date, there has been a lack

[3] For a detailed overview on the innovation-related peculiarities of LSPs, please consult Section 2.1.

of empirical research on selected technology adoption activities and the underlying mechanisms (Makkonen & Johnston, 2014).

Furthermore, innovation management scholars have stressed that technology adoption might depend on technology characteristics, thereby also triggering increased attention being placed on the adoption object in operations management research (Lanzolla & Suarez, 2012; Rogers, 2003). On the one hand, the adoption of single technologies has been investigated such as radio-frequency identification (RFID) (C.-Y. Lin & Ho, 2009) or big data analytics (Y. Lai et al., 2018). On the other hand, technological categories have been researched, with a clear focus on information and communications technology (ICT) (Evangelista et al., 2013; K.-H. Lai, Ngai, & Cheng, 2005; Luisa dos Santos Vieira, Sérgio Coelho, & Mendes Luna, 2013; Marchet, Perego, & Perotti, 2009; Perego, Perotti, & Mangiaracina, 2011). Due to the proliferation of ICT solutions in logistics over the last decades, studies on the adoption of standardized software solutions are overrepresented (Mathauer et al., 2018). Notwithstanding, the neglect of technologies including customized and hardware elements is to be questioned for at least two reasons. First, asset intensity, and therefore the presence of hardware, is a key distinguishing characteristic of LSPs, and is inherent to the provision of logistics services related to physical goods (Hofmann & Lampe, 2013; Konstantinos Selviaridis & Spring, 2007). Second, a new category of technologies is currently gaining ground that combines digital and physical elements through the integration of data from sensor-equipped hardware (e.g. tracking devices in temperature-controlled logistics). The increased complexity of interrelated physical and digital systems can be expected to evoke new challenges for technology adoption and hampers the applicability of existing knowhow. For this reason, researchers have called for more research on the adoption of such hybrid innovations (Barrett et al., 2015; Barrett, Oborn, Orlikowski, & Yates, 2012).

Additionally, most firm-level technology adoption studies of the logistics industry tend to take a single firm view (Sternberg & Norrman, 2017). Following the current development toward the vertical division of labor in service industries (MacKenzie, 2008; Walsh & Deery, 2006), LSPs are typically embedded in multi-level logistics service chains that can result in veritable subcontracting cascades (Cui & Hertz, 2011; Rajahonka, 2013).[4] In consequence, the actors making a technology adoption decision

[4] The discussion of technology diffusion in multi-level logistics service chains represents an extended extract from Appendix C, which should be consulted for a more detailed examination.

(e.g. third-party logistics providers or 3PLs) frequently differ from the actual users (e.g. carriers) (Cui & Hertz, 2011; Lanzolla & Suarez, 2012). Technology adoption no longer stops at organizational boundaries, but requires interorganizational adoption efforts (Lyytinen & Damsgaard, 2011; Tanskanen, Holmström, & Öhman, 2015). As is known from the adoption literature on supply chain management (SCM), there are various challenges associated with interorganizational technology adoption, for example, information diffusion (Patterson et al., 2004). The studies that have dealt with technology adoption in interorganizational settings have instead focused on horizontal (Rogers, 2003; Zhu et al., 2006) rather than on vertical diffusion (Autry, Grawe, Daugherty, & Richey, 2010; Iacovou, Benbasat, & Dexter, 1995). This is problematic for LSPs, as vertical service chains that require multi-level technology adoptions are currently proliferating (Cui & Hertz, 2011). A better understanding of the associated problems and necessary solution mechanisms is urgently needed to push the knowledge frontier on technology adoption by LSPs further.

The analysis of the literature on technology adoption by LSPs shows that the managerial challenges presented in Section 1.1 have remained largely unaddressed. Furthermore, it is still unclear why some LSPs can cope better than others with the discussed technology adoption activities. Thus, there is a need to address the following theoretical shortcomings:

- *Theoretical shortcoming 1 (TS1)—Undifferentiated treatment of technology adoption*: Little is known about the specific activities associated with technology adoption by LSPs. Existing findings on the antecedents, moderators, and consequences only make a limited explanatory contribution to the identified managerial challenges, as it remains unclear whether these findings are also applicable to single adoption activities.
- *Theoretical shortcoming 2 (TS2)—Dominance of software technology adoptions:* Previous studies have mainly focused on the adoption of standard software technologies and have not sufficiently covered hardware technologies and customized solutions. Hybrid technologies are gaining ground but are not yet considered in adoption studies.

- *Theoretical shortcoming 3 (TS3)—Technology adoption in service networks:* Empirical analyses that systematically investigate technology adoption beyond the firm level are scarce. Considering the complexity of multi-level logistics service chains, more nuanced research is required that distinguishes between different levels in these service chains.

1.3 Research objectives

Given the relevance of this research (Section 1.1 and Section 1.2), the overarching research objective (RO_0) is derived as follows:

> RO_0: An examination of why some logistics service providers struggle less than others do with selected technology adoption activities under certain circumstances.

RO_0 is approached by pursuing three partial research objectives (RO_1–RO_3) that are largely independent. This allows for the specific shortcomings of existing research on technology adoption to be addressed and to make a contribution to the multifaced phenomenon of adoption in terms of breadth rather than depth.

Some LSPs have difficulties with effective resource allocation during technology searches (Busse & Wallenburg, 2011). Individual technologies are filtered out opportunistically rather than systematically (Cui et al., 2012), whereby the actual impulse for this lies in the unconscious. Existing research provides general antecedents of technology adoption by LSPs (C.-Y. Lin, 2008), but has not yet investigated the single adoption activity of searching for technological innovations. Insights from practice show that some large LSPs have developed more systematic search approaches (e.g. technology radars) and have built up resources in this field (Chung et al., 2019). However, the drivers behind attention allocation remain unaddressed, although they would be of interest for LSPs of all sizes to increase search effectiveness. Thus, the first partial research objective is derived as follows:

> RO_1: An examination of the attentional antecedents of searching for technological innovations by LSPs when accounting for firm size.

In the light of an ever-wider range of technological innovations (e.g. hybrid technologies with software and hardware elements), the possibilities of accessing them has become more extensive as well. Decision-makers have to select an appropriate access mode depending on both the technological innovation and the specific situation the company currently finds itself in (Daugherty et al., 2011; Schmidt et al., 2015). Existing research has not yet sufficiently addressed what the relationship between technology access and integration looks like. Furthermore, there might be other factors (e.g. the relationship with other companies in the supply chain) that could influence this relationship (Asare, Brashear-Alejandro, & Kang, 2016; Gnekpe & Coeurderoy, 2017). As it is of great importance to better understand the link between technology access and integration from both a managerial and theoretical point of view, the second partial research objective is stated in the following way:

> *RO_2:* An examination of the potential relationship between technology access modes and integration success when accounting for the moderating effects for LSPs.

Given that LSPs are embedded in multi-level service chains through various subcontracting relationships, a single firm perspective is insufficient to understand and manage the adoption of technologies that are vertically passed on down the service chain (Cui & Hertz, 2011). The initiating LSP might have difficulties with observing the intended use, while the LSPs using the technologies might have difficulties in understanding the initial intentions. Research has not yet treated comparable settings in interorganizational constellations, although the vertical division of labor can be expected to increase its expansion (MacKenzie, 2008). Governance mechanisms that are known from one-to-one relationships might push against their limits (Saam, 2007), but appropriate ones for interorganizational settings have not yet been identified. Against this backdrop, the following third partial research objective is derived:

> *RO_3:* An examination of the service chain constellations in interorganizational LSP technology adoptions to identify effective governance mechanism designs.

Figure 1 provides a comprehensive overview of the managerial relevance, the theoretical relevance, and the derived research objectives of the present dissertation.

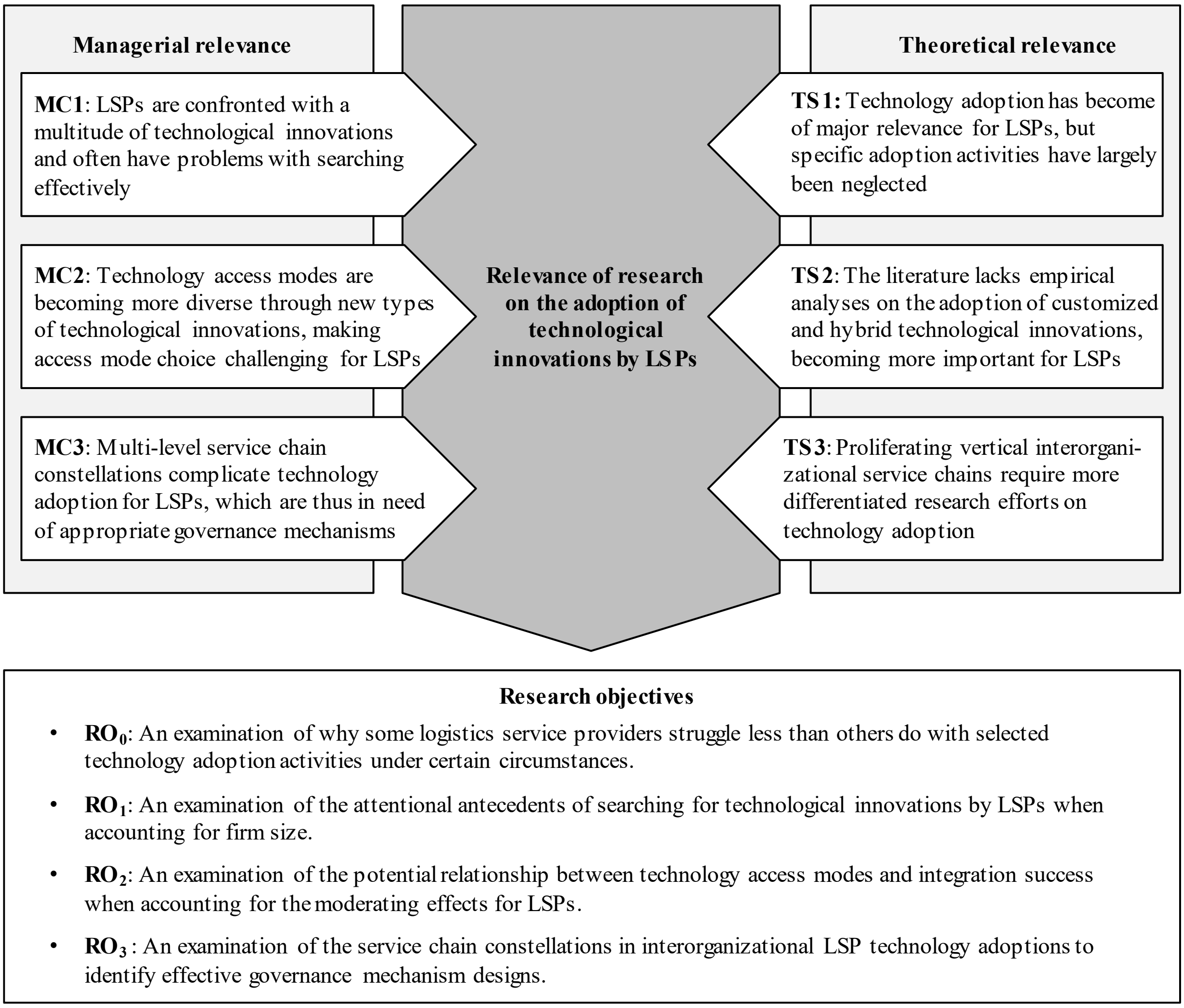

Figure 1. The managerial and theoretical relevance of the research on technology adoption by LSPs leads to the research objectives

1.4 Thesis structure

The dissertation is subdivided into six chapters. Figure 2 graphically depicts the structure of this thesis.

Chapter 2 provides the fundamentals of the dissertation. It outlines the characteristics of LSPs with a special emphasis on their peculiarities in terms of technology adoption (Section 2.1). Thereafter, an overview of innovation concepts is presented to characterize the technological innovations incorporated in this study (Section 2.2). Section 2.3 derives an ideal-typical concept for studying technology adoption at LSPs, thereby providing a first overview of the literature of innovation management and adjacent fields.

Chapter 3 presents the state-of-the-art research on the adoption activities carved out in Section 2.3. It starts with an outline of technology searching (Section 3.1), goes on to provide an overview of accessing technology (Section 3.2), and finally covers the diffusion of technology (Section 3.3). For each adoption activity, both general and LSP-specific research is analyzed. The chapter ends with the derivation of the research gaps and questions (Section 3.4).

Chapter 4 is concerned with the theoretical positioning of the present dissertation. Section 4.1 discloses the theory selection procedure, which includes the identification of theoretical approaches relevant to the specific research context. The following Sections 4.4 to 4.3 explain the contributions of the selected theories to the present study on technology adoption by LSPs. A theoretical framework closes this chapter, illustrating the concrete application of the theories within the scope of this dissertation (Section 4.6).

Chapter 5 starts with an overview of the research setting and the applied methodology (Section 5.1). Sections 5.2 to 5.4 contain an overview of the studies included in this research. Objectives, methodologies, key findings, and contributions are briefly presented.

Chapter 6 includes an overview of the overall contributions of the studies with a special emphasis on the implications for the overarching concept of technology adoption (Section 6.1). After that, managerial implications are presented that go beyond the level of the individual studies (Section 6.2). The chapter ends with a discussion of the limitations and suggestions for future research (Section 6.3).

The *Appendix* contains the full papers of the three studies conducted in the course of this dissertation.

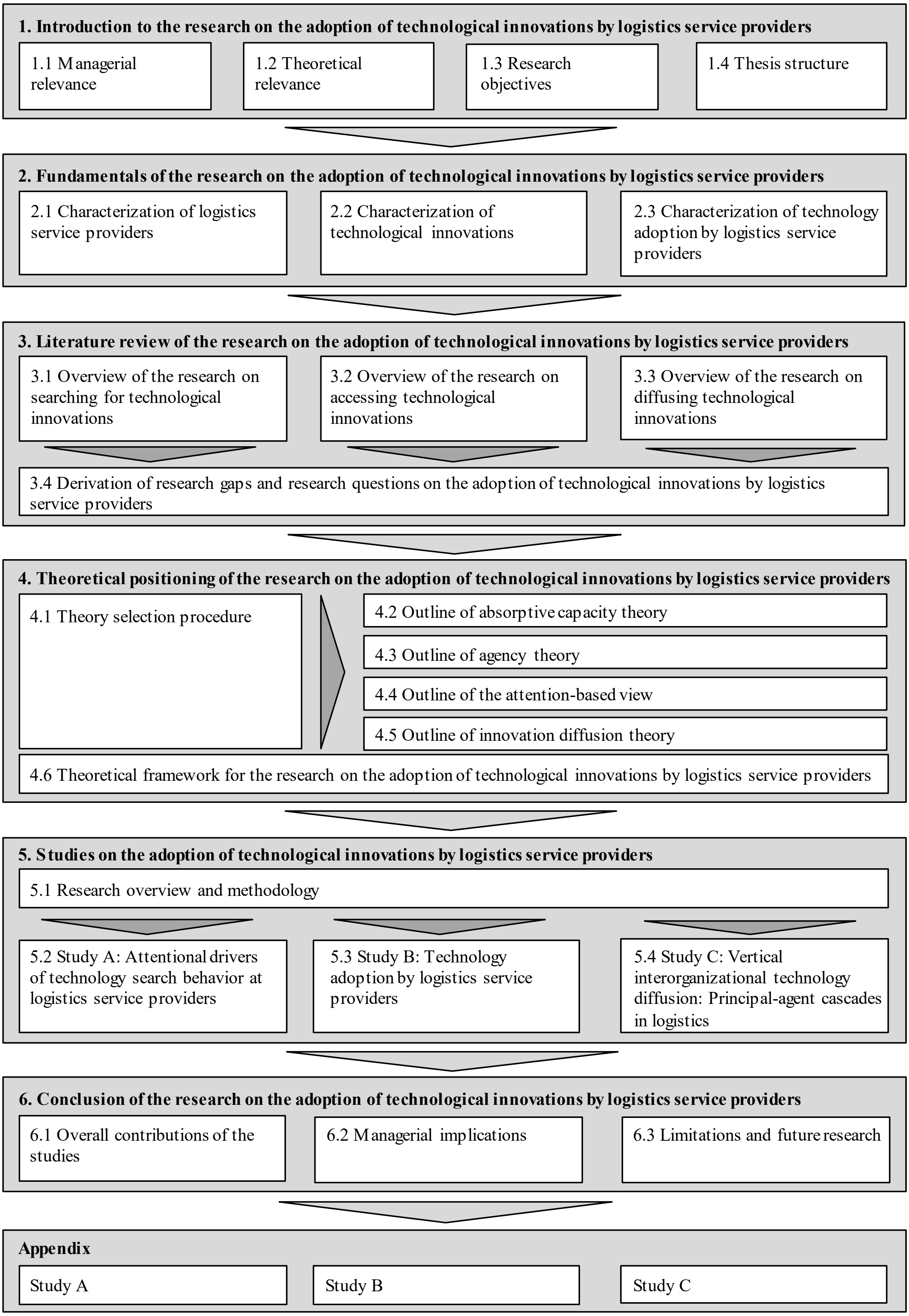

Figure 2. Outline of the thesis structure

2 Fundamentals of the research on the adoption of technological innovations by logistics service providers

This chapter aims to lay the conceptual groundwork for the investigations on technology adoption by LSPs. First, LSPs are characterized regarding their peculiarities and the potential implications for technology adoption (Section 2.1). Second, an outline of technological innovations helps to narrow down the technological innovations included in this dissertation (Section 2.2). Third, the concept of technology adoption is presented in order to structure the overall research setting and to locate the selected technology adoption activities (Section 2.3).

2.1 Characterization of logistics service providers

LSPs are a central component of the analyses included in this research, which is why their understanding is presented in compact form below. Following a very broad notion, LSPs comprise all "companies which perform logistics services on behalf of others" (Delfmann, Albers, & Gehring, 2002, p. 204). As there is still no widely accepted definition in the literature, an overview of the LSP types most frequently encountered in the scientific discussions will support the characterization:

- Carrier (also 2PL): Carriers are focused on hauling products and embody the most fundamental type of LSP (Hofmann & Lampe, 2013; Sink, Langley Jr, & Gibson, 1996). Offerings typically include basic services such as transportation ("box on wheels"; Sheffi, 1990, p. 31). The terms "carrier" and "second-party logistics provider" are used synonymously in research on LSPs.
- 3PL: 3PLs are most often discussed in the literature. There is both a narrow and a broad understanding of this specific LSP type (S. Li & Chen, 2019). According to a narrower framing, 3PLs have a long-term focus and provide rather customized services based on contracts that exceed the service portfolio of carriers (Murphy & Poist, 1998; Konstantinos Selviaridis & Spring, 2007). The broader framing assigns all types of logistics services to this company type and does not distinguish activities based on specific criteria (Sink et al., 1996; Stefansson, 2006; Zacharia, Sanders, & Nix, 2011). Both perspectives agree that 3PLs typically own physical assets and have direct contact with the shipper (Hofmann & Lampe, 2013).

- 4PL: Fourth-party logistics providers have the most comprehensive service portfolio of all LSPs. Being prime (and often global) logistical contractors of a shipper, 4PLs orchestrate all logistics activities along the supply chain (Cezanne & Saglietto, 2015). To perform this coordinating role, they enter into subcontracting agreements with other LSPs (e.g. carriers or 3PLs) (Mehmann & Teuteberg, 2016). In contrast to 3PLs, they do not own physical assets (Win, 2008).
- Logistics intermediaries: Logistics intermediaries take over a coordinating and connecting role between logistics actors (Cui & Hertz, 2011). Their core business is the consolidation of physical goods (Bowersox, Closs, & Cooper, 2010). The variety of logistics intermediaries is large, ranging from freight forwarders to consolidators and brokers (Coyle, Bardi, & Novack, 2000). There are both asset-based and non-asset-based intermediaries (Cui & Hertz, 2011). In contrast to 4PLs and 3PLs, logistics intermediaries do not regularly maintain a direct customer relationship with the shipper and focus on a specific section of the supply chain. Most often, they are subcontractors of 3PLs and serve as a link to carriers.

Figure 3 provides an overview of the presented LSP types for illustration purposes.[5] They are located along two dimensions: (1) the scope of their services (Hofmann & Lampe, 2013; Stefansson, 2006; Zacharia et al., 2011) and (2) the degree of customization (Hofmann & Lampe, 2013; Stefansson, 2006). The scope of their services ranges from the provision of transport or warehousing as basic logistics services (near scope) to value-added and supply chain coordination services as advanced logistics services (broad scope) (Evangelista et al., 2013). The degree of customization spans from standardized services “off the shelf” (a low degree of customization) to customized services on individual needs (a high degree of customization) (Schmoltzi & Wallenburg, 2011).

[5] The literature highlights further LSP types that are less clearly assignable. Lead logistics providers, for example, take over 4PL tasks, but are asset-based (Lampe, 2014). However, many 3PLs are advancing into this business segment, which is why no further distinction is made for this type. Other LSP concepts from the literature are too general to be comparable with the presented types. For instance, logistics service integrators can take over the role of 4PLs, 3PLs, or logistics intermediaries, and are thus not separately listed (W. Liu & He, 2018; Wagner & Sutter, 2012).

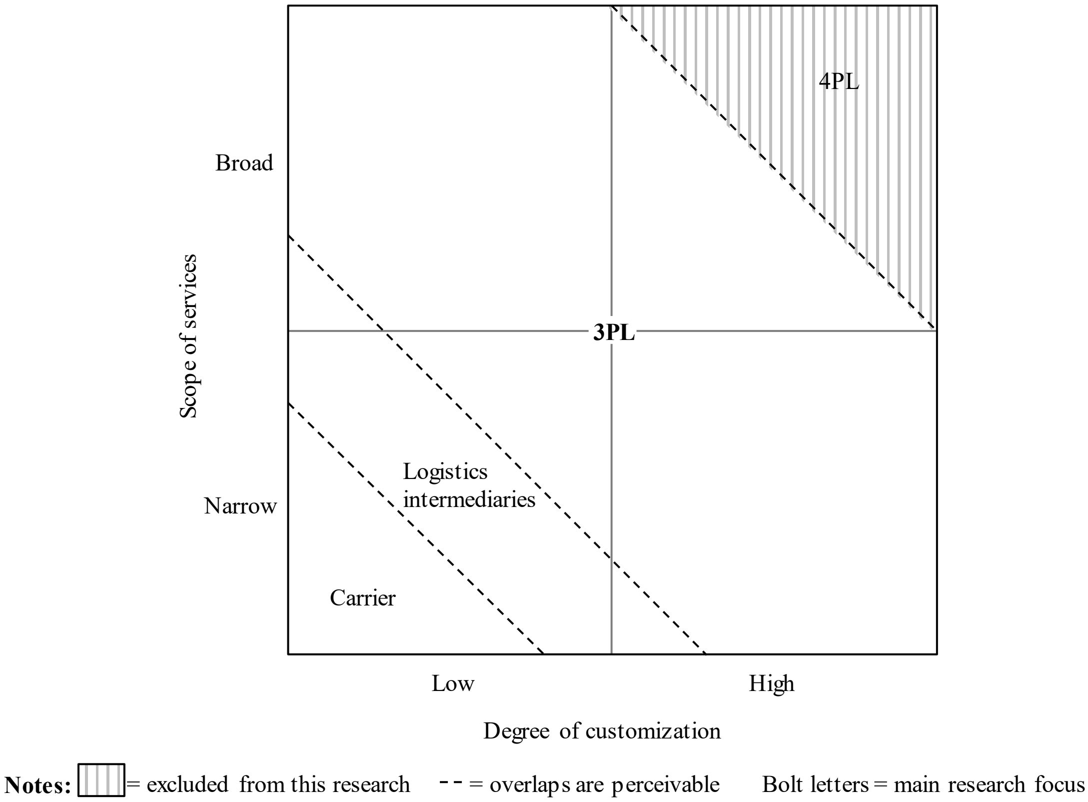

Figure 3. Overview of the different LSP types included in this research[6]

The interrelation between the different types of LSPs can take very complex forms. One basic constellation comprises of three levels. In such settings, a shipper outsources logistics activities to a 3PL (first level). The 3PL passes on individual activities to logistics intermediaries (second level), which enter into subcontracting relationships with carriers (third level). This vertical cascade of LSPs is referred to as the logistics service chain hereafter (Cui & Hertz, 2011; Mathauer & Hofmann, 2019a).[7]

To narrow the LSPs included in this research, a distinction must be made between the *unit of analysis* and the *unit of observation*. This dissertation's *unit of analysis* refers to selected technology adoption activities of LSPs who act as 3PLs on the logistics market. It is based on the narrow understanding of 3PLs. However, as the boundaries between LSPs are fluid, the companies included in the unit of analysis must visibly appear on the market as 3PLs.[8] The *unit of observation* includes all potential actors of the logistics

[6] Own illustration based on Hofmann and Lampe (2013); Zacharia (2011); Stefansson (2006).
[7] The explanation of the logistics service chain represents an extended extract from Appendix C.2.1, which should be consulted for a more detailed examination.
[8] Unless otherwise indicated, the use of the term LSP in the context of this study always refers to this stated understanding.

service chain with one decisive restriction. Only LSPs that pursue asset-based business models are incorporated, because technological innovations with a hardware component would otherwise not be relevant for them. Thus, 4PLs are not part of the present research (see Figure 3).[9]

Furthermore, LSPs exhibit peculiarities that, taken together, make their management in general and the management of technology adoptions different from those of other company types. These characteristics are presented in Table 1 hereafter and justify LSP-specific research on technology adoption.[10]

Table 1. Overview of the different peculiarities of LSPs and their implications for technology adoption

Peculiarity	Description	Implications for technology adoption	Selected literature
Capital intensity of services	Logistics services are rather capital-intensive due to the required production resources (e.g. trucks)	Technology adoptions often affect technology ecosystems, are thus expensive, and impede technology access	Busse (2010); Busse & Wallenburg (2014); Wagner (2008)
Fire-fighting mentality	A high level of standardized tasks implies an operative-driven mentality of the workforce	Employees are reluctant to change and can be a major obstacle for all technology adoption activities	Esper, Fugate, & Davis‐Sramek (2007); Sauvage (2003); Wagner (2008)
Function of covering distances	Logistics services are geographically spread and often provided from mobile entities	Transfer of information is challenging and hampers (interorganizational) technology adoption	Busse & Wallenburg (2011); Grawe & Ralston (2019)
Heterogeneity of customer demands	Customers from different sectors are served, leading to a strong relationship between service requirements and customer activities	Systematic technology searches are difficult because the customer-specific individual case might overrule more general approaches	Flint et al. (2008); Lemoine & Dagnæs (2003); Wagner & Sutter (2012)
Heterogeneity of offered services	Due to customer diversity, services need to be customized to individual needs or industry standards	The multi-user capability of technologies is poorly pronounced, complicating technology adoption activities	C. König et al. (2019); Selviaridis & Spring (2007)

[9] What has deliberately not been included are also two types of companies that are increasingly appearing in current discussions on the logistics market: digital platform operators and e-commerce companies with their own logistics services. Digital platform operators, e.g. Uber Freight, were excluded because they only provide asset-neutral services and, in contrast to the related category of logistics intermediaries, seek direct customer contact (UberFreight, 2020). E-commerce companies, e.g. Amazon, partially enter the logistics market through forward and backward integration (Hofmann & Osterwalder, 2017). When this work was written, their logistics services primarily aimed at satisfying their own need and orders from third parties accounted for less than approximately 1% of US revenue (Reimann, 2019). If the business orientation systematically changes, it may well make sense to include these players in future research.

[10] The peculiarities of LSPs are an extension of Lampe (2014) and Bachmann (2008).

Table 1 (continued)

Peculiarity	Description	Implications for technology adoption	Selected literature
Restrictive outsourcing contracts	Outsourcing contracts are often based on service-level agreements that strictly define the services to be provided	Contractual conditions do not stimulate innovation, so that technological innovations are most often initiated in reaction to a problem	Andersson & Norrman (2002); Cichosz et al. (2017); A. König & Spinler (2016)
Special position within the supply chain	LSPs are embedded in supply chain networks and thus positioned between their customers and their customers' customers	Technology adoptions raise questions on the interoperability of systems and often have to meet the requirements of several stakeholders	Huemer (2012); Selviaridis & Spring (2007); Stefansson (2006)
Use of subcontractors	Demand for more specialized, as well as single-source solutions, leads to enhanced use of subcontractors	The rising complexity of service-level constellations makes technology diffusion difficult	Cui & Hertz (2011); Y. Li, Wang, & Adams (2009); Rajahonka (2013)

2.2 Characterization of technological innovations

For the logistics context, no generally accepted definition of innovation has yet been established. What is often cited is the understanding of Flint and colleagues (2005), which will also serve as a starting point for the present research.[11] They refer to a logistics innovation as "any logistics-related service from the basic to the complex that is seen as new and helpful to a particular focal audience. This audience could be internal where innovations improve operational efficiency or external where innovations better serve customers" (Flint et al., 2005, p. 114). Technological innovations are a specific type of logistics innovation, as they presuppose technological developments as the basis of a new service (Garcia & Calantone, 2002). However, this very general understanding of technological innovations in logistics is not sufficient to comprehensively describe and identify them for the present dissertation. Thus, differentiation criteria are additionally considered, which originally stem from the classical innovation literature. The most popular dimensions along which innovations can be differentiated are the *object dimension*, the *subject dimension,* and the *intensity dimension*.[12] These three are outlined and exemplified for the logistics context hereafter.

[11] Among others, the following studies draw on this definition: Grawe et al. (2011); Zailani et al. (2011); Grawe (2009); Wagner and Busse (2008).
[12] This classification is based on Lampe and Stölzle (2012).

The *object dimension* of innovations provides an answer to the question of what is new. Process, product, and business model innovations can be assigned to this category (Snihur & Wiklund, 2019). Process innovations are concerned with increasing the efficiency of product or service provision processes through the introduction of new elements (Damanpour, 2010; Damanpour & Gopalakrishnan, 2001). The adoption of electronic data interchange for improved electronic communication between business partners is a typical example of a frequently studied process innovation in logistics (Autry et al., 2010; Premkumar, Ramamurthy, & Crum, 1997). Product innovations refer to the introduction of new products or services to commercially benefit from satisfying an external user's need (Damanpour, 2010). In logistics, this innovation type most often occurs in the form of technologically advanced infrastructure (Wagner, 2008). If an LSP, for example, expands its fleet with temperature-controlled trucks, a service innovation can be offered to the customer (e.g. food transportation). Product and process innovations "often occur in tandem" (M. Schilling, 2013, p. 46), as either new processes pave the way for new products or vice versa. Thus, both are considered in this research. Business model innovations are a more recently recognized innovation type (Foss & Saebi, 2017), and comprise new value chain configurations that create additional value to the customer and are new to the industry (Amit & Zott, 2012; Zott, Amit, & Massa, 2011). A business model innovation in logistics would be the entry into contract logistics with services that are not yet extensively offered within the industry (e.g. 3D printing of spare parts) (Lampe & Stölzle, 2012). The management of business model innovations differs considerably from the management of the other innovation objects and exceeds adoption activities (Foss & Saebi, 2017), which is why this innovation type is not further considered.

The *subject dimension* answers the question regarding to whom the innovation is new. Research discusses new-to-the-world (Kriz & Welch, 2018), new-to-the-industry (Ettlie & Rosenthal, 2011), or new-to-the-firm (Carnabuci & Operti, 2013) innovations as common perspectives on "newness." New-to-the-world innovations are accompanied by the highest level of uncertainty concerning market success and pose the most challenging tasks from a managerial perspective (Fagerberg, 2005). This type of innovation is usually the domain of high-tech firms and is therefore excluded from the present research on LSPs (Kriz & Welch, 2018).[13] New-to-the-industry innovations are frequently encountered in logistics. Both market leaders and niche specialists launch such innovations regularly, for example, collaborative robots for commissioning processes (Chung et al., 2019). Although an innovation might already exist within an industry, an LSP (e.g. a regional actor) can still be the first adopter in its direct market environment (new to the firm). Thus, the newness of an innovation should always be understood in relative terms (Garcia & Calantone, 2002; Lampe & Stölzle, 2012). Both new-to-the-industry and new-to-the-firm innovations are considered in this dissertation.

The *intensity dimension* delivers answers to the question of how new an innovation is.[14] Scholars usually distinguish incremental and radical innovations as the two extremes of a continuum (Dewar & Dutton, 1986), with moderate innovations placed somewhere between these two (Garcia & Calantone, 2002). Radical innovations imply revolutionary technology changes that deviate from existing practices and result in new markets (Ettlie, Bridges, & O'Keefe, 1984). Such innovations are, per definition, extremely rare (e.g. the steam engine, world wide web, etc.) and are therefore excluded from this research with a logistics focus. Incremental innovations refer to adjustments of existing technologies in existing markets (Dewar & Dutton, 1986). As this innovation type is especially associated with firms having an efficiency culture, they often occur at LSPs (e.g. replacing a scanner with a smartphone) (Gatignon, Tushman, Smith, & Anderson, 2002). Moderate innovations result in new services, service extensions, or new markets, but do not exhibit high levels of radicality (Kleinschmidt & Cooper, 1991). As they account for the majority of innovations, moderate innovations are included in this research (Garcia & Calantone, 2002).

The presented and established characteristics for distinguishing technological innovations are complemented by two more recent dimensions that focus more on the sphere

[13] This is by no means saying that these innovations do not exist or are not relevant for the logistics market—the contrary is true. From an actor's perspective, however, these innovations are more likely to be launched by other players such as e-commerce companies that enter the logistics market (Hofmann & Osterwalder, 2017).

[14] What is closely related to the intensity dimension of innovations is the current debate on the impact dimension, meaning whether a new technology is disruptive or sustaining (Christensen, 1997; Keller & Hüsig, 2009; Klenner, Hüsig, & Dowling, 2013; Nagy, Schuessler, & Dubinsky, 2016). Disruptive innovations combine radical functionality and discontinuous technological standards with new forms of ownership (Nagy et al., 2016). Selected scholars claim that disruptiveness can only be defined *ex post* (Danneels, 2004; Tellis, 2006) and is relative to the individual firm (Bower & Christensen, 1995). As the focus of this research rests on technology adoption activities and not on the consequences of adoption, it is not considered purposeful to take a deeper look at this dimension.

of technology: (1) the *tangibility dimension* and (2) the *personalization dimension*. Concerning *tangibility*, a coarse distinction between logistics hardware and software has long dominated the scientific debate (Germain, Droge, & Daugherty, 1994).[15] In the times of industry 4.0, equipping physical elements with sensors for data collection blurs the line between soft- and hardware (Glas & Kleemann, 2016). So-called hybrid technological innovations evolve that combine elements from the physical and the virtual world (Barrett et al., 2012, 2015). These innovations proliferate in logistics and SCM (e.g. smart charge carriers, temperature tracking devices, etc.) and are thus of special interest for this research.

Furthermore, the *personalization* of technological innovations is gaining ground at LSPs (Mathauer & Hofmann, 2019c). The degree of personalization can vary, although logistics services—as services in general—exhibit a natural tendency toward customization due to their simultaneous production and consumption (Hipp & Grupp, 2005). While customized logistics services meet the needs of one specific customer, standardized logistics services are designed for various customers (da Mota Pedrosa et al., 2015; Wagner & Sutter, 2012). Both are included, because there is little knowledge of their potential implications regarding technology adoption activities.

Figure 4 provides an overview of the innovation dimensions and the corresponding characteristics that are considered in this research. Only one characteristic of the object and the personalization dimension can be assigned to an individual innovation. In the following, the term “technological innovation”[16] thus refers to all technology-based logistics innovations, which can be described based on the highlighted fields in Figure 4.

[15] The explanation of the tangibility and personalization dimensions represent extended extracts from Appendix B.2.2, which should be consulted for a more detailed examination.

[16] To simplify the readability of the dissertation, the term “technology adoption” omits the addition of “innovation.” Nevertheless, it refers to the definition of technological innovations provided above.

Dimensions of technological innovations in logistics	Characteristics		
Object dimension	Process	Product/Service	Business model
Subject dimension	Firm	Industry	World
Intensity dimension	Incremental	Moderate	Radical
Tangibility dimension	Physical	Virtual	Hybrid
Personalization dimension	Standardized		Customized

▭ = included in this research

Figure 4. Dimensions for the classification of technological innovations in logistics

2.3 Characterization of technology adoption by logistics service providers

The following section is concerned with structuring the field of technology adoption by LSPs. In the first step, an overview is provided of the most relevant adjacent literature streams to position the dissertation. In the second step, different levels for studying technology adoption are depicted. In the third step, technology adoption by LSPs is conceptualized by drawing on different activities from the literature.

Overview of the relevant research streams for technology adoption

Research on the adoption and diffusion of innovations has yielded an extensive body of literature and is deeply rooted in the domain of innovation management (van Oorschot, Hofman, & Halman, 2018). The present dissertation on technology adoption by LSPs is therefore predominantly anchored in the interdisciplinary field of innovation management. Due to the specific research focus, however, at least three additional research streams are touched upon: (1) *operations management*, (2) *service management*, and (3) *strategic management*. These streams are succinctly outlined hereafter, including potentially relevant sub-streams and their relation to the present research. An in-depth analysis of research on technology adoption in innovation management is provided separately in the next subsection.

Operations management is devoted to the effective design of operations and processes to enhance value creation through productive resources. It links strategic long-range planning and ongoing daily activities (Slack & Brandon-Jones, 2018). For the dissertation, the sub-stream of logistics management from a service provider's perspective is particularly relevant. Logistics management is concerned with the planning, coordination, and optimization of activities along the supply chain (Lambert & Cooper, 2000). Due to the rising complexity of logistics activities (Gunasekaran, Subramanian, & Papadopoulos, 2017), they are increasingly sourced out to specialized LSPs (Evangelista et al., 2013).[17] In consequence, research has evolved on both the management of LSP relationships (e.g. Mortensen & Lemoine, 2008; Stefansson, 2006) and the management of LSPs themselves (e.g. Hertz & Alfredsson, 2003). Since the turn of the millennium, the latter research stream has further gained in relevance, especially from an innovation management (Busse & Wallenburg, 2011) and a service management perspective (C.-L. Liu & Lyons, 2011). Of particular interest for the present research is the identified gap between the required technological innovations by LSPs for the improved service provision of logistics activities and their difficulties in implementing such innovations in practice (Busse, 2010).

As service-based business models are globally on the rise, the scientific examination of innovation has also gained in importance within the past 15 years of *service management* research (Gummesson, 1994; Maglio & Spohrer, 2013). The characteristics of services are essential to the understanding of technological innovations by service providers. Among others, services are intangible (Neu & Brown, 2005), perishable (Johne & Storey, 1998), simultaneously produced and consumed (uno actu principle) (Cowell, 1988), as well as influenced by external factors (e.g. the customer) (Hipp & Grupp, 2005). Thus, and in contrast to product innovations, the value of a technological innovation in the service industry only unfolds during the provision of the service. The market success of innovations in the service industry is therefore indirectly related to their service characteristics. Both the service management and business marketing literature reflect an increasing interest in innovation in service networks (Henneberg, Gruber, & Naudé, 2013). Due to the rising knowledge-intensity and customization of business services, whole networks of service providers become necessary to provide services to the customer. The logistics industry exemplifies this development with its nested outsourcing relationships, which is why research on service innovation in service networks could prove to be particularly valuable for the present dissertation (Rust & Chung, 2006).

[17] For a more nuanced discussion, please consult Section 2.1.

"*[S]trategic management* deals with the major intended and emergent initiatives taken by general managers on behalf of owners, involving utilization of resources to enhance the performance of firms in their external environments" (Nag, Hambrick, & Chen, 2007, p. 942). Generally speaking, technological innovations aim at improving the resource endowment of a firm, thereby contributing to the achievement of a competitive advantage (Kannan-Narasimhan & Lawrence, 2018). Innovation processes are typically organized as projects (Browning & Ramasesh, 2007) and pose various managerial challenges, the overcoming of which is one topic of strategic management. Managing innovation adoption at the firm level arouses particular research interest, for example, concerning the connection between resource mobilization and strategic context determination for successful adoption (Burgelman, 1983a, 1983b; Noda & Bower, 1996). What is especially promising for the present dissertation are insights into organizational structures and processes for innovative business models (see Zott, Amit, & Massa, 2011) and the management of innovations in firm networks (e.g. Schilling & Phelps, 2007).

Figure 5 depicts an overview of the research streams that are considered as relevant to this research on technology adoption by LSPs. The literature discussed in the course of this dissertation is only sporadically assigned to the individual streams, as they flow into each other and a clear demarcation is not always possible. The next subsection continues with a deep-dive into the innovation management literature on technology adoption.

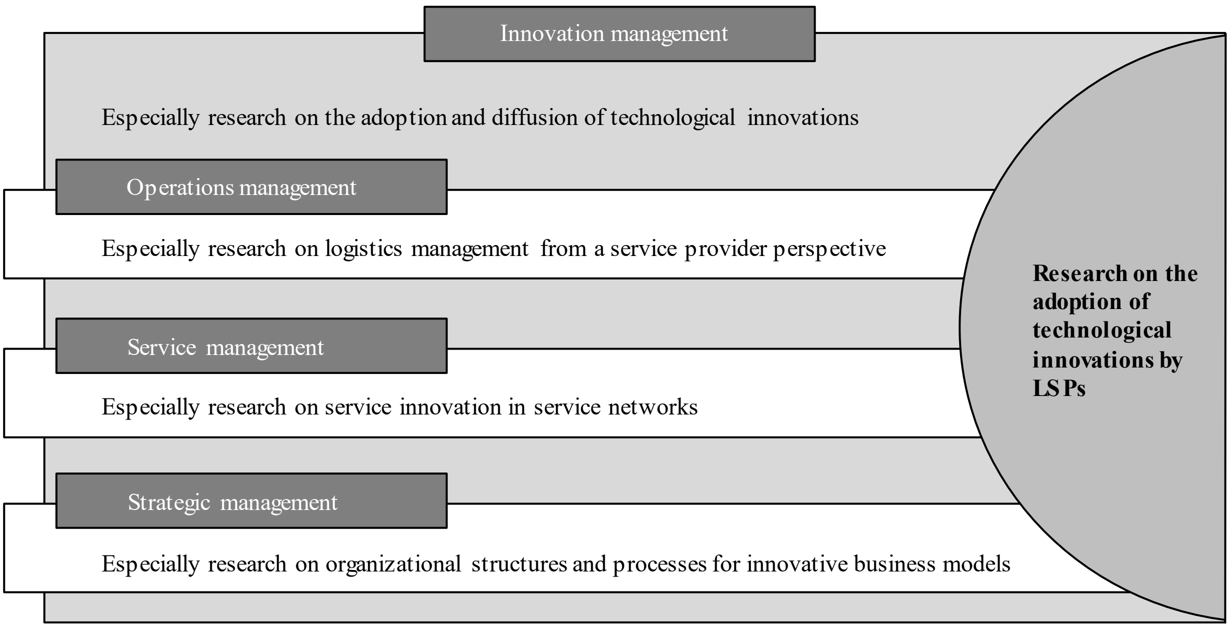

Figure 5. Overview of the relevant research streams for research on the adoption of technological innovations by LSPs

Demarcation of different levels for studying technology adoption

The proliferation of studies on the adoption of technological innovations has led to a fragmented body of innovation management literature that is difficult to grasp (van Oorschot et al., 2018). Three different levels for studying adoption must be distinguished to ensure a clear and concise discussion: (1) *individual-level*, (2) *firm-level* and, (3) *market-level adoption*.

Research on *individual-level adoption* is significantly impacted by the technology acceptance model (TAM; Davis, 1986).[18] The TAM provides explanations for the behavioral motivations of individual technology acceptance. The basic assumption is a causal relationship between a technology's perceived usefulness, perceived ease of use, and user acceptance. The original model (Davis, 1989; Davis, Bagozzi, & Warshaw, 1989) has been refined, resulting in the TAM 2 (Venkatesh & Davis, 2000) and the unified theory of acceptance and use of technology (Venkatesh, Morris, Davis, & Davis, 2003). Research on *firm-level adoption* most often draws on the models of Rogers (1962, 2003), Tornatzky et al. (1990), and Iacovou et al. (1995). The core of these research efforts is the conceptualization of the adoption process with all its activities as well as the determination of contingency effects including technology, the organization, and the environment. Research on *market-level adoption* regularly builds on mathematical modeling. The most seminal work is Bass' (1969) model of diffusion, which allows for forecasting the time of new product purchases based on the number of previous purchases. The model was later extended (Bulte & Joshi, 2007; Chatterjee & Eliashberg, 1990), for example, for international diffusion (Tellis, Stremersch, & Yin, 2003). Rogers (1962, 2003) also advanced market-level adoption and, among others, classified adopters into categories.

Individual-level adoption is typically associated with the term "acceptance," firm-level adoption with the term "adoption," and market-level adoption with the term "diffusion."[19] The present research focuses on firm-level technology adoption. While technology acceptance on the individual level will no longer be considered in the following,

[18] The TAM is rooted in the theory of reasoned action (Fishbein & Ajzen, 1975), from which the theory of planned behavior evolved (Ajzen, 1991; Taylor & Todd, 1995).

[19] The mentioned terms are neither exclusively nor consistently used in the literature, as the boundaries between the three perspectives are fluid. Rogers' (2003) innovation diffusion theory, for example, takes both a firm and a market perspective, as it also allows for the interorganizational diffusion of innovation among firms to be explained.

technology diffusion provides implications for interorganizational adoption settings and will thus be taken up repeatedly in the course of this research. Table 2 presents an overview of the different adoption levels with their seminal articles.

Table 2. Different perspectives for studying innovation adoption

Level	Purpose	Selected studies
Individual	Explaining the behavioral motivations of individual technology acceptance as well as further influencing factors	Davis (1986); Davis (1989); Davis et al. (1989); Venkatesh & Davis (2000); Venkatesh et al. (2003)
Firm	Explaining the multi-stage process of adopting and implementing technological innovations at organizations as well as determining factors	Tornatzky & Klein (1982); Cooper & Zmud (1990); Tornatzky et al. (1990); Damanpour (1991); Iacovou et al. (1995); Zhu et al. (2006); Frambach & Schillewaert (2002)
Market	Explaining the timing of new consumer product purchases in the market drawing on the number of previous buyers	Bass (1969); Norton & Bass (1987); Mansfield (1961); Rogers (1962); Chatterjee & Eliashberg (1990); Geroski (2000); Tellis et al. (2003), Bulte & Joshi (2007)

Derivation of an activity-based concept of technology adoption

In general terms, innovation scholars ideal-typically distinguish two stages of firm-level technology adoption:[20] (1) the *initiation* and (2) the *implementation* (Rogers, 2003; Zaltman, Duncan, & Holbek, 1973). There is a consensus that the actual adoption decision marks the transition between the two stages (Frambach & Schillewaert, 2002). Every stage can include several technology adoption activities (Rogers, 2003). Hereafter, a concept of technology adoption is derived that will help to structure the research setting. Literature from the research streams presented in the previous sub-sections helps to highlight potential blind spots in the context of LSPs. No claim is made that the described activities are directly observable in the presented order. These are only activities that can typically occur in the course of technology adoption and therefore they call for a better understanding.

Initiation. The initiation of technology adoption includes the firm-level activities of searching and evaluating. Triggers of the initiation stage can either stem from the inside

[20] Following a broad understanding, technology adoption is sometimes also called technology assimilation, e.g. by Zhu et al. (2006). Therefore, Appendix B frequently draws on the term “assimilation.” However, this dissertation treats adoption and assimilation as equivalents and predominantly uses the term “adoption” to improve readability.

(e.g. a specific problem; "pull") or from outside the firm (e.g. a new technological solution; "push") (Cooper & Zmud, 1990). While searching is about the identification of useful technological innovations from the firm environment, evaluating is about the consideration of whether a technological solution fulfills the prioritized needs (Rogers, 2003). Initiation activities aim to balance the perceived benefits of an identified technological innovation, a firm's technological endowment, and market expectations (Mathauer & Hofmann, 2019c).

Scholars from innovation and strategic management have long emphasized the critical role of searching for firm innovativeness (Katila, 2002; March, 1991). For instance, it could be shown that there is a relationship between how a search is conducted (e.g. where and how intensively) and the innovation outcome (Cohen, 1995; Greve, 2008; Laursen & Salter, 2006). In consequence, studies evolved on agenda setting before searching (Dutton, 1997; Rogers, 2003) or on the organization of searching (Rohrbeck, Battistella, & Huizingh, 2015; Rohrbeck & Gemünden, 2011; Vecchiato, 2015). Complex cognitive processes that guide search activities have prompted researchers to increasingly incorporate an attentional perspective in their studies (Q. Li, Maggitti, Smith, Tesluk, & Katila, 2013; Piezunka & Dahlander, 2015). However, existing research on searching does not yet provide a sufficient understanding of what drives organizational search activities in large and small service firms—a pending managerial problem for resource allocation, as described in Section 1.1 (MC1). LSP-specific research from operations management has highlighted the customer's role for the initiation of technological innovations (Flint et al., 2008, 2005), but has almost neglected specific technology search activities (Busse & Wallenburg, 2011). Evaluating, in contrast, has received much more academic interest, especially in innovation management. Decision-makers can draw on concepts for both criteria development (Rohrbeck, 2010; Tuominen & Torkkeli, 2002; Yap & Souder, 1993), as well as on sophisticated selection models, for example, for firms acting under conditions of technological uncertainty (Krishnan & Bhattacharya, 2002; Shen, Chang, Lin, & Yu, 2010).

Implementation. The implementation of technological innovations is triggered by a positive technology adoption decision (Rogers, 2003). It should be noted that technology adoption and the technology adoption decision are not congruent—although this has been suggested by many studies that operationalize technology adoption as a dichotomous adoption decision (Frambach & Schillewaert, 2002; Yang et al., 2015). Thus, there is a more comprehensive understanding of technology adoption decisions than of many adoption activities (van Oorschot et al., 2018). The implementation stage of technology adoption comprises the activities of accessing, integrating, diffusing, and routinizing. Accessing is about making a technological innovation available for firm-level integration (Mathauer & Hofmann, 2019c). Integrating means the incorporation of a technological innovation into organizational procedures (Cooper & Zmud, 1990). It is not to be understood as purely technological, as human and organizational aspects (structures and tasks) are affected as well (Leavitt, 1965). Diffusing reflects the spread of a technological innovation within and across firm boundaries to fully incorporate it into service provision (Mathauer & Hofmann, 2019a). Routinization, finally, refers to making a technological innovation an integral part of the value chain activities (Zhu et al., 2006).

Innovation scholars tend toward taking technology access for granted and often do not treat it as a separate activity of adoption (Rogers, 2003). This is problematic because the available technology access modes differ between firms because the capability of managing different access modes does (Van de Vrande, 2013). Especially in service management, external technology sourcing has thus become an important topic of interest (Kang & Kang, 2014). For the above-stated managerial challenge of choosing an appropriate technology access mode when considering the implications for integration success, there is not yet any research available (MC2). The integration of technological innovations has been thoroughly examined (Iansiti, 1995), for instance, with regard to the determinants relating to external technology integration (Iansiti, 1995; G. Stock & Tatikonda, 2008). The diffusion of technological innovations typically exceeds the firm level when studying LSPs (Mathauer & Hofmann, 2019a). For interorganizational settings, however, diffusion has mostly been studied horizontally for independent firms (Giachetti & Lanzolla, 2016; Zhu et al., 2006). Insights are lacking on how to vertically diffuse technology innovations in different constellations of affiliated firms. Routinizing has finally attracted substantial research attention and can guide decision-makers in practice. Kim and Malhotra (2005) revealed the mechanisms underlying continued use such as sequential updating or feedback mechanisms. Hazen and colleagues (2012) derived activities that are conducive for routinizing in the logistics context.

Figure 6 presents the ideal-typical, activity-based concept for studying technology adoptions by LSPs and locates therein the managerial challenges from Section 1.1.[21] A succinct discussion regarding the selected literature reveals blind spots where managerial challenges are to be found. Thus, the following *interim conclusion* can be drawn:

Technology adoption by LSPs ideal-typically comprises the stages of initiation and implementation, which are separated by the technology adoption decision and include several adoption activities. The initiation consists of searching and evaluating, and the implementation of accessing, integrating, diffusing, and routinizing. For LSPs embedded in interorganizational service networks, diffusing and routinizing exceed the firm level. Managers of LSPs are particularly struggling with searching, accessing, and diffusing technological innovations, while research on these activities is scarce. The present dissertation will thus focus on these selected technology adoption activities, which are deepened in the literature review hereafter.

[21] Many scholars refer to technology adoption as a process (e.g. Cooper and Zmud (1990) or Zhu et al. (2006)). Therefore, Study B (see Appendix B) also uses the term “process” to describe a set of technology adoption activities. However, to avoid the impression that technology adoption necessarily has to follow a certain sequence, the term “concept” is applied here.

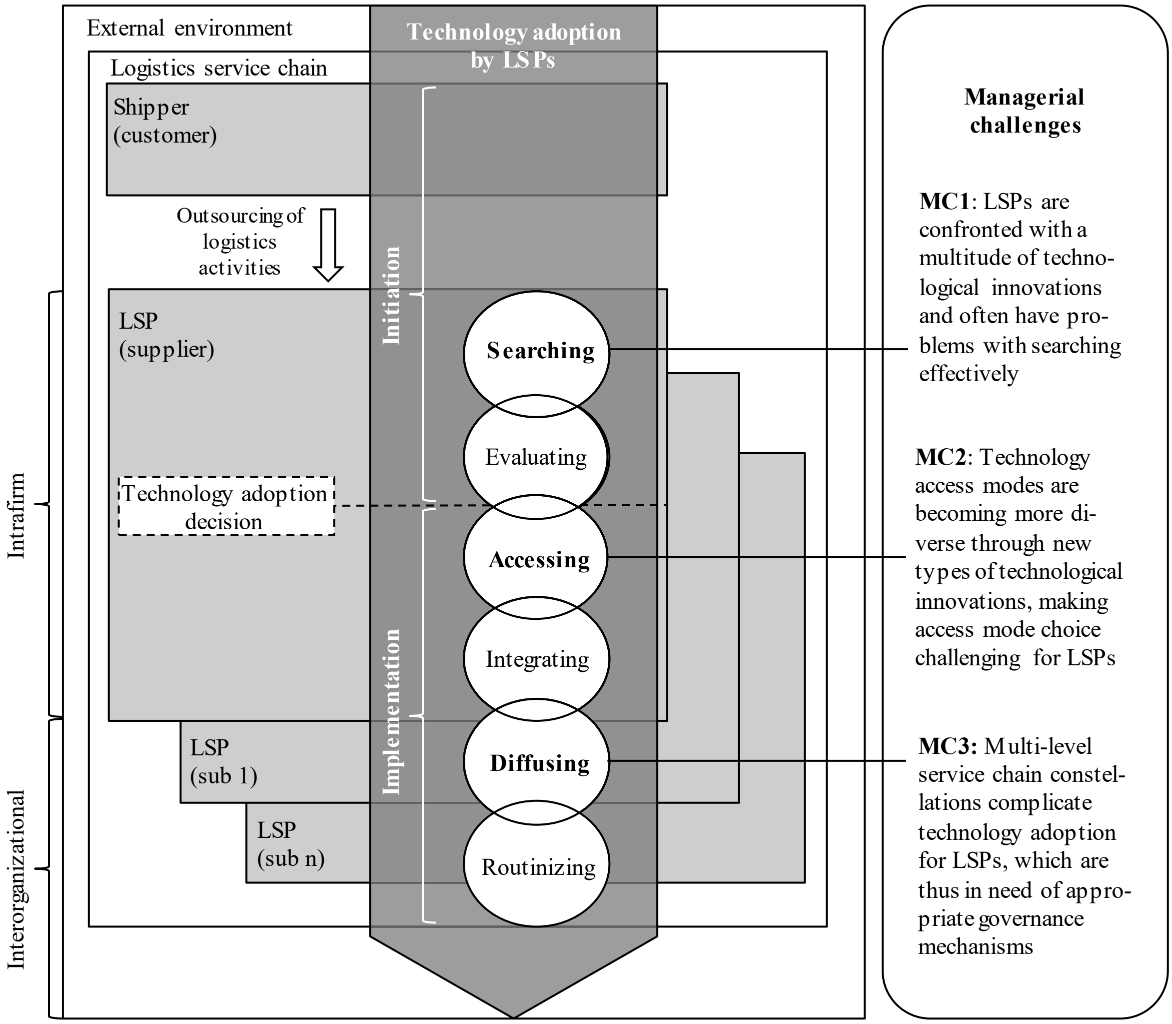

Figure 6. Depiction of an ideal-typical concept of technology adoption by LSPs[22]

[22] Own illustration based on Cooper & Zmud (1990); Rogers (2003); Zhu et al. (2006).

3 Literature review of the research on the adoption of technological innovations by logistics service providers

This chapter seeks to outline the relevant literature for the investigation on technology adoption by LSPs to finally arrive at the concrete research gaps and questions. Drawing on the fundamentals (Section 2.3), the literature is deepened in a targeted manner. Each section is devoted to one selected technology adoption activity. Section 3.1 provides an overview of technology searching, Section 3.2 of accessing technology, and Section 3.3 of diffusing technology. The research gaps are summarized in Section 3.4, where the research questions are also distilled.

3.1 Overview of the research on searching for technological innovations

Organizational searching can be defined as "the controlled and proactive process of attending to, examining, and evaluating new knowledge and information" (Q. Li et al., 2013, p. 893). This research is focused on technology searching, being one specific type of organizational searching that aims at technological innovations.

In reviewing the literature on the initiation of technology adoption by LSPs, it was found that technology search activities were rarely addressed (see Table 3).[23] Flint and colleagues (2005) were the first ones to systematically and empirically approach innovation in logistics. They find a dominating role of the customer during early innovation activities, as the customer might, for example, provide clues for technology searches. Grawe (2009) developed a model of logistics innovation including antecedents from the spheres of the environment and the organization. However, a lack of empirical material on the innovation initiation activities by LSPs was denounced and still applies today (Wallenburg, Johne, Cichosz, Goldsby, & Knemeyer, 2019). Wagner (2008) is among the few exceptions who explicitly treated internal and external technology searching. He stated that technology search activities are very weakly pronounced in logistics compared to other branches. It becomes apparent that more recent research on technology search activities by LSPs is needed. LSPs are currently, more than ever, building up

[23] Section 3.1 on technology searching by LSPs partly contains extended extracts from Appendix A, which should be consulted for a more detailed examination.

expertise in the field of technology searches, as numerous examples show (Cichosz et al., 2017).[24] However, this development is not yet reflected in the research.

Table 3. Overview of the selected literature with relevance for technology searching by LSPs[25]

Author	Type of study	Key outcomes	Relation to technology searches
Flint et al. (2005)	Empirical (interview/case)	There are four phases of logistics innovation: setting the stage; ideas gathering; negotiating, clarifying, reflecting; interorganizational learning	Implicitly related to technology searches
Flint et al. (2008)	Empirical (survey)	Supply chain learning management and the extent of innovation management antecede technological innovation in logistics	Implicitly related to technology searches
Wagner (2008)	Empirical (survey)	Internal search and development, external search and development, investment in infrastructure and capital goods, acquisition of knowledge, and training and education typically trigger logistics innovation	Explicitly related to technology searches
Grawe (2009)	Conceptional	Antecedents of logistics innovation stem from the external environment (e.g. competition) and the internal organization (e.g. financial resources)	Implicitly related to technology searches
Bellingkrodt and Wallenburg (2013)	Empirical (survey)	Examination of various knowledge sources (e.g. existing customers) for different innovation types (e.g. innovations for new customers)	Implicitly related to technology searches
Steinbach et al. (2017)	Empirical (survey)	Outcome-oriented contracts can antecede proactive improvements by LSPs based on technological innovations	Implicitly related to technology searches
Wallenburg et al. (2019)	Empirical (survey)	Innovation alignment between the buyer and supplier is positively related to proactive improvements by LSPs; the relationship is moderated by the hierarchy of the relationship	Implicitly related to technology searches

In contrast to the dearth of literature from an LSP perspective, technology searches have attracted the increased academic interest of scholars from the field of innovation management throughout the past years. Researchers have most often investigated the consequences of searches and arrived at the key logic that search activities determine the speed of new product introductions (Katila & Ahuja, 2002; Maggitti, Smith, & Katila, 2013).

[24] The increasing importance of technology search activities for LSPs can be illustrated by the example of DHL presented by Wagner (2008). The former Deutsche Post World Net (which has now been merged into DHL) had stated back in 2008 that, as a service provider, it would not carry out R&D in the strict sense. However, DHL established the world's first LSP trend research team in 2015 (DHL, 2015). In the meantime, they use a structured approach to spot technological developments with relevance for logistics and supply chain management and publish them yearly by means of a trend radar (Chung et al., 2019).
[25] Own illustration based on Wallenburg et al. (2019) and Grawe (2009).

Other perspectives include the antecedents of searches and the search activities as such. Antecedents stem from either inside or outside the firm. One typical internal antecedent of a search is an organizational problem, which is why researchers speak of problemistic searches in this case.[26] Such organizational problems may, for example, result from performance gaps (Posen, Keil, Kim, & Meissner, 2018). An externally triggered search is, for instance, driven by a competitor adopting a certain technology (Gnyawali & Park, 2011). Firms can also engage in opportunistic scanning of the organizational environment, being driven by solutions rather than by problems (March, 1981). In such cases, the search is not aimed at meeting specified needs (Rogers, 2003).

External search activities can be assigned to two broad categories: (1) search breadth and (2) search depth (Laursen & Salter, 2006). Search breadth is concerned with where firms search. Scholars have contrasted local and distant searches (Helfat, 1994), broad and narrow searches (Katila & Ahuja, 2002), as well as familiar and unfamiliar searches (Rosenkopf & Almeida, 2003). The tenor of these contributions is that distant, broad, and unfamiliar searches are particularly challenging (Laursen, 2012; Q. Li et al., 2013; Snihur & Wiklund, 2019). Search depth covers the investment and the duration of search activities. There is a positive correlation between search depth and firm innovation, as confirmed by various studies (Cohen, 1995; Greve, 2003). Both wide and deep searches have a positive impact on innovativeness, but only up to a certain point (Laursen & Salter, 2006).

Due to the complex attentional processes underlying technology searches, there is a call for research to incorporate cognitive processes when studying technology search behavior (Q. Li et al., 2013). In recent years, there has therefore been a growing interest in viewing search activities through an attentional lens (Piezunka & Dahlander, 2015; Rhee & Leonardi, 2018; Rhee, Ocasio, & Kim, 2019). These studies theoretically contribute to the notion of the behavioral firm[27] and regularly draw on Ocasio's ABV (Ocasio, 1997). The ABV states that firm behavior is a reflection of how managerial attention is

[26] The concept of a problemistic search is rooted in the Carnegie School tradition and draws on the seminal work of Simon, Cyert, and March (e.g. Cyert & March, 1963; March & Simon, 1958). Firm behavior is explained as a reaction to performance feedback. This notion has attracted consistent research interest for more than half a century (Posen et al., 2018).

[27] Behavioral firm theorists developed the argument that organizational action depends on individual cognitive processing and the structural impact on decision-makers' attention. Seminal contributions are, among others, Simon (1947), March and Simon (1958), Cyert and March (1963), and March and Olsen (1976).

channeled and distributed within organizations (Ocasio, 1997).[28] Also from an ABV, the consequences of search behavior are studied rather than the antecedents (Monteiro, 2015; Scalera, Perri, & Hannigan, 2018). The few available insights into the antecedents are still valuable to draw conclusions about LSPs.

According to Ocasio (1997), there are three categories of issues that might attract the attention of decision-makers: problems, opportunities, and threats. This is notable, because decision-makers are highly selective in what captures their attention and antecedents from these categories might be decisive for how an organizational search is conducted (Joseph & Ocasio, 2012; Monteiro, 2015; Ocasio, 1997; Simon, 1947). Chen and Miller (2007), for example, addressed internal problems as antecedents of search intensity. They found performance gaps, slack resources, and bankruptcy to trigger search intensity, as all of them move into the focus of attention in the individual situations (W.-R. Chen & Miller, 2007; Posen et al., 2018). Barreto (2012) criticizes the focus on internal antecedents of technology searches and expanded the debate to also include external antecedents from an ABV. He proved the opportunity for market expansion to be an important trigger for both search behavior and choice. External threats can be expected to attract the attention of decision-makers as well. However, they have not yet been part of the scientific debate on the antecedents of technology search behavior.

Importantly, an attentional perspective on technology searches might also help to explain systematic differences between the technology search behavior of large and small LSPs. Evangelista et al. (2013), for example, found that ICTs adopted by LSPs of different sizes varied significantly in their complexity. Thus, the preceding technology search behavior might also have been different. The ABV highlights the role of internal attention structures for the attention focus of decision-makers; attention structures vary between large and small firms (Ocasio, 1997).[29] Knowhow on the impact of firm size on the relationship between technology search antecedents and technology search behavior is necessary to effectively manage LSP technology searches when accounting for firm size.

[28] Please consult Appendix A for a more thorough analysis of the attentional mechanisms during technology searches.
[29] Please consult Appendix A for an in-depth discussion on the impact of firm size on attention structures.

3.2 Overview of the research on accessing technological innovations

For this research, accessing technology is defined as the way in which a firm makes technological innovations available for integration into its organizational procedures, either through an import from outside its boundaries or from creation within its boundaries (Rogers, 2003).[30] Therefore, accessing technology is part of the superordinate concept of technology sourcing, which additionally comprises tasks such as contracting or supplier management (Kostas Selviaridis, Agndal, & Axelsson, 2011). Due to its central position within the concept of technology adoption (see Section 2.3), accessing technology is influenced by the preceding technology adoption decision, as well as influencing the subsequent integration and diffusion of technological innovations (Rogers, 2003).

An extant body of research has explored technology access modes, which are often also called technology sourcing vehicles.[31] At a general level, three technology access modes can be distinguished (Capron & Mitchell, 2012; Lungeanu, Stern, & Zajac, 2016; Pisano, 1990):

- *Make (internal):* A make refers to the internal development of new products or services. It always implies a promise of future technological innovations and can comprise the opening of an innovation center, the launch of a new process, the creation of a new division, or the establishment of a new project for developing a service (Borah & Tellis, 2014).
- *Buy (external):* A buy means the purchase of an available technological innovation on the market (Capron & Mitchell, 2009). Purchase transactions can reach from an arms-length purchase (the simplest form of a market transaction) over a facilitated purchase (a market transaction with a higher level of interaction than an arms-length purchase) to a collaborative hand-off (market transactions that include high levels of knowledge transfer from the supplier to the buyer) (G. Stock & Tatikonda, 2000).
- *Ally (external):* An ally describes either the formation of an alliance for the joint development of a technological innovation by two or more parties or equity investments (e.g. in a technology supplier). The three types of alliances include

[30] The creation of technological innovations by service firms is a re-invention of existing solutions from the market rather than a complete development by a firm (Rogers, 2003).
[31] Section 3.2 on LSP accessing technology partly contains extended extracts from Appendix B, which should be consulted for a more detailed examination.

joint ventures, strategic alliances, or licensing agreements. Equity investments cover the acquisition of a whole firm, the acquisition of parts of a firm, or the acquisition of research personnel (Borah & Tellis, 2014).[32]

Studies focused on single technology access modes concentrate on what impacts the probability of using a certain access mode (Ahuja, 2000; Dushnitsky & Lenox, 2005). Comparative studies on different technology access modes deal with questions around the choice between selected modes (L. Wang & Zajac, 2007; X. Yin & Shanley, 2008). Firms typically use a mix of different technology access modes (Lamont & Anderson, 1985), also referred to as a portfolio (Lungeanu et al., 2016; Van de Vrande, 2013). This portfolio perspective is gaining in importance because fast technological advancements make it risky to rely on single access modes (Rothaermel & Alexandre, 2009). Firms have to develop capabilities in different technology access modes (Capron & Mitchell, 2009, 2012; Helfat et al., 2006; Leiponen & Helfat, 2010). Findings on the drivers of access mode decisions suggest that financial slack antecedes the choice of technology access modes, because firms with unused debt capacity might increase technology access mode diversity in response to poor innovation performance (Lungeanu et al., 2016). Furthermore, it has been shown that the diversity of technology access modes positively impacts innovation performance (Van de Vrande, 2013). Unsurprisingly, research on the implications of make, buy, and ally decisions typically analyze manufacturing firms from high-technology environments (Kang & Kang, 2009; B. Lin & Wu, 2010). To obtain conclusions for LSPs, it is therefore necessary to check the transferability of the notion of technology access modes for service companies in general and for LSPs in particular.

For service firms, questions relating to the access mode choice is closely related to knowledge sourcing. These firms often do not have comprehensive technological knowledge, which is why they tend to buy it, in conjunction with technological innovations, from outside. This can make sense, as it allows them to focus on their core service competencies instead of building up non-industry technology knowhow (Kang & Kang, 2014). The possibilities of how to access technological innovations as a service firm are congruent with the abovementioned categories, while the external strategies of buying

[32] In the literature, equity investments are often assigned to buy strategies (Borah & Tellis, 2014). As the present research excludes hostile takeovers and assumes a cooperative background for the equity investments, this technology access mode is considered as an ally strategy in the present research.

(e.g. technology purchasing) or allying (e.g. joint development) are more pronounced than the internal making strategy (Kang & Kang, 2014; Mathauer & Hofmann, 2018). The lower the available technological knowhow, the more likely is the choice of purchasing a technological solution instead of a firm developing its own one (Harrigan, 1986; Walker, 1984). Following Grant and Baden-Fuller (2004), it is, from a service provider perspective, more about accessing technological knowledge than about acquiring it.

Research on accessing technological innovations at LSPs is still in its infancy. Scholars have highlighted the relevance of external sources for specialized technology knowledge due to the increasing complexity of logistics services (Chapman, Soosay, & Kandampully, 2003; Konstantinos Selviaridis & Spring, 2007). Bellingkrodt and Wallenburg (2013) thus scrutinized relationships to customers, external service providers, and other LSPs, and investigated their role for LSP innovativeness. Interestingly, they skipped the chosen access mode and thereby impaired their results. This indicates that the latest insights from innovation and strategic management around technology access modes—for instance, the impact of technology access mode choice on innovation performance (Van de Vrande, Vanhaverbeke, & Gassmann, 2010)—have not yet been examined in the research on LSPs. Other studies underline this argument. Chu and colleagues (2018) investigated the impact of special kinds of customer relationships on the speed of logistics service innovation without considering the intermediary stage of technology access. Wallenburg et al. (2019) examined the effect of buyer–supplier alignment on supplier-initiated innovation and also left out a discussion on technology access modes (e.g. alliances for innovation development).

The partial neglect of this topic in LSP-specific research may also be due to the seemingly limited choice of many LSPs in terms of technology access. In his sample of Chinese LSPs, Lin (2007) found only 4% of sample firms to have an R&D department and therefore the possibility of being able to develop logistics innovations on their own. Furthermore, slack resources are the exception rather than the rule at LSPs, which could restrict access mode choice (Lungeanu et al., 2016). Nevertheless, it is undisputed that LSPs are opening up new ways of accessing technology in the meantime (Mathauer & Hofmann, 2019c). The drivers behind this are evident. The rising importance of technologies for service provision manifests itself in the form of increased technological diversity. This development is amplified by the specialization of logistics services, which requires at least the customization of a technological innovation, if not the firm's own developments (Hofmann & Osterwalder, 2017). Standard purchases might still be preferred but can no longer be the single technology access mode.

In reflection of this development, LSPs do not only have to develop the competencies for coping with different technology access modes, but they also need to situationally choose the appropriate one by considering the expected consequences. Knowing about the relationship between technology access strategies and the expected number of resulting innovations—as it is most often investigated for manufacturing firms—is hardly helpful for LSPs. Service companies will find it much more difficult than manufacturing companies to integrate technologies into their service provision, especially if the technologies come from outside the company (Wagner, 2008). Additionally, measures for the success of technology access mode choice should also be oriented toward the customer, as the customer is the center of interest for every service provider (Hipp & Grupp, 2005). Taken together, LSPs have to understand the relationship between technology access modes and the selected dimensions of integration success (e.g. integration speed) so that they know whether they can meet certain customer requirements (e.g. the fast provision of a technology-enabled service) by choosing a certain technology access mode.

It is widely accepted that technology adoption by LSPs is impacted by various factors (C.-Y. Lin, 2008). Being a central part of the technology adoption process, these factors might also play a role in the specific relationship between the technology access mode and integration success. Drawing on the innovation adoption literature and the technology adoption literature with an LSP focus, at least three clusters of relevant factors can be derived (C.-Y. Lin, 2007, 2008; Tornatzky et al., 1990): (1) technology-related factors (e.g. the complexity of the technological innovation); (2) firm-related factors (e.g. the qualification of the LSP's workforce); and (3) environment-related factors (e.g. pressure by competitors who adopt a technological innovation). Additionally, numerous scholars from operations management highlight the role of relationships for technology adoption within supply chains. Against the backdrop of LSPs' special position within the supply chain,[33] relation-related factors are expected to play a major role as well. For

[33] The peculiarities of LSPs are outlined in Section 2.1.

example, Asare and colleagues (2016) found power distribution and trust between supply chain partners to impact the intention to adopt. The role of the aforementioned factors has not yet been explicitly explored for the relationship between the technology access mode and integration success.

3.3 Overview of the research on diffusing technological innovations

In the course of this research, technology diffusion is understood as an interorganizational, information-based process of spreading a technological innovation through certain constellations over time among a social system's members (Rogers, 2003). This definition draws on the notion of Rogers' (1962) IDT, who has equated innovation diffusion with a communication process. The present research focuses on the business-to-business (B2B) context, where interorganizational innovation diffusion starts with the adoption by an initiating firm and can further proceed in a horizontal or vertical direction. In the broad understanding of this work, technology diffusion is seen as part of technology adoption, as adoption and use are not separated from each other (Lanzolla & Suarez, 2012). From an intrafirm perspective, a technology is only adopted after it is also used by a previously defined unit, which presupposes prior diffusion through this unit. From an interorganizational perspective, a technology is adopted if it is used by the affiliated firms who are involved in interorganizational, technology-based service provision.

Reviewing the literature on technology diffusions yields four different perspectives on how the phenomenon can be studied:[34] (1) horizontal intrafirm diffusion, (2) vertical intrafirm diffusion, (3) horizontal interorganizational diffusion, and (4) vertical interorganizational diffusion:[35]

- *Horizontal intrafirm diffusion* is concerned with the spread of a technological innovation within a firm's boundaries. Seminal contributions by Mansfield (1961) and Stoneman (1981) found differences in the speed of diffusion between horizontal intrafirm diffusions, while later studies suggest that a technology's degree of substituting already-existing technologies depends on the adopting firm (Battisti & Stoneman, 2003; Fuentelsaz, Gómez, & Palomas, 2009).

[34] Section 3.3 on technology diffusion by LSPs partly contains extended extracts from Appendix C, which should be consulted for a more detailed examination.
[35] For a more nuanced discussion please consult Appendix C.2.2.

- *Vertical intrafirm diffusion* focuses on how intensively firms use a technology. Cooper and Zmud (1990) provide pioneering insights such as the importance of technology acceptance by employees so that an innovation can be incorporated in daily activities and finally enhance firm performance. Innovation diffusion then becomes measurable and is reflected in productivity, for example (Boothby, Dufour, & Tang, 2010).
- *Horizontal interorganizational diffusion* is most often studied, especially for the adoption of new technologies by independent firms from the same industry. Rogers' (1962) groundwork contributed to the understanding by linking technology characteristics with the adoption rate. Bass (1969) developed a diffusion model that allows to predict the future spread of an innovation in a market based on previous product purchases.
- *Vertical interorganizational diffusion* has been established as the last of the perspectives presented. It was driven by technological developments; namely, the upcoming interorganizational systems that induced scholars to study their adoption in constellations of affiliated companies. Factors preceding interorganizational technology adoption are perceived benefits, organizational readiness, and external pressure (Iacovou et al., 1995).

The majority of diffusion studies from the field of logistics and SCM is concerned with the first three perspectives. *Horizontal intrafirm diffusion* is mostly associated with efficiency wins and therefore what firms should certainly strive for; especially in logistics, where technological innovations typically exhibit high levels of customization and multi-user capability is impaired (F. Lai, Li, Wang, & Zhao, 2008). Tanskanen and colleagues (2015) thus found a standard and efficient set-up of technological innovations to be associated with repeated use. Grawe and Ralston (2019) suggest that task interdependence and intra-organizational face-to-face communication for enhanced cognitive congruence are necessary to improve the diffusion of technological innovations throughout the customer network of LSPs. *Vertical intrafirm diffusion* is important to overcome a divide between adoption and use. If firms do not fully incorporate technological innovations in their activities, they cannot profit from them. Hazen et al. (2012) figured out mechanisms to foster innovation incorporation in SCM contexts, including formal guidance, training programs, or the promotion of key personnel. In another study, Hazen et al. (2014) specifically investigated the diffusion of logistics enterprise architecture within firms and found regulatory guidance, and activities promoting depth, diversity, and breadth of use as especially effective. These studies highlight that the spread of innovation-related information plays a decisive role in vertical diffusions. *Horizontal interorganizational diffusion* has been extensively studied for LSPs, as research on the antecedents, consequences, and the context of technology adoption by LSPs can be assigned to this category (de Oliveira Neto, Costa, de Sousa, Amorim, & Godinho Filho, 2019; C.-Y. Lin, 2008; Wagner & Busse, 2008).

The *vertical interorganizational diffusion* of technological innovations has produced hardly any studies, neither on a general nor on a logistics-related level. Yet the characteristics of the provided services and the diffused technologies in the logistics industry give particular relevance to this perspective. Due to the inexorable vertical division of labor in service industries (MacKenzie, 2008; Walsh & Deery, 2006), the use of subcontractors in the logistics industry has been steadily growing throughout the past 30 years (de Oliveira Neto et al., 2019). If a manufacturing firm (shipper) outsources logistics activities to a 3PL, it is the rule rather than the exception that the 3PL will not conduct the logistics services by itself. Instead, the 3PL is likely to enter into a subcontracting arrangement with a carrier chosen out of a large number of affiliated firms (Y. Li et al., 2009). The subcontractor, in turn, might make use of another subcontractor—a veritable vertical subcontracting cascade emerges that can also be referred to as a multi-level logistics service chain (Cui & Hertz, 2011; Rajahonka, 2013).[36] From a technology adoption perspective, such constellations are challenging. It is no longer sufficient to adopt a technology (e.g. a smart charge carrier) at the level of the 3PL. Instead, technological innovations have to be diffused down the cascade to the technology-user level. This can be particularly challenging concerning hybrid innovations, which consist of soft- and hardware elements (Daugherty et al., 2011; Schmidt et al., 2015). While the hardware must be passed on from the top to the bottom, the accompanying flow of information must be provided from top to bottom and from bottom to top (and maybe to other authorized parties as well).

Indications for the vertical interorganizational technology diffusion at LSPs can be derived from the more general operations management literature with a supply chain focus. Sternberg and Norrman (2017) investigated the diffusion of the Physical Internet. This

[36] For more information on the actors in the logistics service chain see Section 2.1.

concept of collaborative, interoperable, sustainable freight transport is inspired by the digital internet and can only work if all those involved in service provision adopt the technological concept elements. Thus, the setting is comparable to the multi-level logistics service chains on which the service provision of most 3PLs is based. Inspired by research on information systems, they highlighted the role of perceived benefits, organizational readiness, and external pressure as the key drivers of adoption at the firm level (Iacovou et al., 1995; Sternberg & Norrman, 2017). As adoption can vary at the different levels of the logistics service chain, it is necessary to differentiate the individual actors (Lanzolla & Suarez, 2012). Autry et al. (2010) contributed to research on supply chain technology diffusion with their finding that the adoption behavior of firms embedded in supply chains is comparable to individuals, as it is mainly driven by the perception of technology characteristics (e.g. technology usefulness). However, Lyytinen and Damsgaard (2011) highlight that research needs to look beyond the single adopting firm and consider so-called adoption units. Adoption varies depending on the individual supply chain constellation. This also makes sense when being applied to the service chains of LSPs. For example, technology diffusion might be different if subcontractors are involved who are already using the diffused technology for another principal. On the other hand, subcontractors might struggle if they have to use several different technologies for the same principal at the same time (Mathauer & Hofmann, 2019a).

Innovation management researchers have long emphasized the crucial role of information distribution for technology diffusion, especially if the diffusion process is vertically directed (Abrahamson & Rosenkopf, 1997; Davis, 1989; Rogers, 2003). In the interorganizational context, potential disruptions to diffusion are even more likely to stem from information asymmetries between the actors (Akerlof, 1970; Mansfield, 1961, 1968). If there are three or more levels in logistics service chains, the initiating 3PL might face difficulties with passing information down to the user level (e.g. carrier) that would be relevant for the appropriate use. Conversely, it becomes more difficult to control the user level, and information on the actual technology use then reaches the 3PL—if at all—only in a filtered form. Comparable three-level intrafirm settings of information asymmetry have been scrutinized by agency scholars. Tirole (1986), for example, found that new forms of information asymmetries emerge in hierarchical relationships, as supervisors and agents might form coalitions to trick the principal. The information asymmetry characteristics can vary on every level (Wilhelm, Blome, Bhakoo, & Paulraj, 2016). Although such an agency perspective appears promising to approach the underlying information-related challenges in vertical interorganizational technology diffusions, it has not been applied yet (Fayezi, O'Loughlin, & Zutshi, 2012; Wilhelm et al., 2016). For this reason, it has remained unclear as to what the information distribution in logistics service constellations looks like and whether existing governance mechanisms from AT are applicable to overcome the challenges.

3.4 Derivation of research gaps and research questions on the adoption of technological innovations by logistics service providers

Drawing on the literature review in Sections 3.1 to 3.3 allows for the derivation of research gaps and research questions for each of the selected technology adoption activities. The research gaps are addressed with three pairs of research questions. These pairs of research questions do not directly build on each other, but they all contribute to the overall research objective (RO_0). Thus, they are subordinated to an overarching why-question.

Research gaps and research questions for technology searching at LSPs

The analysis of the literature with relevance for technology searching at LSPs has identified the following gaps:

- *LSP-specific research on technology search behavior:* Research on technology search behavior is becoming increasingly popular, but contrary to general innovation management, LSP-specific searching for technological innovations has remained almost uninvestigated.
- *Antecedents of technology search behavior:* Internal antecedents to search behavior are well understood, while external antecedents have hardly been explored. The consideration of threats promises to enrich the scientific debate.
- *Role of firm size for the attention allocation during technology searches:* The growing use of an attentional perspective to examine technology search activities has led to a more profound understanding and should thus be extended to explain the effects of firm size as well.

In consideration of these research gaps, the first two sub-questions ($RQ1_a$ and $RQ1_b$) systematically address the relationship between empirically explored antecedents and technology search behavior at LSPs. As antecedents from the internal firm environment are quite well understood (W.-R. Chen & Miller, 2007; Rhee et al., 2019), the focus is placed on factors from the external firm environment. The ABV (Ocasio, 1997) is used to identify the antecedents, group them into clusters, and assign them to categories of opportunities and threats (Jackson & Dutton, 1988). Furthermore, the ABV serves as a basis for exploring the impact of firm size on the studied relationship. Thus, the first two research questions are derived as follows:

> $RQ1_a$: From an LSP perspective, what factors from the external firm environment antecede organizational technology search behavior?
>
> $RQ1_b$: From an LSP perspective, how does firm size moderate the relationship between external search antecedents and technology search behavior?

Research gaps and research questions for accessing technology at LSPs

Having analyzed the literature with relevance for accessing technological innovations at LSPs, the following gaps have been revealed:

- *LSP-specific research on technology access modes:* Scholars have intensified their research efforts on technology access mode choices by manufacturing firms, whether concerning the antecedents or the consequences. The literature on the technology access by service firms is insufficient and LSP-specific studies do not exist.
- *Implications of technology access mode choice on integration success dimensions*: Existing research has mostly left out a decisive step between technology access and innovation performance: the integration success. Knowledge on the implications of technology access on integration is indispensable for service firms, especially if they externally source technologies they have not been familiar with before.
- *Moderators of the relationship between access mode and integration success:* As the underlying interdependence of the technology access mode and integration success has not yet been researched, it is also unclear which factors moderate this relationship. The relevance of relation-related factors is presumed, but not yet explored.

Considering these research gaps, the second pair of research questions (*$RQ2_a$* and *$RQ2_b$*) aims at carving out the implications of technology access modes for selected integration success dimensions at LSPs. The investigations are informed by IDT (Rogers, 1962), which helps to locate the examined relationship within the notion of technology adoption. An overview of technology access modes is provided and scrutinized from the perspective of LSPs. The empirical analyses furthermore cover the potential moderating effects of the relationship under study (Tornatzky et al., 1990). Absorptive capacity theory (Cohen & Levinthal, 1990; Zahra & George, 2002) serves as a theoretical underpinning of the investigations, as various studies indicate that absorptive capacity is an essential capability for accessing knowledge, especially from external sources (H. Liu, Ke, Wei, & Hua, 2013). The following two research questions will be answered:

> $RQ2_a$: From an LSP perspective, in how far do technology access modes impact the success of the integration process?
>
> $RQ2_b$: From an LSP perspective, which factors moderate the relationship between technology access modes and the success of the integration process, and how can these factors be clustered?

Research gaps and research questions for technology diffusion at LSPs

After analyzing the literature on diffusing technological innovations at LSPs, three research gaps become apparent:

- *Insights on the vertical interorganizational diffusion of technological innovations:* Scholars have examined technology diffusion from different angles but have neglected vertical interorganizational diffusion. This is problematic, as the vertical division of labor by service firms is on the rise, while the accompanying challenges are not sufficiently understood.
- *Systematic empirical analyses of interorganizational, multi-level technology diffusion constellations in logistics:* Multi-level logistics service chains are spreading but have not yet been investigated in terms of technology diffusion. Empirical material on diffusion practices is not yet available.
- *Information asymmetries in interorganizational diffusion constellations*: As technology diffusions can be seen as communication processes based on information transmission, it is surprising that diffusion research has hardly treated the role of

information asymmetries in interorganizational diffusion constellations. Especially in vertical multi-level settings, information asymmetries at different levels must be recognized and overcome. Existing governance mechanisms from dyadic relationships have not yet been reviewed in multi-level service chains.

Concerning the stated research gaps, the last two sub-questions (*RQ3*$_a$ and *RQ3*$_b$) focus on the diffusion of technological innovations in multi-level logistics service chains. Drawing on AT (Jensen & Meckling, 1976), the notion of principal–agent hierarchies is transferred to the interorganizational setting (Tirole, 1986). Different principal–agent constellations are worked out to allow for a more nuanced discussion of information asymmetries by considering the different actors in the supply chain (Wilhelm et al., 2016). In-depth case studies serve as a basis to identify governance mechanisms about different information asymmetry types at different service chain levels. These are used to refine the governance mechanisms known from overcoming information asymmetries in dyadic or intrafirm technology diffusions. As 3PLs typically coordinate technology diffusions in logistics service chain, their specific perspective is chosen for the investigations. Consequently, the following two research questions guide the investigations:

> *RQ3*$_a$: From a 3PL perspective, what are the principal–agent constellations under which technological innovations are diffused in vertical interorganizational settings?
>
> *RQ3*$_b$: From a 3PL perspective, how can information asymmetries of technological innovation diffusions in vertical interorganizational settings be overcome?

By investigating selected technology adoption activities at LSPs (searching, accessing, diffusing), the aim is to close specific gaps in technology adoption research. If the presumed role of interorganizational service chain constellations for information asymmetries during technology diffusion was determined, a substantial contribution to AT could be made. The outcomes shall equip logistics professionals with (1) a better understanding of the drivers behind LSP search behavior, (2) possible implications of technology access for integration, and (3) governance mechanisms to better manage vertical technology diffusions.

4 Theoretical positioning of the research on the adoption of technological innovations by logistics service providers

This chapter addresses the theoretical anchoring of the dissertation. Section 4.1 comprises a detailed overview of the theory selection procedure and presents relevant theoretical perspectives that have been used in recent research on technology adoption. According to this theory selection procedure, four theories were selected for the present study: information diffusion theory, absorptive capacity theory, AT, and the ABV. Sections 4.4 to 4.3 describe these theories in detail, before their application within the scope of this dissertation is illustrated with a theoretical framework in Section 4.6.[37]

4.1 Theory selection procedure

Logistics research does not exhibit a rich history of theory development or empirical research in comparison to more mature academic disciplines (J. Stock, 1997). For this reason, logistics scholars regularly deploy theories from other disciplines (Defee, Williams, Randall, & Thomas, 2010). In the context of technology adoption by LSPs, the application of theories from the following four categories is strongly observed:

- *Social psychology theories*: This theoretical lens can be applied both at the individual level to study human behavior within the organization as well as at the firm level to study organizational behavior. With regard to technology adoption by LSPs, a social psychology perspective is promising for understanding technology searches. Examples are the organizational information-processing theory (Cegielski, Allison Jones-Farmer, wu, & Hazen, 2012) or the ABV (Rhee et al., 2019).
- *Competitive theories*: The overarching focus of competitive theories is the explanation of how firms can achieve a competitive advantage in the market. The knowledge-based theory of the firm is often employed in the context of searching for technological innovations (Snihur & Wiklund, 2019). Absorptive capacity theory provides an understanding for the knowledge-related aspects of accessing technologies (Rothaermel & Alexandre, 2009). Others draw on the resource-

[37] Chapter 4 is partly related to the contents of Sections A.3, B.3, and C.3. Furthermore, the theory selection procedure is inspired by the approaches of previous dissertations written at the Institute for Supply Chain Management, University of St. Gallen, e.g. Hänsel (2018), Oettmeier (2017), and Lampe (2014).

based view when investigating make, buy, or ally decisions in technology sourcing (Borah & Tellis, 2014; Sabidussi et al., 2014). Contingency theory can help to explain impact factors on the individual adoption activities (Zhu et al., 2006).

- *Microeconomic theories*: Mostly applied on a firm level, microeconomic theories assume that the choice of efficient governance models is based on the comparison of different governance institutions (e.g. markets and firms) (Poppo & Zenger, 1998). Following that premise, transaction cost economics is often applied in studies on accessing technological innovations (Geyskens, Steenkamp, & Kumar, 2006; Van de Vrande, Vanhaverbeke, & Duysters, 2009), while AT is becoming increasingly important for governing interorganizational innovation efforts (Fayezi et al., 2012; Wallenburg et al., 2019).
- *Institutional theories*: Institutional theories are concerned with the processes of establishing structures (e.g. rules, routines) as guidelines for the social behavior of firms. The application of institutional theory can regularly be found in operations management, as it, for example, allows for an explanation of how rules are passed on in interorganizational supply chain constellations during technology diffusions (Hazen, Skipper, Ezell, & Boone, 2016).
- *Innovation theories:* Innovation theories are concerned with innovations from their creation to their spread in the market, and can take an individual, firm, or market perspective.[38] The application of IDT is observed both for studies on technology adoption in general as well as for studies on single adoption activities (e.g. diffusing technological innovations) (Hazen et al., 2012).

To select appropriate theories and scientific constructs from the presented categories that provide an explanatory contribution to the technology adoption phenomena under study, requirements for theory application can be derived. Based on the insights of Sections 2 and 3, an applicable theory, therefore, has to fulfill the following *context-specific criteria*:

- Provision of insights on the impact of factors from the external and internal firm environment on the technology search behavior of LSPs (Study A)
- Potential for systematizing the examinations on technology adoption by LSPs on the level of adoption activities (Studies A, B, C)

[38] For a more detailed discussion please consult Section 2.3.

- Acknowledgment of the critical role of information for diffusing technological innovations in interorganizational settings (Study C)

As no theory can be expected to meet all of the stated requirements, applicable theories must furthermore be capable of being integrated with other theories. Adding to the context-specific criteria, Stölzle (1999) identified four categories of *general criteria* to structure theory selection:

- *Theoretical attractiveness:* The theoretical attractiveness results from the existence of a research paradigm and an orientation toward critical rationalism. The former refers to the problem-solving power of a theory, its generalizability, and its precision potential. The latter is concerned with a theory's explanatory contribution as well as its potential to generate hypotheses.
- *Design orientation:* The design orientation includes the existence of design variables, efficiency criteria, and determinants that together allow for the operationalization of the theoretical construct. For the present research, the design orientation requirements are met by a theory if it provides insights into the technology adoption activities of LSPs.
- *Integrative power:* A theory's integrative power stems from its potential for learning and systematization, as well as from its ability to be integrated with other theories. In the context of this dissertation, a theory is considered to have integrative power if it—in combination with other theories—can make a substantial contribution to structuring the analyses on technology adoption activities.
- *Adaptability:* The adaptability of a theory refers to its overall applicability to the specific research context. If a theory meets at least one of the abovementioned context-specific criteria for investigations on selected technology adoption activities by LSPs, it is considered adaptable.

Furthermore, theories are only deemed suitable if they have been applied frequently to explain either technology adoptions (particularly in the context of LSPs) or to examine complex supply chain constellations (particularly for service chains in the logistics industry). With regard to these requirements, the following ten theories from the categories of behavioral, competitive, microeconomic, institutional, and innovation appear to be potentially applicable:

- Absorptive capacity theory
- Agency theory
- Attention-based view
- Contingency theory
- Innovation diffusion theory
- Institutional theory
- Knowledge-based theory of the firm
- Organizational information-processing theory
- Resource-based view
- Transaction cost economics

All ten potentially relevant theories are succinctly described as well as assessed regarding their adaptability to this study on selected technology adoption activities by LSPs.

- *Absorptive capacity theory*: Absorptive capacity is a firm's "ability to recognize the value of new information, assimilate it, and apply it to commercial ends" (Cohen & Levinthal, 1990, p. 128). It can be interpreted as the limit for absorbing technological information and is therefore critical to technology adoption at the firm level (Gassmann, Frankenberger, & Sauer, 2016). The theory implies that a company can absorb all the more knowledge if a lot of knowledge is already available. Zahra and George (2002) reconceptualized the theory and introduced a distinction between potential (receptivity to the acquisition and assimilation of external knowledge) and realized absorptive capacity (capability for the transformation and exploitation of that knowledge). The theory acknowledges the critical role of information in the course of technology adoption and could thus be a suitable theoretical lens.
- *Agency theory*: AT addresses the business relationship between two parties, in which the principal delegates work to an agent who carries out the work (Eisenhardt, 1989a). There are two potential sources of agency problems: (1) conflicting goals of the principal and agent, and (2) an asymmetric information distribution that impedes the verification of the principal's behavior by the agent. To overcome these problems, the theory suggests an efficient contract design. As

subcontracting relationships in logistics service chains are typical agency constellations that may be accompanied by agency problems, the theory seems to apply to the specific research context.

- *Attention-based view*: The ABV draws on the notion that "firm behavior is the result of how firms channel and distribute the attention of their decision-makers" (Ocasio, 1997, p. 187). As the attentional capability of decision-makers is limited, attention can be considered a scarce resource (Ocasio, 2011). In consequence, individuals have to be selective in how they focus their attention, depending on the specific situation and the structural distribution of attention within the firm (Ocasio, 1997). Assuming that the ABV can help to understand the attentional mechanisms underlying searching for technological innovations, the theory is deemed applicable to the present study.
- *Contingency theory*: Contingency theory assumes that organizational effectiveness is about fitting firm characteristics (e.g. structure) to the contingencies of a firm's situation (Donaldson, 2001). A difference can be determined between external (e.g. firm environment) and internal (e.g. firm strategy) contingencies. The theory appears to be relevant because it might help to explain the influence of contingent factors on single technology adoption activities (Frambach & Schillewaert, 2002; Zhu et al., 2006).
- *Innovation diffusion theory*: IDT provides explanations for how innovations spread ("diffuse") through a social system over time (Rogers, 1962, 2003). It is among the most often applied theories for studying innovation-related phenomena and is also frequently used in the logistics context (Holmqvist & Stefansson, 2006; Y. M. Wang, Wang, & Yang, 2010). As the theory provides systematic insights into how technology adoption proceeds, it might be helpful to the present research for structuring purposes.
- *Institutional theory*: Institutional theory "examine[s] the processes and mechanisms by which structures, schemas, rules, and routines become established as authoritative guidelines for social behavior" (Scott, 2004, p. 411). Organizational actions thus reflect patterns of how firms arrived at doing things in the way in which they do them (Eisenhardt, 1988). The underlying assumption of institutional isomorphism assumes that firms are becoming gradually like their peers (DiMaggio & Powell, 1983). Institutional theory is considered to apply to this

research, as the transfer of structures and rules represents an important component of diffusing technological innovations.

- *Knowledge-based theory of the firm*[39]: The knowledge-based theory of the firm views knowledge as residing within individuals so that firms should focus on knowledge application rather than on knowledge creation (Grant, 1996). Implications of the theory relate to "the organizational capability, the principles of organization design […] and the determinants of the horizontal and vertical boundaries of the firm" (Grant, 1996, p. 109). This theory seems less applicable to the research context, because technology adoption is about accessing new technological innovations and the associated knowledge and is not about the application of already-existing knowledge.
- *Organizational information-processing theory*: The organizational information-processing theory assumes that the information level of managers impacts the effectiveness of decision-making (Galbraith, 1974; Tushman & Nadler, 1978). Managers face two major information contingencies (Daft & Lengel, 2008): (1) a lack of information ("uncertainty") and (2) a lack of clarity regarding the available information ("ambiguity"). As the effectiveness of decision outcomes depends on whether the information needs of decision-makers are adequately addressed, firms must adapt their information-processing capacities to overcome the information contingencies. Due to this dissertation's focus on selected technology adoption activities and the explicit exclusion of the actual technology adoption decision, it does not seem purposeful to select a theory that focuses on decision effectiveness.
- *Resource-based view*: Drawing on the resource-based view, firms can achieve a sustainable competitive advantage based on resources that are rare, valuable, non-substitutable, and imperfectly imitable (Barney, 1991). Despite the enormous spread of this theory in management research, the theory is controversially debated in adjacent fields such as operations management because a competitive advantage cannot be directly translated to the level of operations (Bromiley & Rau, 2016). This dissertation does not aim to explain competitive advantage,

[39] The knowledge-based theory of the firm is often also called the knowledge-based view or knowledge-based theory.

which is why the theoretical perspective of the resource-based view is not applicable.

- *Transaction cost economics*: Transaction cost economics is concerned with the costs incurred in business transactions, for example, through negotiating or monitoring (Williamson, 1979). Firms will compare the performance of different governance structures to choose the most efficient and thus less costly ones (Poppo & Zenger, 1998). Transaction cost economics is regularly applied to research around make, buy, or ally decisions, even in SCM (Williamson, 2008). Although the present research includes accessing technological innovations, the focus is placed on the implications of technology access on the integration success rather than on the governance of the technology sourcing transactions. Therefore, the theory is not considered to be applicable in the given context.

Based on a first analysis of the adaptability of the presented theories, only six out of ten generally seem applicable to the specific research context. In the next step, these theories are evaluated concerning the remaining selection criteria by Stölzle (1999); namely, theoretical attractiveness, design orientation, and integrative power. Table 4 presents the outcome of this evaluation.

Table 4. Evaluation of theoretical attractiveness, design orientation, and integrative power

Theory	Theoretical attractiveness	Design orientation	Integrative power	Applicability
Absorptive capacity theory	Extensively applied in innovation management, especially in innovation adoption research (e.g. Fabrizio, 2009; Garcia Martinez, Zouaghi, & Sanchez Garcia, 2019; Rothaermel & Alexandre, 2009)	Explains the choice of different technology access modes based on the capacity to absorb technological knowledge from external sources; the construct is difficult to operationalize (Zahra & George, 2002)	Allows for integration with agency theory (e.g. Zahra, Filatotchev, & Wright, 2009), the attention-based view (e.g. Sakhdari & Burgers, 2018), and innovation diffusion theory (e.g. Gomez & Vargas, 2009)	High
	L H	L H	L H	
Agency theory	Frequently applied in operations management literature, e.g. to study interorganizational innovation in logistics (Wallenburg et al., 2019) or the governance of supply chains (e.g. Wilhelm et al., 2016)	Outlines governance mechanisms to overcome information asymmetries during technology diffusion; can be operationalized transparently, e.g. through contractual stipulations (Eisenhardt, 1989a)	Allows for integration with the attention-based view (Bednar, 2012; Ocasio, 1997) and the institutional theory (Eisenhardt, 1988)	High
	L H	L H	L H	
Attention-based view	Extensively used in innovation management (e.g. Kaplan, 2008), especially for technology search activities (e.g. Laursen, 2012)	Provides explanations for firm behavior during technology adoption based on several attentional mechanisms (Ocasio, 1997)	Allows for integration with absorptive capacity (e.g. Sakhdari & Burgers, 2018) and agency theory (e.g. Bednar, 2012)	High
	L H	L H	L H	
Contingency theory	Often applied in innovation management, e.g. for research on technology adoption (e.g. Bellingkrodt & Wallenburg, 2013; Ketokivi & Schroeder, 2004)	Can be operationalized through various factors, but reaches its limits in rapidly changing technological environments of firms (Donaldson, 2006)	Allows for integration with innovation diffusion theory (Nooteboom, 1994)	Medium
	L H	L H	L H	

Table 4 (continued)

Theory	Theoretical attractiveness	Design orientation	Integrative power	Applicability
Innovation diffusion theory	Extensively applied in innovation management to study innovation adoption at different levels (e.g. Jeyaraj, Rottman, & Lacity, 2006; Y. M. Wang et al., 2010)	Provides different operationalizations for technology adoption patterns and time, which can even be related to innovation attributes (Rogers, 2003)	Allows for integration with absorptive capacity (e.g. Gomez & Vargas, 2009) and contingency theory (Nooteboom, 1994)	High
	L H	L H	L H	
Institutional theory	Extensively applied in general management, but only partly applied in the context of innovation adoption (Defee et al., 2010; Zhang & Dhaliwal, 2009)	Explains how patterns of firm activities evolve, but is very difficult to grasp through operationalization (Donaldson, 2006)	Allows for integration with agency theory (Eisenhardt, 1988)	Medium
	L H	L H	L H	

Notes: L = low, H = high. The black bars visualize the assessment outcomes for the different dimensions

The theories chosen for this research are absorptive capacity theory, AT, the ABV, and IDT. On the one hand, they all meet the theory selection requirements by Stölzle (1999). On the other hand, they jointly fit in the specific research context.

IDT (Rogers, 1962, 2003) is one of the most seminal contributions to innovation adoption research (van Oorschot et al., 2018). Due to its comprehensive treatment of the phenomenon including the consideration of technology characteristics for adoption, it is used to structure the present research. Absorptive capacity theory (Cohen & Levinthal, 1990; Zahra & George, 2002) is also very widespread in the research domain and provides significant insights about accessing technological innovations (Rothaermel & Alexandre, 2009). Furthermore, its integration with AT (Zahra et al., 2009), the ABV (Sakhdari & Burgers, 2018), and IDT (Gomez & Vargas, 2009) has encouraged the choice. The ABV (Ocasio, 1997) is preferred over contingency theory (Donaldson, 2001), as this research is focused more on organizational actions of LSPs during technology adoption than on their organizational characteristics. In contrast to contingency theory, the ABV allows for an explanation of organizational actions when considering organizational characteristics but is not limited to them. AT (Jensen & Meckling, 1976) fosters the understanding of business relationships in interorganizational settings. This is especially important for technology diffusion activities, where asymmetric information distribution might impede appropriate technology use down the service chain. AT is preferred over institutional theory, as the application of institutional theory for interorganizational settings is controversially debated and has prompted researchers to call for a return to the original focus of the theory—the single firm (Royston Greenwood, Hinings, & Whetten, 2014). Furthermore, constructs of the institutional theory (e.g. theoretical logics; Thornton & Ocasio, 2008) are difficult to operationalize, which might be one reason for its rare application in the more operationally-driven logistics context (Defee et al., 2010).

The subsequent Sections 4.2 to 4.5 more deeply outline the four selected theories, assign them to the research questions, and discuss their contributions to the present dissertation. Section 4.6 depicts the research framework, in which the different perspectives are summarized and related to each other.

4.2 Outline of absorptive capacity theory

Introduced by Cohen and Levinthal (1989, 1990), absorptive capacity has developed into one of the most influential constructs of organizational research in the past three decades. It can be understood as a learning process consisting of three components (Cohen & Levinthal, 1990): (1) the identification, (2) assimilation, and (3) exploitation of external knowledge from the firm environment (Cohen & Levinthal, 1990). Identification refers to building up knowledge on certain technologies and on how they are related to the products or services and the market. Assimilation encompasses the processes and routines based on which this knowledge is internally shared. Exploitation finally means the strategic use of knowledge (Lane, Koka, & Pathak, 2006). In their reconceptualization, Zahra and George (2002) extended the concept by adding transformation as the transition between knowledge assimilation and exploitation, and split these routines up into the abovementioned categories of potential and realized absorptive capacity. Absorptive capacity has attracted considerable research attention, also from innovation management scholars. It is undisputed that absorptive capacity is positively related to innovation performance, for example, due to increased innovation abilities (Y. S. Chen, Lin, & Chang, 2009).

Absorptive capacity theory is chosen to investigate the implications of different technology access modes on the integration success in the second research phase ($RQ2_a$). Current contributions highlight that diversity in technology access modes is positively associated with innovation performance (Van de Vrande, 2013). As absorptive capacity is an important factor to achieve diversity in technology access modes (Rothaermel & Alexandre, 2009), this theoretical perspective is considered especially valuable to study the accessing of technological innovations. Zahra and George (2002) introduced a distinction between potential (the capability to acquire and assimilate external knowledge) and realized absorptive capacity (the capability to transform and exploit external knowledge). This notion can be transferred to selected technology adoption activities, as accessing requires potential and integrating realized absorptive capacity. To date, no research is available that has provided this transfer of absorptive capacity to accessing as a selected technology adoption activity.

4.3 Outline of agency theory

AT was introduced more than 40 years ago by Jensen and Meckling (1976). The assumption of an asymmetric information distribution between two contracting parties (principal and agent) is transferable to nearly every business transaction and led to an enormous spread of the theory in social sciences (Eisenhardt, 1989a). In dyadic relationships (e.g. shipper and LSPs), four types of information asymmetries typically occur: (1) hidden characteristics, (2) hidden intention, (3) hidden information, and (4) hidden actions (Jensen & Meckling, 1976; Saam, 2007). They can be overcome with the help of governance mechanisms such as signaling (e.g. an LSP demonstrates technological competence by providing references) or screening (e.g. the shipper controls the technology use of the LSP via a tracking device) (Spence, 1973; Stiglitz, 1975). Although the value of the theory for research in the field of logistics was recognized early on (J. Stock, 1997), the perspective has long received little attention (Fayezi et al., 2012). In the meantime, its application in supply chain settings has sharply increased, as scholars came to appreciate the explanatory contribution to interorganizational constellations (Halldórsson & Skjøtt-Larsen, 2006; Norrman, 2008).

AT is highly attractive for application on the third pair of research questions because it facilitates comprehending technology adoption constellations that exceed the dyad—a typical setting for diffusing technological innovations from the 3PL over an intermediary to the carrier (Cui & Hertz, 2011). Thus, the purpose of applying AT is twofold: (1) understanding the multi-level constellations under which technologies are vertically diffused in interorganizational constellations, and (2) providing guidance for the effective governance concerning potentially occurring information asymmetries ($RQ3_a$ and $RQ3_b$). However, multi-level constellations (also called hierarchies) have only been investigated from an agency perspective in the intrafirm setting to date (Tirole, 1986). As interorganizational principal–agent hierarchies are not yet captured in AT, this dissertation has the potential to yield a theoretical extension. Furthermore, existing governance mechanisms have to be revisited to examine their appropriateness in interorganizational application contexts.

4.4 Outline of the attention-based view

Rooted in earlier contributions on the behavioral firm (Cyert & March, 1963; March & Simon, 1958; Simon, 1947), Ocasio (1997) developed the ABV to explain firm behavior based on attentional mechanisms. Attention refers to “the noticing, encoding, interpreting, and focusing of time and effort” on issues (e.g. problems) and answers (e.g. routines) (Ocasio, 1997, p. 189). Decision-makers have to focus their attention, as their cognitive capacity does not allow them to attend to every issue in the business environment (Monteiro, 2015). This keeps them efficient in their work, but also makes them selective (Ocasio, 1997). In consequence, the appropriate allocation of attention is paramount and impacts decision outcomes and their quality (Ocasio & Joseph, 2005). The theory has influenced various sub-streams of strategic management, for example, top management teams, strategic planning, or technology strategy (Ocasio, Laamanen, & Vaara, 2018). In the meantime, many studies have emerged at the intersection of strategic and innovation management (Kaplan, 2008; Rhee & Leonardi, 2018; Vuori & Huy, 2016), also highlighting the importance of this perspective for studying technology adoption activities.

The ABV is applied to address the first two research questions of this dissertation and thereby responds to calls for more research on the antecedents of attention in general (Gavetti, Levinthal, & Ocasio, 2007) and on attention-driven examinations of technology searches (Q. Li et al., 2013). As this theoretical lens can mirror the complexity of technology search activities in fast-changing firm environments, the application of the theory aims at understanding the drivers behind external technology search behavior by LSPs in reaction to opportunities and threats ($RQ1_a$). Based on the theory's assumption that organizational structure is decisive for attention distribution and, in consequence, also for organizational actions, the ABV shall further help to explain differences in technology searches between large and small LSPs ($RQ1_b$). Search behavior is distinguished into search selection and intensity because the concept of attention also consists of these components (Q. Li et al., 2013). However, this distinction has not yet been incorporated in search studies with an attentional perspective to date. Furthermore, related studies have exclusively focused on the influence of external opportunities on technology searches, but not on threats. Thus, there might be potential for a theory extension.

4.5 Outline of innovation diffusion theory

IDT (Rogers, 1962, 2003) can be regarded as a cornerstone for research on technology adoption. It stimulated academic studies in this field, which have proliferated rapidly over the last 60 years (van Oorschot et al., 2018). Apart from processes for innovation decisions at the individual level and for innovation adoption at the firm level, Rogers (2003) established a relationship between innovation characteristics and the innovation adoption rate. Following his notion, relative advantage, compatibility, complexity, trialability, and observability are positively associated with innovation adoption. Due to the comprehensive treatment of the phenomenon of technology adoption, IDT is the only theory that is used both descriptively and explanatorily.

IDT is applied descriptively for structuring this dissertation's unit of analysis. It allows for deriving the constituting stages of technology adoption (initiation and implementation) as well as the related activities (searching, evaluating, accessing, integrating, diffusing, routinizing) (see Section 2.3). Thereby, the theory contributes to all research phases. Furthermore, the theory enables an understanding of the implications of innovation characteristics on technology adoption activities. Given the dissertation's focus on relatively unexplored hybrid innovations, IDT can thus make a valuable contribution. Rogers (2003, p. 13) was among the first to acknowledge the importance of this innovation type: "[W]e should not forget that a technology almost always represents a mixture of hardware and software." IDT is also applied explanatorily in the second research phase. Thereby, the moderating impact of innovation characteristics suggested by Rogers (2003) is explored in a new context ($RQ2_b$).

4.6 Theoretical framework for the research on the adoption of technological innovations by logistics service providers

Figure 7 depicts the theoretical framework of this study. It serves as guidance for the overall investigations by linking the research context and the applied theories. The framework is based on the managerial and theoretical relevance of the adoption of technological innovations by LSPs presented in Chapter 1, the related fundamentals outlined in Chapter 2, the literature review of selected technology adoption activities in Chapter 3, as well as the theories described in the present chapter. The research pursues a pluralistic approach by drawing on four different theoretical lenses (i.e. the ABV, absorptive capacity, IDT, and AT). This is considered necessary concerning the discussed selection criteria, which could not have been met with a singular theory approach (see Section 4.1).

The investigations are—figuratively speaking—embedded in IDT, as this theoretical lens serves to structure and guide this research. From a single firm perspective, the ABV is used to explain the attentional mechanisms of LSP search behavior when considering firm size. Absorptive capacity helps to grasp the accessing of technological innovations and its potential implications on integration success dimensions at LSPs. As this relationship might be moderated by further factors, IDT is considered regarding technological moderators. From the perspective of a 3PL as part of a multi-level logistics service chain, AT is used to derive interorganizational technology diffusing constellations and potentially occurring information asymmetries.

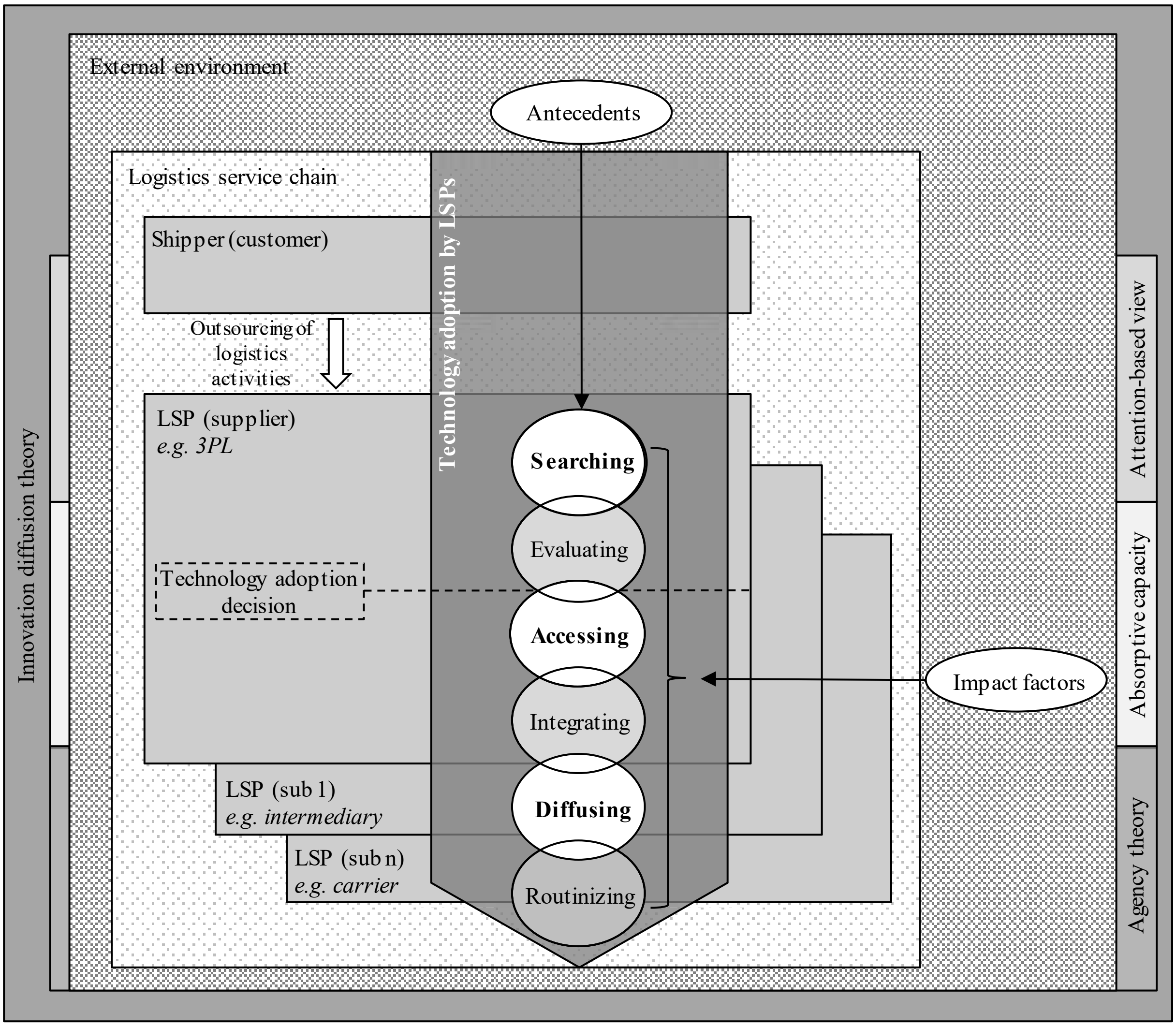

Figure 7. Theoretical framework of the dissertation

5 Studies on the adoption of technological innovations by logistics service providers

Chapter 5 provides an overview of the applied research methodology and the results of the individual studies on which this work is based. In Section 5.1, the research studies are related to each other by taking into account the methodological approach. Sections 5.2 to 5.4 describe the studies in terms of their research design, findings, and key contributions.

5.1 Research overview and methodology

Figure 8 depicts the positioning of the three studies within the theoretical research framework. It is built around technology adoption activities that overlay the actors in the logistics service chain. The highlighted technology adoption activities of LSPs that act as 3PLs on the market serve as the *unit of analysis*. The *unit of observation* depends on the individual study focus. For Study A and Study B, the aforementioned LSPs are exclusively observed, while Study C also includes the other actors of the logistics service chain (shipper, logistics intermediaries, and carriers) in the observations. All actors are surrounded by an external firm environment containing various technological stimuli, which are particularly relevant as antecedents for technology searching (Study A) and as moderators for the relationships of accessing and integrating (Study B) technological innovations.

Due to the different foci of the three studies, each of which is devoted to one selected technology adoption activity, this research is subdivided into the following three research phases:

- *Phase 1*: Examination of the attentional antecedents of technology search behavior at LSPs
- *Phase 2*: Examination of the potential relationship between technology access modes and integration success at LSPs
- *Phase 3:* Examination of the information distribution during technology diffusion in multi-level logistics service chains

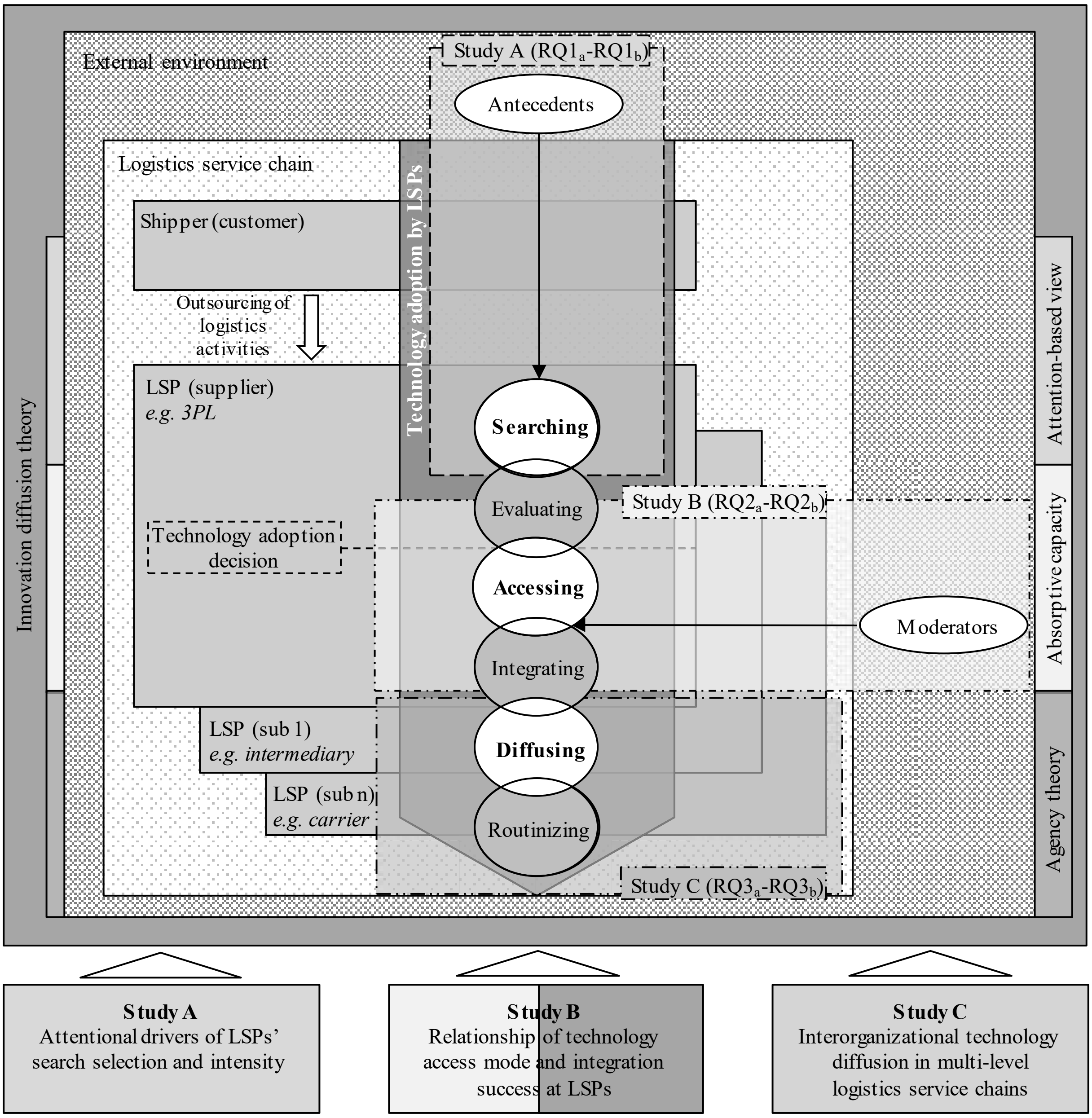

Figure 8. Positioning of the studies on the adoption of technological innovations by LSPs within the theoretical framework

To meet the overarching research objective—an examination of why some LSPs struggle less than others do with selected technology adoption activities under certain circumstances—and to answer the research questions, one study has been conducted in the course of each research phase. As a focus is placed on selected technology adoption activities, the studies provide individual contributions and do not directly build on each other. Nevertheless, they are conceptually interrelated to the extent that they are all part of the concept of technology adoption (Rogers, 2003) (cp. Section 2.3). Other technology adoption activities did not exhibit a similarly compelling degree of managerial relevance (cp. Section 1.1) or were already extensively treated in the literature (cp. Section 2.3 and Chapter 3).

Study A, conterminous with research phase 1, scrutinizes technology search behavior at LSPs. It provides answers to $RQ1_a$ by identifying factors from the external firm environment that antecede searches. Furthermore, and in response to $RQ1_b$, the moderating role of firm size is explored. The ABV is applied to provide insights into the attentional mechanisms that influence search selection and search intensity. As attention structures are related to firm size, this theoretical lens also provides explanations for differences in technology search behavior between large and small firms.

Study B, conterminous with research phase 2, examines different technology access modes (make, buy, and ally) and their influence on integration success dimensions at LSPs ($RQ2_a$). Moderators of this relationship are identified and assigned to different categories ($RQ2_b$). The investigations are based on both standardized and customized technological innovations. IDT is used to structure the activities of accessing and integrating and to understand technology-related moderators, while absorptive capacity theory helps to explain the access mode choice and the associated implications.

Study C, conterminous with research phase 3, analyzes the different constellations of multi-level logistics service chains through which technological innovations are vertically diffused ($RQ3_a$). The information distribution among the actors in the service chain depends on the specific constellations and can lead to information asymmetries. Thus, how such asymmetric distributions of technology-related information can be overcome is further examined ($RQ3_b$). AT serves as the theoretical underpinning, as it can explain different information asymmetry types occurring in certain service chain constellations as well as providing governance mechanisms from intrafirm settings that can be scrutinized for interorganizational constellations. Table 5 presents an overview of the studies conducted in the course of this research.

The choice of the methods applied in each study followed the premise to adequately answer the research questions. While the field of technology adoption is mature and can draw on a wide-ranging body of literature on the one hand, its fragmentation has led to scattered blind spots on the other (van Oorschot et al., 2018). As was shown in Section

2.3, this is true for selected technology adoption activities such as searching (Study A), accessing (Study B), and diffusing (Study 3). Thus, the studies follow qualitative case study approaches.[40]

Table 5. Overview of the three studies on technology adoption by LSPs

	Study A	Study B	Study C
Title	Attentional drivers of technology search behavior at logistics service providers	Technology adoption by logistics service providers	Vertical interorganizational technology diffusion: Principal–agent cascades in logistics
Objective	Identifying factors from the external firm environment that drive technology search behavior at LSPs and understanding the role of firm size in this context	Obtaining insights into the impact of technology access modes on technology integration success at LSPs and identifying potential moderators of this relationship	Analyzing the information distribution in multi-level, interorganizational technology service constellations and obtaining insights into how information asymmetries can be overcome
Related research questions	$RQ1_a$: From an LSP perspective, what factors from the external firm environment antecede organizational technology search behavior? $RQ1_b$: From an LSP perspective, how does firm size moderate the relationship be-tween external search antecedents and technology search behavior?	$RQ2_a$: From an LSP perspective, in how far do technology access modes impact the success of the integration process? $RQ2_b$: From an LSP perspective, which factors moderate the relationship between technology access modes and the success of the integration process, and how can these factors be clustered?	$RQ3_a$: From a 3PL perspective, what are the principal–agent constellations under which technological innovations are diffused in vertical interorganizational settings? $RQ3_b$: From a 3PL perspective, how can information asymmetries of technological innovation diffusions in vertical interorganizational settings be overcome?
Methodology	• Multiple case study design (comparative) • 7 case studies (4 large LSPs and 3 small LSPs) from 16 interviewees, company observations, and additional firm- and technology-related data	• Multiple case study design (general) • 10 case studies at 7 LSPs with 23 interviewees in total, company observations, and additional firm- and technology-related data	• Multiple case study design (multi-level) • 4 case studies from 36 interviewees on different levels of the service chain, company observations, and additional firm- and technology-related data
Applied theories	• Attention-based view	• Absorptive capacity theory • Innovation diffusion theory	• Agency theory

[40] For a detailed outline of methodology choice, please consult the corresponding full papers in the Appendix.

The subsequent subchapters (Sections 5.2 to 5.4) outline the research design, the findings, as well as the key contributions for each research study.

5.2 Study A: Attentional drivers of technology search behavior at logistics service providers

The following Section 5.2 provides a succinct overview of Study A. First, the research design for the investigations on the drivers of LSP search behavior is presented. Second, a focus is placed on the specific contributions, which will be discussed on a more general level in the final chapter of this dissertation.[41]

Research design of Study A

Study A underlines the relevance of attentional processes for understanding the technology search behavior of firms. Decision-makers are selective in what they attend to, which is why search results essentially depend on how attention is organizationally allocated. This finding, together with the lack of studies on the antecedents of searches, motivates Study A's positioning within the context of search behavior in innovation management. The study seeks to alleviate the dearth of knowledge on the external drivers of searches ($RQ1_a$), as internal drivers (e.g. problemistic searches in response to missed financial targets) have predominantly been studied to date. External factors, however, can be expected to be particularly relevant for service firms such as LSPs, whose service provision typically includes an external factor due to the innate customer orientation (see Sections 2.1 and 2.3). Furthermore, existing research falls short in explaining the differences in searching for technological innovations between large and small firms comprehensively or with profound arguments that go beyond resource endowment. Study A follows the notion that firm size impacts the attention structure in organizations and finally results in partially deviating search behavior between large and small LSPs. Thereby, the impact of firm size on the relationship between external antecedents and search behavior is explored from an attentional perspective ($RQ1_b$).

The investigations are based on a comparative case study design including seven LSP cases. *Case selection* followed a two-step sampling logic (Seawright & Gerring, 2008). The first step served to ensure homogeneity among the cases, which was achieved by

[41] Section 5.2 largely draws on extracts from the corresponding full paper in Appendix A.

applying the following four selection criteria derived from the literature (Bastl, Johnson, & Finne, 2019): (1) comparable attention structures, (2) hybrid technological innovations, (3) organizational assignment of technology searches, and (4) basic logistics service providers. In response to emerging patterns from the data, the second sampling step ensured that comparable groups of large and small firms were included in the sample. Eisenhardt (1989b) highlights the value of such adjustments in theoretical sampling during case study research. *Data collection* involved 16 semi-structured interviews with decision-makers who held senior positions in general management or held technology search functions. The interviews were supplemented by informal follow-up interviews whenever necessary. To prevent retrospective biases and to achieve data triangulation, archival material on both the firm and the technology under study supplemented the interviews (Strauss, 1987; R. K. Yin, 2017). *Data analysis* started with comprehensive descriptions of each case (Hannah & Eisenhardt, 2018). Next, the qualitative data-analysis approach by Glaser (1978) was applied, including open, selective, and theoretical coding. Finally, a cross-case analysis based on tables helped to carve out in a pairwise manner the differences between firms, before the whole groups of large and small firms were contrasted (Eisenhardt, 1989b; Eisenhardt & Bourgeois, 1988).

Findings and contributions of Study A

The results of the exploratory research identify factors from the external firm environment that antecede technology search behavior at LSPs. These search drivers can be classified into two groups: opportunities and threats. While the opportunities include customer- and market-related factors, the threats consist of market- and technology-related factors. The effect of the antecedents on technology search behavior is moderated by firm size, with an impact on both the breadth (search selection) and the depth of the search (search intensity). An ABV proves to be particularly valuable in explaining these findings. For example, if there is an opportunity to solve a customer problem through a technological innovation, small firms tend to increase search breadth and search intensity, while large firms just increase search intensity. This is due to different attentional structures depending on the firm size: The search principle of large LSPs might be more holistic than that of small firms, where an external search trigger from the customer is required to widen the search. Thus, firm size is innately associated with different attention structures, which influence the attention focus by decision-makers and the resulting search behavior of the firm. Table 6 presents an overview of the propositions and moderating effects derived from the case study analysis.

The study contributes at least threefold to theory building on organizational searches as a technology adoption activity. First, it directs the current debate on the antecedents of search behavior from internal to external factors—which are becoming increasingly important in a service economy. The most often studied concept of inside-out problemistic searches (search behavior impacted by an internal problem) is complemented by the notion of outside-in problemistic searches (search activities impacted by an external problem). Furthermore, a new category of external search antecedents is established beside the existing category of opportunities: external threats. Although Ocasio (1997) already pointed out that threats have the potential to attract attention, their impact on search behavior has not yet been empirically investigated. Second, the conceptualization of search behavior with its two constituents of search selection and search intensity is transferred to the organizational level. Li and colleagues (2013) introduced this distinction based on attentional mechanisms, but tested it only on the individual level. Third, firm size is suggested, from the attention-based research on search activities, as an important impact factor on attention structures, which is why it unfolds considerable moderating effects on the studied relationship.

With regard to MC1, decision-makers at LSPs will profit from the insights of the study, as their searching for technological innovations—especially in small firms—is often conducted opportunistically and seemingly without a higher-level logic. The study allows them to understand the drivers behind their behavior, which should help them to scrutinize and adjust their existing practices. For example, technological uncertainty seems to be positively associated with search breadth and search depth at large LSPs but is negatively associated with both dimensions of search behavior at small LSPs. If large LSPs want to become more efficient in their search behavior, they should ensure that they do not to chase after every trend, but they should define, for example, technology maturity levels that need to be met before additional resources are allocated to search activities. Small LSPs that want to become more innovative, in contrast, should find ways to better cope with technology uncertainty and overcome the prevalent anxiety of the new. In consequence, the study allows for more efficient resource allocation during technology searches and accounts for size effects as well. Knowing about the typical search behavior of competitors also opens up the possibility of pursuing a counterintuitive strategy and thus being one step ahead in the highly competitive logistics market. Shippers can also benefit from the insights. Knowhow about how to grasp attention proves to be very helpful in consciously steering the behavior of logistics suppliers concerning desired technological innovations.

Table 6. Overview of the derived propositions of Study A

Dimension	Proposition/ Moderator	Description
Opportunity for a positive perception by the customer	P1	The opportunity for a positive perception by the customer antecedes the technology search behavior of LSPs.
	Moderator of P1	The relationship between a positive perception by the customer and the technology search behavior of LSPs is moderated by firm size, so that large firms increase search selection and intensity, while small firms increase search intensity.
Opportunity for solving a customer problem	P2	The opportunity for solving a customer problem antecedes the technology search behavior of LSPs.
	Moderator of P2	The relationship between the opportunity for solving a customer problem and the technology behavior of LSPs is moderated by firm size, so that large firms increase search intensity, while small firms increase search selection and intensity.
Opportunity for market expansion	P3	The opportunity for market expansion antecedes the technology search behavior of LSPs.
	Moderator of P3	The relationship between the opportunity for market expansion and the technology search behavior of LSPs is moderated by firm size, so that large firms increase search selection and search intensity, while small firms decrease search selection and intensity.
Threat of a direct competitor adopting a technology	P4	The threat of a direct competitor adopting a technological innovation antecedes the technology search behavior of LSPs.
	Moderators of P4	The relationship between the threat of a direct competitor adopting a technological innovation and the technology search behavior of LSPs is moderated by firm size, so that large firms increase search intensity, while small firms increase search selection and intensity.
Threat of business segment substitution	P5	The threat of business segment substitution due to a technological innovation antecedes the technology search behavior of LSPs.
	Moderators of P5	The relationship between the threat of business segment substitution due to a technological innovation and the technology search behavior of LSPs is moderated by firm size, so that both large and small firms increase search selection and intensity.

Table 6. (continued)

Dimension	Proposition/ Moderator	Description
Threat of technological uncertainty	P6	The threat of the technological uncertainty of a technological innovation is related to the technology search behavior of LSPs.
	Moderators of P6	The relationship between the threat of the technological uncertainty of a technological innovation and the technology search behavior of LSPs is moderated by firm size, so that large firms increase search intensity, while small firms decrease search selection and intensity.

5.3 Study B: Technology adoption by logistics service providers

Section 5.3 is devoted to the research on the effects of technology access mode choice on the integration success at LSPs, which has been conducted in the course of Study B. Both theoretical and managerial contributions are outlined to make the most important results readily apparent.[42]

Research design of Study B

Study B starts after a technology adoption decision has been made and deals with accessing technological innovations. The antecedents and consequences of different access modes (make, buy, ally) have attracted considerable research interest throughout the years. Currently, the debate is gaining momentum, because the multitude of available technologies more often requires the situation-specific selection of appropriate technology access modes (Lungeanu et al., 2016). While the overall effects of sourcing portfolios on innovation performance have been investigated (Van de Vrande, 2013), the implications of specific technology access modes on integration success dimensions have remained unexplored. Thus, Study B addresses this gap and investigates to what degree technology access modes prejudge the acceptance, process quality, speed, and costs of technology integration at LSPs ($RQ2_a$). Besides, potential moderators of this relationship are identified and clustered ($RQ2_b$).

The study pursues a multiple case study approach to cover a wide variety of technological innovations. It draws on ten different technology projects from seven LSPs. For *case selection*, a two-step sampling logic was applied (Seawright & Gerring, 2008). To

[42] Section 5.3 largely draws on extracts from the corresponding full paper in Appendix B.

ensure homogeneity of the sample in a first step, all case firms had to be open toward new technologies, stem from the German-speaking part of Europe, and adopt a technological innovation that was new to the direct competitive environment as well as to the individual LSP. The second sampling step should also lead to a certain degree of heterogeneity by making sure that the companies differed in size, owner structure, and their scope of services. Such diverse sampling for multiple case studies increases the generalizability of the results (Eisenhardt, 1989b). Furthermore, one unsuccessful technology project was incorporated as well to be able to draw comparative conclusions (Mena, Humphries, & Choi, 2013). Twenty-three semi-structured in-depth interviews with people from the corporate and the business level found their way into the study. *Data collection* additionally included archival material (e.g. company documents, company websites, internal documents on technology projects) and records from site visits for data triangulation (R. K. Yin, 2017). *Data analysis* was based on the qualitative approach by Strauss and Corbin (1990). A within-case analysis allowed the individual cases to be fully grasped, before a cross-case analysis served to identify common patterns between cases. This was especially helpful to carve out the moderating factors of the relationship under study.

Findings and contributions of Study B

The results of Study B show that technology integration success at LSPs is dependent on technology access mode choice and—if a buying strategy is pursued—the type of the adopted technology. If, for example, a standardized software or hardware technology is purchased “off the shelf,” integration seems to be particularly fast and cheap. This relationship holds for customized hardware as well, but not for customized software. Acceptance by the customer and the firm’s own employees can be achieved through the firm’s own development of technological innovations or by it entering into strategic alliances. The highest level of process quality is induced with ally strategies (either strategic alliances or participation with suppliers). The effects of technology access-mode choice on integration success are moderated by various factors, which can be grouped into the categories of technology-related, firm-related, environment-related, and relation-related. Table 7 depicts the results of the study in the form of propositions.

Study B offers various theoretical contributions to the innovation adoption literature at the intersection of the strategic and innovation management literature. As one of the first studies of its kind, it differentiates between the technology adoption decision and the decision on the type of technology access. Drawing on IDT (Rogers, 2003), the process of technology adoption by LSPs is refined and the underlying activities (e.g. accessing and integrating) are scrutinized. Also, the strategic management literature will profit from a more nuanced discussion of technology access mode implications on success, as Study B shows integration success to precede overall innovation performance. Furthermore, the study reveals a new application field for absorptive capacity theory by relating this theoretical construct to specific technology adoption activities (potential absorptive capacity for accessing technological innovations and realized absorptive capacity for diffusing them). The view through this theoretical lens allows, for example, for a better understanding of the differences between large and small firms concerning technology access mode choice and the corresponding integration success. For instance, higher levels of potential absorptive capacity allow for more technology access mode diversity at large LSPs. Besides the direct effects of technology access modes on integration success, Study B contributes to the technology adoption literature through the identification of factors moderating the specific relationship under study. The often applied technology–organization–environment framework (Tornatzky et al., 1990) for studying technology adoption at LSPs is supplemented by a further category with particular relevance for research in logistics and SCM: relation-related factors, including power and trust.

With regard to MC2, practitioners from the field of logistics are provided with a new perspective on managing accessing technology. The insights of Study B show that it might make sense to evaluate different technology access modes depending on the specific situation; that is to say, depending on what is intended through the adoption of a technological innovation. Technology access-mode decisions at LSPs are typically dominated by the associated direct costs and availability (often there appears to be only one access option). As the results show, these considerations do not go far enough. On the one hand, a more expensive technology access mode might, for instance, lead to higher process quality and thereby raise the level of customer satisfaction. On the other hand, building up different technology access modes positively impacts absorptive capacity and might lead to the improved access of technological innovations in the long run. Other insights for decision-makers at LSPs are provided by the discussion on the results from different angles such as the owner structure of the firm or the scope of services. The role of relation-related factors, for instance, should be made clear to all those who work in family businesses. Relationships can be used here as a lever to increase the success of the integration process. For managers in basic LSPs, firm-related moderators are of particular interest as they allow them to tap efficiency potential.

Table 7. Overview of the derived propositions of Study B

Dimension	Description
Relationship between accessing and integrating technological innovations at LSPs	*P1*: From an LSP perspective, buying standardized technological innovations (hardware and software) is positively associated with a fast and cost-efficient integration process.
	P2: From an LSP perspective, buying customized hardware technological innovations is positively associated with a fast and cost-efficient integration process. This relationship does not hold for customized new software technologies.
	P3: From an LSP perspective, entering into a strategic partnership to co-develop technological innovations is positively associated with a cost-efficient integration process and high process quality.
	P4: From an LSP perspective, participating with a technology supplier to access technological innovations is positively associated with high innovation acceptance and process quality.
	P5: From an LSP perspective, developing proprietary technological innovations is positively associated with high innovation acceptance and fast integration.
Moderators of the relationship between accessing and integrating technological innovations at LSPs	*P6*: From an LSP perspective, the effects of technology access modes on the success of the integration process are moderated by complexity, trialability, and the relative advantage of the technological innovation, so that the first impairs and the latter two enhance process success dimensions (acceptance, process quality, speed, and costs).
	P7: From an LSP perspective, the effects of technology access modes on the success of the integration process are moderated by technological compatibility and employee qualifications, so that process success dimensions (acceptance, process quality, speed, and costs) are enhanced.
	P8: From an LSP perspective, the effects of technology access modes on the success of the integration process are moderated by environmental uncertainty and competitive pressure, so that process success dimensions (acceptance, process quality, speed, costs) are enhanced.
	P9: From an LSP perspective, the effects of technology access modes on the success of the integration process are moderated by power and trust, so that process success dimensions (acceptance, process quality, speed, and costs) are enhanced.

5.4 Study C: Vertical interorganizational technology diffusion: Principal–agent cascades in logistics

Section 5.4 presents Study C's research on diffusing technological innovations in multi-level logistics service chains. Following the structure of the two previous subchapters, a short overview of the research design is provided. Afterwards, the contributions of the study are outlined with regard to their theoretical and managerial relevance.[43]

Research design of Study C

Study C applies the specific 3PL focus and investigates the interorganizational diffusions of technological innovations. Scholars highlight the relevance of subcontracting in logistics service chains (Cui & Hertz, 2011), but have almost exclusively studied the vertical diffusion of technologies within firms to date (Hazen et al., 2014). This is not sufficient, because the governance of information distribution is particularly challenging in interorganizational diffusion settings. Study C addresses these shortcomings in the literature and takes an agency perspective to systematically examine vertical technology diffusion in multi-level logistics service chains. The elaboration of different principal–agent constellations helps to identify and locate different information asymmetry types during diffusion ($RQ3_a$). These insights are used for carving out appropriate governance mechanisms by considering the individual service chain levels ($RQ3_b$). As only the 3PL can design governance mechanisms for the whole service chain, this perspective is chosen, while the other actors in the service chain are also observed.

Due to the underexplored nature of the phenomenon, the study draws on a multi-level case study approach consisting of four deep-dive cases. A theoretical sampling logic guided *case selection* and was based on the following four criteria derived from the literature (Eisenhardt, 1989b): (1) the stability of interorganizational relationships, (2) multi-level service chains, (3) hybrid technological innovations, and (4) the application of different governance mechanisms. Each case included a service chain with at least three levels. Once a key company had been identified, contact was established with the other companies in the service chain via this company (Bastl et al., 2019). *Data collection* started by collecting information on the diffused technology from the respective key company before the interviews. This information was supplemented by additional

[43] Section largely draws on extracts from the corresponding full paper in Appendix C.

secondary data sources on the technology, which together allowed the researchers to pre-discuss individual diffusion mechanisms that were accounted for in the interview guides (Vaskelainen & Münzel, 2018). In total, 36 interviews were conducted in ten different organizations. The combination of the interviews with records from company visits, archival data on the technology, and additional firm-related data from databases allowed for data triangulation (T. Choi & Hong, 2002). *Data analysis* was guided by Glaser's (1978) approach for qualitative data analyses. As described for Study B, both a within-case analysis and a cross-case analysis were conducted.

Findings and contributions of Study C

The findings of Study C reveal the emergence of principal–agent cascades and different sub-constellations during the vertical technology diffusion in logistics service chains. Sub-constellations that are prone to asymmetric information distribution among the actors are one technology–multiple principal (the agent uses the same technology for different principals) and multiple technology–one principal constellations (the agent uses different technologies for the same principal). The occurrence of information asymmetries mainly depends on three aspects that are closely related to the constellations of diffusion: (1) technological diversity, (2) the breadth of the principal–agent cascades, and (3) the depth of the principal–agent cascades. As an extension to previous research (cp. Eisenhardt, 1989a), Study C suggests, for example, that information systems do not counteract information asymmetries in every case. While technological innovations acquiring data for the 3PL (primary principal) are negatively associated with hidden information and hidden action at the user level (due to the facilitated control possibilities for the 3PL), the hidden intentions of the primary principal might occur, as subsequent levels cannot control what the 3PL intends to do with the data. Study C therefore makes explicit that interorganizational technology diffusions are accompanied by information asymmetries that can differentiate depending on the service chain level. To overcome these information asymmetries, collaborative governance mechanism design, contracts that incorporate the degree of technological interaction, and adjusted forms of mutual monitoring appear to be especially promising. The results of Study C are derived in the form of observations and are presented in Table 8.

Study C is theoretically positioned as one of the very few research pieces to empirically investigate vertical interorganizational technology diffusions and thus offers wide-ranging insights for innovation and strategic management. By applying an agency perspective on technology diffusion in complex service chains, Study C contributes to the current efforts of extending AT to business relationships that exceed the dyad. Scholars have already investigated intrafirm principal–agent hierarchies (Tirole, 1986), as well as interorganizational double-agency constellations (Child & Rodrigues, 2003; Wilhelm et al., 2016) and multiple agency constellations (Arthurs, Hoskisson, Busenitz, & Johnson, 2008; Child & Rodrigues, 2003). Study C, however, is the first one to theoretically transfer principal–agent hierarchies to interorganizational settings and to empirically examine the resulting principal–agent cascades. This allows for a more nuanced discussion of potentially occurring information asymmetries, as a differentiation can (and must) be made between the different service chain levels (primary principal, secondary principal, etc.). Besides, known governance mechanisms and their underlying logics are revisited to evaluate their applicability to interorganizational constellations. Thereby, existing governance mechanisms are extended (e.g. linking contract design to the application context of the diffused technology) and new governance mechanisms suggested (e.g. rotation-based monitoring).

With regard to MC3, the study makes a considerable contribution to helping practitioners become aware of different constellations of technology diffusion and thus learn to recognize the challenges of potential information asymmetries. By analyzing the individual service chain setting and the characteristics of the technological innovation to be diffused, managers can apply the study insights to anticipate possibly occurring information asymmetries *ex ante*. Also, Study C proposes governance mechanisms that appear suitable for tackling information asymmetries in a targeted manner, taking into account the affected levels in the service chain. Thus, the insights might also be helpful to actors in the logistics service chain that differ from the 3PL. Especially the technology-user level could proactively support the implementation of governance mechanisms, for example, by offering joint governance mechanism designs. Besides positive effects on technology diffusion, this could become an increasingly important way of differentiation in a highly competitive environment.

Table 8. Overview of the derived observations of Study C

Dimension	Description
Information asymmetries: Technological diversity	*O1a*: Technological innovations that acquire usage data exclusively for the primary principal are negatively associated with hidden information and hidden action at the technology-user level. *O1b*: Technological innovations that acquire usage data exclusively for the primary principal are positively associated with the hidden intention, hidden action, and hidden transfer of the primary principal.
	O2: The increasing integration of technological innovations is positively associated with hidden action and hidden transfer at the technology-user level.
Information asymmetries: Breadth of principal–agent cascade	*O3*: One technology-multiple principal constellations are positively associated with the hidden information of the secondary principal.
	O4: Multiple technology-one principal constellations are negatively associated with hidden characteristics and hidden intentions at the subsequent levels.
Information asymmetries: Depth of principal–agent cascade	*O5*: An increasing number of principal-agent cascade levels during technology diffusion is positively associated with hidden transfers at the subsequent levels.
Governance mechanism design	*O6*: Active involvement of the subsequent levels for the design of governance mechanisms during technology diffusion is negatively associated with hidden characteristics, hidden intention, and hidden information.
	O7a: Outcome-oriented contracts are negatively associated with hidden actions at the technology-user level if there are high-interaction constellations between the technology-user level and the technological innovation. *O7b*: Behavior-oriented contracts are negatively associated with hidden actions at the technology-user level if there are low-interaction constellations between the technology-user level and the technological innovation.
	O8: A quasi-principal role of the consignee for mutual monitoring is negatively associated with hidden actions at the technology-user level.
	O9: Rotation of the principal's people who are in direct contact with and control agents during technology diffusion is negatively associated with hidden transfers at the subsequent levels.

6 Conclusion of the research on the adoption of technological innovations by logistics service providers

After a detailed consideration of the individual studies in Chapter 5, the following Chapter 6 takes a broader perspective. Section 6.1 complements the answers to the research questions through a reflection on the contributions from Studies A–C to the other technology adoption activities that have not been the focus of this dissertation. Furthermore, the theoretical contributions are outlined on a general level. Section 6.2 discusses the managerial implications of this work and exceeds the level of the individual studies to provide more general recommendations. The last Section 6.3 addresses the limitations of this dissertation and provides areas for future research.

6.1 Overall contributions of the studies

This section aims to put the findings of this dissertation into the overall research context. For this purpose, the answers to the research questions are briefly summarized. Afterwards, the implications of the findings are discussed for other technology adoption activities. The section culminates in a reflection on the theoretical findings of the individual studies on a more general level.

Answers to the research questions

In summary, Studies A–C were each focused on one selected technology adoption activity of LSPs: Study A examined the antecedents of *searching* for technological innovations, Study B investigated the potential impact of *accessing* technological innovations on integration success, and Study C scrutinized *diffusing* technological innovations in vertical interorganizational logistics service chains. The answers to the research questions are briefly outlined hereafter.

Study A, which reveals the antecedents of LSP search behavior from the external firm environment, provides answers to $RQ1_a$ and $RQ1_b$. Concerning $RQ1_a$, it finds customer-related (an opportunity for a positive perception by the customer and an opportunity for solving a customer problem), market-related (an opportunity for market expansion and the threat of a direct competitor adopting a technology), and technology-related (the threat of business segment substitution and the threat of technological uncertainty) drivers of technology searches. Their impact on search selection (breadth of search) and search intensity (depth of search) varies individually depending on firm size (answer to $RQ1_b$). By applying an ABV, the study can grasp the complex cognitive processes underlying organizational search behavior. Firm size unfolds a moderating effect due to the potentially different attention structures of large and small firms. The study contributes to the overarching research objective (RO_0), as it finds that those LSPs that have little difficulty in searching for technological innovations are aware of what drives their attention during searches and they allocate resources more effectively.

Study B, which uncovers the effect of technology access modes on the integration success at LSPs, provides answers to $RQ2_a$ and $RQ2_b$. In response to $RQ2_a$, it finds accessing technological innovations via makes (own development), buys (purchase of standardized or customized solutions), and allies (strategic alliances or participation with suppliers) to impact the integration success. Their impact is different for the integration success dimensions of internal and external acceptance, process quality, speed, and costs. The relationship between technology access modes and integration success is moderated by factors from the spheres of technology (e.g. complexity), the firm (e.g. employee qualifications), the environment (e.g. environmental uncertainty), and relationships (e.g. trust) (answer to $RQ2_b$). Depending on specific firm characteristics (e.g. firm size), some moderating effects might be more important than others. Drawing on IDT, the technology adoption activities of accessing and integrating are untangled. The application of absorptive capacity theory helps to explain why firms with a wide variety of technology access modes face fewer difficulties in accessing technological innovations than others do: They exhibit higher levels of absorptive capacity. This is an important finding with regard to RO_0.

Study C, which identifies potential information asymmetries during technology diffusions in logistics service chains and governance mechanisms to overcome them, provides answers to $RQ3_a$ and $RQ3_b$. It finds principal–agent cascades (consisting of shippers, 3PLs, logistics intermediaries, and carriers) to emerge in vertical interorganizational technology diffusions. More precisely, the sub-constellations of one technology–multiple principal and multiple technology–one principal have different effects on the existence of information asymmetries ($RQ3_a$). Besides this breadth of the constellations, also their depth (number of levels) and the characteristics of the diffused technology (e.g. degree of integration) influence the occurrence of information asymmetry types (hidden characteristics, hidden intention, hidden information, hidden action, and hidden transfer) at different service chain levels. To answer $RQ3_b$, four governance mechanisms (active involvement of subsequent levels, contract design based on technological interaction, quasi-principal monitoring of the consignee, and rotation-based monitoring of the principal's people) are suggested. From a theoretical perspective, the results contribute to transferring the idea of principal–agent hierarchies to the interorganizational context. Concerning RO_0, it can be stated: LSPs who master the diffusion of technological innovations without a major struggle are aware of the associated diffusion constellations and their impact on information asymmetries in order to proactively prevent information asymmetries.

Implications for other technology adoption activities

Although Studies A–C aimed to examine one selected technology adoption activity each, the results imply contributions to the other activities of technology adoption as well. As outlined in Section 2.3, *evaluating*, *integrating,* and *routinizing* are further constituents of technology adoption. In the following, the results are briefly discussed in the light of these activities.

Evaluating technological innovations can be seen as "reality testing" (Rogers, 2003, p. 423). It is about matching a technology with the needs of the organization by considering what a positive adoption decision could mean for the implementation (Rogers, 2003). Findings from all three research phases of this dissertation provide implications for evaluation. Study A investigated searching separately from evaluating, as a technology must first be identified before proceeding further. In practice, however, it is common that searching and evaluating are conducted by the same person and therefore flow into each other (Scheiner et al., 2015). Even if there are separate responsibilities for searching and evaluating, people who assess an innovation should know the drivers behind searching. As was shown by Study A, technological uncertainty is, for example, negatively associated with search breadth and search depth at small firms. This inevitably results in an incomplete basis for evaluation. If the person responsible for evaluation is aware of the attentional mechanisms behind the search, he or she can adjust the search activities to achieve a more comprehensive basis for evaluation. Furthermore, Study B provides insights for the assessment of a technology's implications for integration. A direct relationship between the technology access mode and integration success was identified, which suggests that the available access modes should be considered in any evaluation

(Lungeanu et al., 2016). Study C delivers further findings for incorporation into evaluation activities. The specific service chain constellation has implications for the occurrence of information asymmetries during technology diffusion. Thus, evaluation could be improved by considering factors beyond the boundaries of the firm such as the concrete service chain constellation, including subcontractors.

Integrating technological innovations refers to their incorporation into organizational procedures (Cooper & Zmud, 1990). The integration is part of the implementation stage of technology adoption and starts after a technology has been accessed, so that particularly the findings from Study B and Study C appear to be relevant for this technology adoption activity. Study B is positioned at the intersection of accessing and integrating technological innovations and suggests that the chosen technology access mode already indicates which dimensions of integration success will be particularly pronounced. This can be helpful in setting an appropriate focus during integration. While buying a technological innovation, for instance, this potentially allows for high levels of cost efficiency and process quality, but the acceptance level might be low. Integration efforts should therefore focus more on improving these aspects. The value of this rationale becomes apparent when reflecting on the fact that there are always different integration levels that should be considered (Lapointe & Rivard, 2007), with the most coarse distinction being between the firm and individual level. Especially the individual level plays a decisive role in successful integration, as innovations need to be personally accepted (Beaudry & Pinsonneault, 2010). Despite the firm-level focus of Study B, it also allows decision-makers to assess when the focus should be placed on the individual level for a particular technology adoption so that there is improved internal or external technology acceptance. Furthermore, Study C provides directions for tackling information asymmetries in vertical interorganizational hierarchies. However, vertical hierarchies are also found during integration within firms (Hazen et al., 2014; Zmud & Apple, 1992), and so are the accompanying information asymmetries (Tirole, 1986). As the governance in vertical intrafirm technology diffusions (which equals integration in this case) can be regarded as less complex than in vertical interorganizational diffusions, the suggested governance mechanisms of Study C should also be applicable to intrafirm settings. Thus, the insights of Study C are helpful to increase the probability of integration success through overcoming potential information asymmetries already during technology integration.

Routinizing, finally, is concerned with what every firm that adopts technological innovations should ultimately strive for: Their use as an integral part of the firm's own value chain activities (Zhu et al., 2006). Technology adoption is not complete until routinization can be achieved (Rogers, 2003). This technology adoption activity is challenging, because, for multi-level service chains, routinization affects all firms that contribute to the technology-based service provision. Thus, especially Study C provides useful insights. Drawing on an agency perspective, Study C determines how interorganizational governance can be designed to make the occurrence of information asymmetries during technology diffusions less likely. This is also relevant for routinizing activities that follow technology diffusion because routinization always implies an adjustment of the organizational governance systems (Zmud & Apple, 1992). However, the majority of studies on routinization take a firm-level perspective (Hazen et al., 2012), which is why their findings cannot be transferred unreservedly to logistics service chains. Study C's findings might therefore be helpful to firms so that they can reconcile governance mechanisms that promote routinization at the firm level with governance mechanisms that have proven to be effective at the interorganizational level. For example, training sessions have been found to encourage the routinization of innovations (Hazen et al., 2012). Study C suggests that joint governance mechanism design, for example, in the form of writing standard operating procedures together with the technology supplier and the actual user levels, helps to overcome information asymmetries during technology diffusion. Drawing on these findings, decision-makers could already design governance mechanisms for technology diffusion in such a way that they would also be beneficial for later routinization. Thereby, they will increase the probability of finally completing a technology adoption.

Theoretical contributions

Sections 5.2 to 5.4 elaborate on the individual theoretical contributions of Studies A–C. When reflecting on the entire dissertation project, the following section serves to show the aggregate theoretical contributions of this research and to relate them to the theoretical shortcomings derived at the beginning (Section 1.2). While the dissertation is rooted in innovation management, the contributions also diffuse into the operations management, service management, and strategic management literature.

TS1, which refers to the undifferentiated treatment of technology adoption by many scholars, manifests itself at least twofold in the literature on technology adoption: (1) a prevalent focus on dichotomous adoption decisions (C.-Y. Lin, 2007, 2008) and (2) a missing holistic view on the phenomenon (van Oorschot et al., 2018). This dissertation addresses these shortcomings by examining the almost neglected technology adoption activities at LSPs (i.e. searching, accessing, and diffusing). It therefore contributes empirically to the completion of the insights into the concept of technology adoption at LSPs, which encompasses activities ranging from searching to routinizing (Rogers, 2003). As the findings show, individual technology activities are impacted by different factors and require focused managerial efforts—both of which cannot be accounted for if technology adoption is framed too narrowly (e.g. as a mere decision) in scientific studies. To grasp the complexity of technology adoption, integration of the fragmented literature is required, as sub-streams across disciplines have scrutinized isolated aspects of technology adoption without contextualizing the adoption as a whole (Q. Li et al., 2013; Lungeanu et al., 2016). The research thus provides a starting point for future studies by carving out the interrelated character of individual adoption activities and by advocating for the pursuit of more holistic research on technology adoption.

TS2 highlights the dominance of software technologies in technology adoption studies, while other types of technological innovations are largely neglected (Cegielski et al., 2012; Evangelista et al., 2013; Luisa dos Santos Vieira et al., 2013; Wu, Cegielski, Hazen, & Hall, 2013). The results of this study advance the adoption literature in general, as they provide insights into the currently proliferating category of hybrid technologies (Barrett et al., 2015, 2012). It shows how specific characteristics of hybrid innovations imply challenges that range from choosing an appropriate technology access mode (Mathauer & Hofmann, 2019c) to ensuring correct technology use (both in terms of hardware and software) (Mathauer & Hofmann, 2019a). Besides, the trend toward product–service customization is accounted for, whereby existing classifications of technological innovations in logistics are complemented (C.-Y. Lin, 2008).

TS3 emphasizes the lack of research on technology adoption by service firms in general (Ettlie & Rosenthal, 2011; van Oorschot et al., 2018) as well as on technology adoption in specific service network constellations (Cui & Hertz, 2011). Taking an LSP perspective, the dissertation draws attention to technology adoptions by service firms that have, for a long time, operated with comparatively few technological innovations, but which are now more than ever affected by new technologies (Q. Wang, Zhao, & Voss, 2016). As the dissertation reveals, these firms are facing severe challenges regarding selected technology adoption activities. Future studies can deepen these findings. Technology adoption in service networks is argued to be especially demanding due to the required interorganizational management of information distribution during technology diffusion (Mathauer & Hofmann, 2019a). Although service firms increasingly rely on subcontractors, and service chains in logistics increasingly have several levels (Cui & Hertz, 2011), there are hardly any empirical studies on the diffusion of technological innovations in vertical interorganizational settings. By investigating this phenomenon, the dissertation not only contributes to the general literature on technology adoption, but also to a proposed extension of AT. The notion of principal–agent hierarchies (Tirole, 1986) is transferred from the intrafirm to the interorganizational level in this context. Thus, diffusion constellations and accompanying information asymmetries can be analyzed more sophisticatedly. Furthermore, governance mechanisms are revisited and refined for tackling information asymmetries concerning the specific service chain level.

6.2 Managerial implications

The incorporation of technological innovations into service provision has become crucial for the competitiveness of LSPs and confronts decision-makers with the challenge of effectively managing technology adoption. This research consequently deals with those technology adoption activities that are considered as particularly difficult to handle (see Section 1.1) and for whose conduct little is known about to date (see Chapter 3). Specific managerial insights on aspects of technology searching, accessing technology, and diffusing technology are presented in Sections 5.2 to 5.4. However, practitioners might still wonder what these findings imply for their settings, as the provided managerial contributions only illuminate partial aspects of the respective technology adoption activities. To address this issue, a more comprehensive framework for structuring technology adoption activities is suggested based on the cumulated experiences from the case interviews and many more formal and informal talks to branch experts in the course of this research. This so-called technology adoption pilot is first presented at a general level and is then applied to the logistics context.

Overview of the technology adoption pilot

This dissertation suggests that the effective management of technology adoption is closely related to not losing sight of the big picture while the individual adoption activities are being carried out, because these activities do not necessarily follow a strict order, they influence each other, and require an individualized design for each adoption setting. The technology adoption pilot provides an overview of the central dimensions of technology adoption, which should in any case be taken into account for the design of adoption activities. It is considered a practice-oriented tool for structuring technology adoption efforts and thus should be applied in workshops rather than in scientific studies. The pilot comprises an activity-legitimizing, an activity-influencing, and an activity-guiding sphere (see Figure 9).[44]

Activity-legitimizing sphere. While conducting this research, it was remarkable how quickly firms tended to lose sight of the overall purpose of a technology adoption. The longer a technology adoption takes, the less important the questions regarding *why* the adoption activities are being conducted seem to become. Study B reveals that these strategic questions should not only be raised at the beginning of a technology project, because the way in which individual adoption activities are conducted can substantially contribute toward achieving the overarching purpose (e.g., choosing a technology access mode that is positively related to quality aspects). Technology adoption activities are typically legitimized by contributing value to the internal or external stakeholders or by generating profit.

Activity-influencing sphere. Technology adoption activities, no matter whether in the initiation or the implementation stage, are impacted by factors from the external and internal environment. Study A, for example, shows that external factors drive technology search behavior and the internal factor of firm size moderates the effects. Study B also identifies moderating factors that influence the relationship between accessing and integrating technological innovations. Therefore, the potential impact factors from the environment *where* technology adoption activities are conducted should be considered for every technology adoption activity. The examined technology projects in food and pharma logistics were strongly driven by regulations, while others had to comply with

[44] The technology adoption pilot is partly based on the business model canvas (Osterwalder, 2004), the business model navigator (Gassmann, Frankenberger, & Csik, 2014), and environmental analyses (e.g. Fahey & Narayana, 1986).

ecological aspects (e.g., the introduction of new trucks). Although such external factors are often easier to grasp, internal ones (e.g., culture) should not be neglected, as they are particularly relevant for implementation.

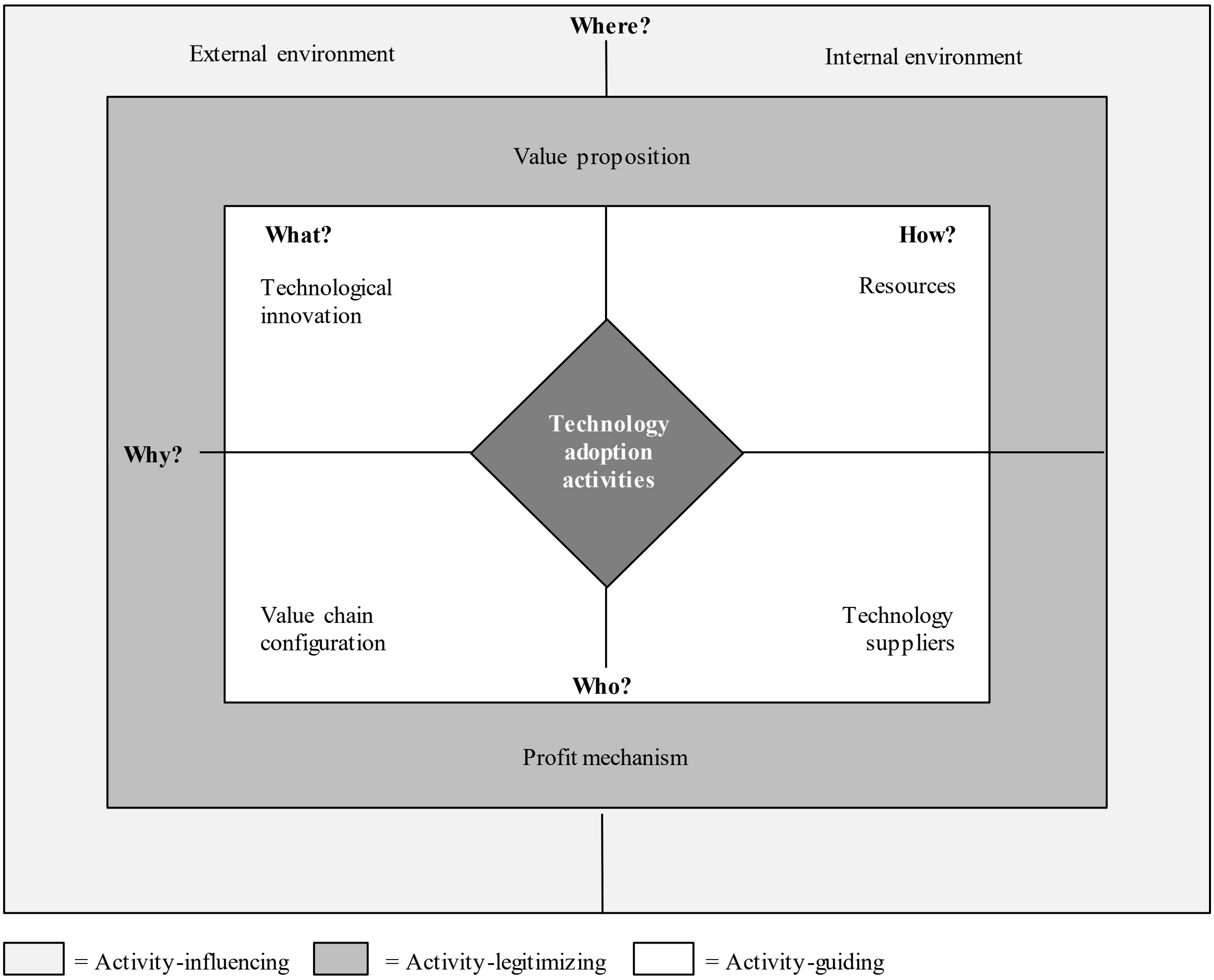

Figure 9. The technology adoption pilot as a proposed framework to structure technology adoption activities[45]

Activity-guiding sphere. Questions of *what* is adopted, *who* is involved, and *how* a technology adoption activity can be conducted with regard to the available resources form the very core of managing technology adoption activities. In contrast to the focus on the overall technology adoption in the activity-legitimizing and the activity-influencing spheres, the activity-guiding sphere is concerned with the concrete technology adoption activities. This research also contributes to overcoming present blind spots in the activity-guiding sphere. Concerning the adopted technological innovations, Studies A–C

[45] Own illustration based on Osterwalder (2004); Gassmann et al. (2014); Fahey and Narayana (1986).

highlight the challenges implied by hybrid innovations that require the management of hardware- and software-related aspects at the same time. Furthermore, Study C shows that firms tend to neglect the value chain configuration they are embedded in. Appropriate technology use by affiliated firms sometimes even requires interorganizational adoption management. It is important to note that the dimensions of the activity-guiding sphere should always be reflected on by considering the other two spheres, because only then is a well thought through handling of technology adoption activities possible. To provide orientation, Appendix D.1 includes a guideline with selected questions for each dimension of the technology adoption pilot. After this general overview of the proposed technology adoption pilot, it is applied to a specific case setting included in this research to derive concrete managerial implications.

Application of the technology adoption pilot to technology adoption by LSPs

Working with the suggested framework follows a three-step approach. The first step is about setting the frame of the technology adoption. Therefore, the activity-legitimizing and the activity-influencing spheres are filled out with a focus on the overall technology project. The second step is about capturing the key points of a specific technology adoption activity. The activity-guiding sphere should therefore be completed with a focus on the individual adoption activities. The third step is finally about deriving implications for the technology adoption activities. These implications are not limited to the activity-guiding fields, as factors from the environment (activity-influencing sphere) and the rationale behind the technology adoption (activity-legitimizing sphere) can also impact technology adoption design. To make the application of the technology adoption pilot more concrete, these three steps are exemplified with a real-life case setting hereafter.[46]

The presented example is about diffusing a technological innovation in a multi-level pharma logistics service chain. More concretely, a large pharma company (shipper) pursued the introduction of a new passively-cooled container, which is among the safest solutions for temperature protection in the world. The 3PL, being a long-term global logistics partner of the shipper, is therefore granted the opportunity to diffuse this new smart charge carrier throughout its service chain. This is challenging, as the 3PL uses various subcontractors who have to appropriately handle the technology. All containers

[46] The setting draws on Case Gamma in Appendix C.4.3. Thus, the descriptions are amended and extended extracts from Study C.

are connected to a cloud solution and send status data for tracking purposes whenever a gateway is passed. Thus, the diffusion is concerned with both hardware- and software-related issues. To set the stage, Table 9 depicts the most important aspects of the activity-legitimizing and the activity-influencing dimensions generated in the first step. The table also includes the activity-guiding dimensions completed in the second step, which are filled out with a focus on technology diffusion and take account of the other two spheres.

Table 9. Exemplification of the three spheres of the technology adoption pilot for diffusing technology

Sphere	Dimension	Exemplified for technology diffusion
Activity-legitimizing	Value proposition	The shipper wishes to increase its supply chain performance by having its most temperature-sensitive products shipped with containers that better protect against temperature deviations. The 3PL is asked to start with a pilot first and later extend the business, which is why a lock-in effect through technology diffusion can be expected.
	Profit mechanism	As the technology is new and its handling considered complex, the 3PL can gain better payment for handling the new containers than for existing ones. Building up the competencies required for the technology diffusion allows comparable services to be offered to other shippers based on the same technological innovation.
Activity-influencing	External	The pharmaceutical industry is highly regulated and requires all actors in the logistics service chain to have various certifications and to comply with different standards. The differentiation from competitors is more about service than about the price.
	Internal	The 3PL is an international logistics service group with a decentral structure, so that knowledge on the handling of certain technologies is distributed all over the world. In general, the attitude toward technological innovations is very open regarding its own workforce, but it is slightly cautious about smaller carriers acting on behalf of the 3PL.
Activity-guiding	Technological innovation	The technological innovation is a passively-cooled smart container for temperature-sensitive pharma products. Besides the standardized hardware, the solution includes software that provides status data. All actors in the service chain directly interact with the technology, e.g. through the control of the goods.
	Resources	The actors of the logistics service chain need information on how to handle the containers. Standard operating procedures and training are very important. For the 3PL, investments refer to building up knowledge and not to buying the technology, as the shipper provides the solutions.

Table 9. (continued)

Sphere	Dimension	Exemplified for technology diffusion
	Value chain configuration	The diffusion includes the shipper, the 3PL, different carriers, as well as their drivers, so that technology-related information asymmetries can be expected. The consignee is actively involved in the technology project, as handling also becomes different for him.
	Technology suppliers	Due to the technological innovation's newness, the technology supplier actively oversees the technology diffusion and provides support.

Departing from the results of the first two steps presented in Table 9, managerial implications are derived for each dimension of the technology adoption pilot. These implications leave the actual case setting and represent a transfer of, reflection on, and extension of the selected findings across cases from Study C. The managerial implications are located in Figure 10, while Table 10 comprises more detailed explanations of the individual implications. A comparable procedure is conceivable for every technology adoption activity. For illustration purposes, further applications of the technology adoption pilot on LSPs searching for and accessing technological innovations are included in Appendix D.2 and Appendix D.3.

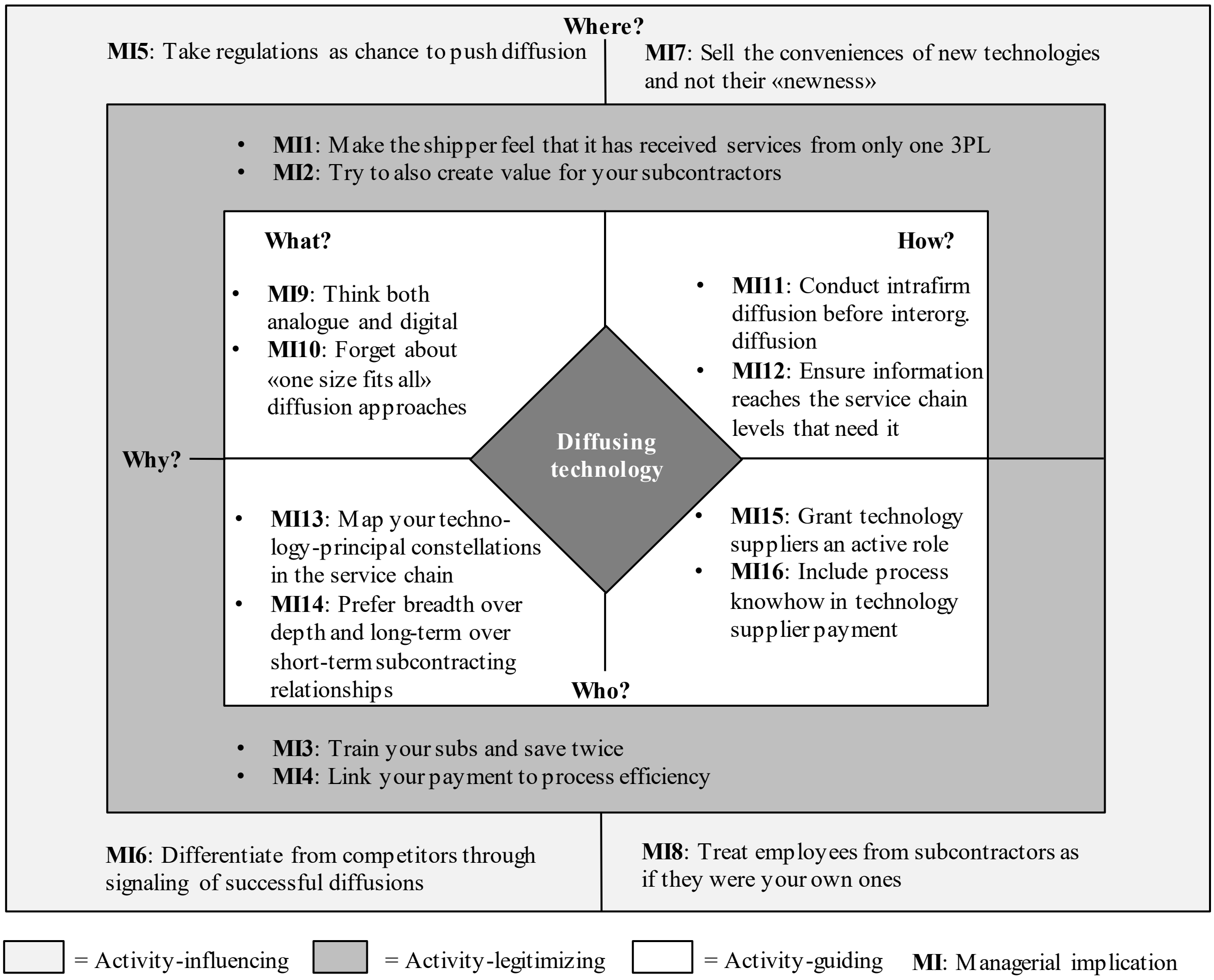

Figure 10. Selected managerial implications for diffusing technology

Table 10. Explanation of the managerial implications for diffusing technology

Dimension	Managerial implications	Explanation
Value proposition	MI1	The shipper wants direct contact with the 3PL and to avoid coordination with any other subcontractors. Subcontractors should therefore internalize the processes of the 3PL, so that the shipper feels it has received services from only one 3PL, although he or she knows about the complex service chain.
	MI2	Subcontractors are the actual users of the technological innovation, which is why the success of the diffusion is largely dependent on them. From a 3PL perspective, it must not be forgotten that value also needs to be created for them as well, e.g. through performance-dependent payments.
Profit mechanism	MI3	Technology diffusions are very much concerned with ensuring that all those involved in the logistics service chain have the information they need for appropriate use. The incorrect handling of the technology can immediately cause horrendous costs in the pharma industry. Training is one option to prevent such costs. If it is carried out by the 3PL, it is often cheaper in the long run than training by external professionals. Furthermore, the know-how can be used for later diffusions of the same technology for other customers. Therefore, 3PLs can save twice by training their subcontractors themselves.
	MI4	Especially if a technological innovation is related to goods of a high-value density, shippers are willing to pay for well-executed processes. Therefore, KPIs linked to a failure rate, for example, can motivate the actors of the logistics service chain and increase the revenue potential of the 3PL.
External	MI5	Strict legal regulations are often perceived as limiting by LSPs. However, they should be seen as a chance for technology diffusions for at least two reasons. On the one hand, they guide procedures on how to handle technologies. On the other hand, all actors of the logistics service chain show high levels of commitment, as they are afraid of potential punishments.
	MI6	Diffusing technological innovations in interorganizational constellations is complex and requires both knowledge and experience. Knowing that subcontracting in logistics service chains is becoming ever more important, 3PLs can use their diffusing capabilities to differentiate themselves from their competitors.

Table 10. (continued)

Dimension	Managerial implications	Explanation
Internal	MI7	Employees at LSPs are said to be particularly reluctant to change and therefore also to take on new technological innovations due to their focus on operational processes. Therefore, 3PLs should instead highlight the positive implications of a technological innovation on the processes rather than presenting all new technology features in detail to avoid a deterrent effect.
	MI8	Boundaries between the firm's own employees and subcontractors are blurred in interorganizational technology diffusions. This makes managing the people difficult, because the firm's own employees are naturally closer to the corporate identity than subcontractors are. However, it is recommended that both kinds of employees are treated equally, as the technology user at the end will give the impression of being a direct employee of the 3PL.
Technological innovation	MI9	For diffusing hybrid technological innovations, both aspects from the analog and the digital world have to be managed. While the physical handling might be a matter of training, the design of the information flow, for example, concerning access rights, can become the subject of major discussions (keyword data sovereignty).
	MI10	The characteristics of the individual technological innovations are the main driver for how diffusion activities should be conducted. Although one should always try to use experiences from previous diffusions, their direct transferability is illusory.
Resources	MI11	Whenever possible and reasonable, 3PLs should diffuse a technological innovation within its firm boundaries before it is diffused interorganizationally. This is because managing intrafirm diffusions is easier and allows problems to be tracked that then can be prevented in the interorganizational case. Knowledge transfer is key.
	MI12	The most important resource for the appropriate use of a technological innovation is knowing about how to use it. Therefore, no investment should be spared to ensure good information dissemination.
Value chain configuration	MI13	Before a technology diffusion can start, it is recommended that 3PLs should map the diffusion constellations within their logistics service chain. If a subcontractor, for example, is already handling a comparable technological innovation for the 3PL, the diffusion needs to be managed differently than for technological innovations that are completely new to the subcontractor. Depending on the individual setting, information asymmetries may exist in favor of either the 3PL or the carrier.

Table 10. (continued)

Dimension	Managerial implications	Explanation
	MI14	From the perspective of the 3PL, some service constellations should be preferred over others to reduce the expected information asymmetries. The more levels a service chain includes, the more difficult it is to tackle information asymmetries. Furthermore, long-term subcontracting relationships can have a signaling effect and reduce information asymmetry. The 3PL, for example, might already know about the technical competence of the subcontractor.
Technology suppliers	MI15	Diffusing technological innovations that are relatively new to the industry are accompanied by particularly high levels of technology-supplier engagement. The technology supplier profits from learning about the technology adoption, and 3PLs should benefit from this situation. Thus, the technology supplier should be granted an active role and used, for example, for providing guidelines for standard operating procedures and material for training.
	MI16	While technology suppliers are usually experts in their technologies, they are lacking in logistics process know-how. Both sides can profit if the LSP helps to co-develop a technological solution. The results will be more applicable for the individual diffusion context and monetary payment is supplemented by know-how transfer.

The discussion of the technology adoption pilot shows that the appeal of this dissertation from a managerial point of view lies in combining a better understanding of the overall concept of technology adoption (see Sections 2.3 and 6.1) with very concrete findings from Studies A–C. For decision-makers at LSPs, it is therefore recommended that they use tools such as the proposed technology adoption pilot to let their overall technology adoption efforts profit from the specific insights of this dissertation.

6.3 Limitations and future research

Although this dissertation is positioned within a well-established research domain (technology adoption research), builds upon recognized theories (i.e. absorptive capacity theory, AT, the ABV), and pursues a profound methodological approach (i.e. case study research), there are still limitations. In the following, content-related and methodology-related limitations regarding the overall research approach and the individual Studies A–C are presented. Drawing on the limitations, avenues for future research efforts can be delineated.

The content-related limitations of this dissertation encompass the broad scope of the research setting, the restricted transferability of results to other contexts, and the lacking quantitative insights into the adoption of technological innovations by LSPs. The present research investigates selected technology adoption activities (i.e. searching, accessing, and diffusing), whose relevance has been derived from a managerial (see Section 1.1) and a theoretical perspective (see Section 1.2). Locating the adoption activities within the overarching concept of technology adoption (see Section 2.3) reveals at least two clearly-stated restrictions: (1) the research focus is broad regarding the overall conceptualization of technology adoption, and (2) activities between the selected technology adoption activities (i.e. evaluating, integrating, and routinizing) are excepted from the investigations. The results should therefore always be interpreted as a stand-alone deepening of selected aspects of technology adoption, which do not directly impact each other, and which do not claim to explain technology adoption as a whole. Implications of the selected technology activities on the other activities were discussed (see Section 6.1), but not empirically investigated. This is recommended for future research.

Furthermore, the entire research process was focused on the logistics service industry. More specifically, Studies A–C take the perspective of LSPs who operate as 3PLs. The transferability of the results to other contexts is thus limited in two main aspects. On the one hand, it is possible that technology adoption activities are conducted differently in other service industries. Especially firms from industries with higher levels of technological affinity might, for example, pursue more structured approaches and make greater use of tools in the course of technology adoption (Boe-Lillegraven & Monterde, 2015; Rohrbeck, 2010). On the other hand, the transferability of the results within the logistics context is also hampered. As hybrid innovations are the focus of this research, findings are not transferable to asset-neutral 4PLs. They should instead draw on insights from information systems research. The applicability to logistics intermediaries and carriers is also limited, as they are often too small to undertake technology adoptions in a more professional way (Evangelista et al., 2013; Evangelista & Sweeney, 2006). Although the investigations of Study B and Study C occasionally included interviews with technology providers and shippers, these perspectives were not further pursued in the overall analyses. It is recommended that future studies should enrich the LSP-specific research on technology adoption by incorporating additional perspectives, as interorganizational innovation efforts are becoming ever-more important (Wallenburg et al., 2019).

The findings of the dissertation might also be limited by the qualitative nature of this research. All discovered effects are systematically described, but not verified by a large-scale survey. Besides, the results do not allow for any conclusions on the financial impact of the investigated technology adoption activities. This may be particularly regrettable from a practitioner's point of view, as the logistics industry is very much driven by the financial aspects of technological innovations (see Section 2.1). However, future studies may be inspired by the findings on searching, accessing, and diffusing, and could thus quantitatively review selected effects. Especially the findings on the implications of technology access mode choice on the integration success of technological innovations call for quantitative research including potential financial effects.

The *methodology-related limitations* of this dissertation include the ideal-typical character of technology adoption in IDT, the type of data used in the case study analyses, as well as the limited research focus of Studies A and C. IDT (Rogers, 2003) is applied as an overarching theoretical lens to structure the research setting. It draws on the assumption that technology adoption at the organizational level follows a multi-stage process including several activities. However, such process models should always be considered as ideal-typical, because firms do not necessarily undergo a deliberate adoption process. Adoption activities might be skipped, performed simultaneously, or run through several times in the sense of iterative loops (Mathauer & Hofmann, 2019c). Technology adoption can even happen in a rather emergent fashion (Mintzberg & Waters, 1985). Therefore, it has to be noted that the isolation of the investigated technology adoption activities can be reasonable for research purposes. However, they might not occur in isolation in practice.

The exploratory studies conducted in the course of this research are based on discrete data gathered at one single point in time. This may hamper the results of the case study analyses in the following way. Study A is devoted to organizational search behavior. Interviewees, therefore, had to recall past behavior, although searches are often performed intuitively (Scheiner et al., 2015). While interview techniques such as event-tacking for memorizing actions step-by-step were used to counteract potential biases (Kownatzki, Walter, Floyd, & Lechner, 2013), they cannot be excluded. Thus, longitudinal studies are common for investigating organizational search behavior (Katila, 2002). Study B examines the effects of technology access modes on integration success. Success can be most conclusively assessed with a sufficient time lag following the actual technology adoption. However, interviews were conducted soon after the technology access-mode choice had been made, so that the results may be distorted. Study C would have profited from a long-run analysis as well, because the examination of technology diffusion could then have been complemented by an investigation of routinization. Therefore, future research should engage more in studying technology adoption activities in the long run.

A final limitation stems from the selective focus of Studies A and C. Study A compares the effects of external search antecedents on organizational search behavior between large and small firms. Thus, no other moderators apart from firm size are accounted for. This research focus was perceived as necessary so as to carve out size effects on the attention structure in depth. Nevertheless, it can be assumed that other factors such as firm culture or the level of formalization might also play a decisive moderating role. Thus, future research is encouraged to examine further potential moderators in this context. Study C focused on the vertical interorganizational diffusion of technological innovations. However, researchers argue that horizontal cooperation among LSPs is becoming increasingly important (Cui & Hertz, 2011; Schmoltzi & Wallenburg, 2011). It can therefore be expected that LSPs will have to develop the capability to simultaneously diffuse technological innovations horizontally and vertically. Future studies should examine this required ambidexterity in technology diffusion and use research designs that mirror the complexity of the investigated settings.

Besides the indicated directions for future studies, two further research avenues are suggested. In the course of conducting this research, it has repeatedly become clear that managerial discretion plays a significant role in how technology adoption activities are conducted at LSPs. Therefore, scholars are required to better understand cognitive processes (e.g. in decision-making) for more comprehensive explanations of individual and organizational behavior. Against this backdrop, the recommendation is made to explore theoretical lenses from the adjacent fields of strategic management or marketing that exceed the standard set of theoretical perspectives on technology adoption (e.g. bounded rationality) (van Oorschot et al., 2018). The final recommendation for future research is closely related to this dissertation's intention of also providing, besides a theoretical impact, a sustainable managerial contribution. Section 6.2 contains a technology adoption pilot that is needed for both empirical testing and practical applications.

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Appendix

Appendix A.[47] Mathauer, M.: Attentional drivers of technology search behavior at logistics service providers

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Appendix B.[48] Mathauer, M., Hofmann, E.: Technology adoption by logistics service providers

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Appendix D. Additional managerial implications

D.1 Dimensions and questions from the technology adoption pilot

D.2 Application of the technology adoption pilot to technology searching by logistics service providers

D.3 Application of the technology adoption pilot to technology accessing by logistics service providers

A. Study A: Attentional drivers of technology search behavior at logistics service providers

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This paper sheds light on the antecedents of technology search behavior by logistics service providers (LSPs) under consideration of firm size, substantially contributing to the understanding of the relationship between external aspects of the search environment and search behavior on the firm level. Based on a comparative case study design including seven technology cases at four large and three small LSPs, organizational search behavior is contrasted with regard to firm size. The attention-based view (ABV) serves as a theoretical underpinning. The findings illustrate that the external antecedents of technology search behavior encompass both opportunities and threats. Customer-, market-, and technology-related triggers stem from these categories. The actual effect of each antecedent depends on firm size and differs in terms of search selection (breadth of the search) and search intensity (depth of the search). This is the first study to identify external antecedents of technology search behavior from an ABV, thereby adding the notion of outside-in problemistic searches and external threats to the debate on attentional drivers of organizational searches. Decision-makers at LSPs profit from understanding the attentional mechanisms underlying their search behavior, as resources can be allocated more effectively and blind spots removed.

Keywords: Technology selection, case study research, logistics service providers, search behavior, innovation adoption, attention-based view.

A.1 Introduction

The ever-growing importance of innovations for the competitive position of firms is broadly recognized and has been highlighted in numerous studies on manufacturing firms in high-technology industries (Damanpour 1991; Smith, Collins, and Clark 2005; Madsen and Leiblein 2015). Service firms, in contrast, are rather neglected by the mainstream research on technological innovations (Ettlie and Rosenthal 2011; Wang, Zhao, and Voss 2016). This is unsatisfactory for at least two reasons: First, the global economy is becoming service-oriented, which is why the majority of national productivity in most developed countries stems from service activities (Maglio and Spohrer 2008; Chae 2012). Second, the service industry is currently under severe pressure to innovate. Due to the constantly increasing service demands and the increasing human capital costs in the service industry, new technologies are seen as promising in terms of alleviating such pressures (Goes et al. 2018). Challenges associated with technological innovations in service firms are therefore of special relevance to both theory and practice.

Dealing with technological innovations in service firms is different than in manufacturing firms, as the value of technological innovations only unfolds during service provision. Thus, technology is seen as a means to an end (Fitzsimmons and Fitzsimmons 2008). In consequence, service firms often lack technology expertise if it is not directly part of their core business (Tschang and Ertug 2016). This applies in particular to companies from service industries that have traditionally been less innovative in the past but that are highly affected by the current technology push through industry 4.0 and digitalization (Wang, Zhao, and Voss 2016). For example, logistics service providers (LSPs), which have long been regarded as the least innovative of all service firms (Wagner 2008; Busse and Wallenburg 2014), are currently undergoing “technologization”: Former hardware (e.g. pallets) has given way to hybrid technological solutions (e.g. smart charge carriers) and the accompanying technology-related services (e.g. track and trace) (Mathauer and Hofmann 2019). Therefore, these kinds of companies are increasingly required to adopt technological innovations on a regular basis to remain competitive (Goldsby and Zinn 2016; Mathauer, Stölzle, and Hofmann 2018). Some innovation activities are especially challenging for them—above all, the front end of innovation, including technology searches (Busse and Wallenburg 2011). This gives support for the notion that the drivers of their search activities have not yet been sufficiently identified.

Given the accelerated development pace of new technologies in combination with their proliferating diversity, it is hardly surprising that technology search activities have become so demanding for LSPs (Scheiner et al. 2015; Giachetti and Lanzolla 2016). Scholars lament the hitherto rather undifferentiated handling of search behaviors and have attempted to fathom the underlying mechanisms (Ahuja, Lampert, and Tandon 2008; Maggitti, Smith, and Katila 2013). Although some researchers have noted the cognitive nature of search processes (e.g. Gavetti and Levinthal, 2000), most empirical studies have ignored this aspect. In the meantime, insights from human attentional studies have been incorporated into the concept of searches by drawing on an attention-based view (ABV) (Ocasio 1997). A distinction was introduced between search selection (where the search is conducted; the breadth of the search) and search intensity (resource investment in the search; the depth of the search), which both have a significant impact on organizational innovation output (Li et al. 2013). The ABV turned out to be very valuable in terms of understanding search behavior and scholars focused on the consequences of search behavior from this perspective (Rhee and Leonardi 2018; Scalera, Perri, and Hannigan 2018). Yet, there is a scarcity of research on search antecedents. Internal environmental antecedents such as the availability of resources or missed performance targets have been addressed (Rhee, Ocasio, and Kim 2019). External environmental factors, however, are largely unexplored (Chen and Miller 2007). This is unsatisfactory, as external factors such as the customer can be expected to be decisive for the search behavior of service firms due to the nature of service provision being innately customer-oriented (Hipp and Grupp 2005). A holistic understanding of such external search drivers is needed to design search activities more effectively. Therefore, the first research question of this paper is formulated as follows:

> *RQ1:* From an LSP perspective, what factors from the external firm environment antecede organizational technology search behavior?

Due to the increasing but under-researched relevance of technology searches for service firms from former low-technology industries and the observable struggle that LSPs have with search activities, this research question is examined using the example of LSPs. By considering search behavior as the complex interplay of attentional processes (Simon 1947; Ocasio 1997), the relationship between the external search environment and search behavior is moderated by additional factors (Barreto 2012). Especially internal attention structures might influence where decision-makers search and at what intensity

(March and Olsen 1976). These structures vary depending on firm size, which is one reason why innovation activities differ between large and small firms (Duran et al. 2016; Savino, Messeni Petruzzelli, and Albino 2017). Given that most LSPs—which also applies to service companies in general—are small (Hipp and Grupp 2005; Evangelista, McKinnon, and Sweeney 2013), understanding potential size effects for technology search behavior is particularly relevant for the present study. Thus, the second research question is derived as follows:

> *RQ2:* From an LSP perspective, how does firm size moderate the relationship between external search antecedents and technology search behavior?

Given the under-researched nature of the antecedents of technology search behavior, this paper is based on a comparative case study design (Eisenhardt and Bourgeois 1988; Eisenhardt 1989). Data on specific technology searches and on general technology search activities are collected from four large and three small LSPs. The ABV (Ocasio 1997) serves as the theoretical anchor for the study, assuming that firm behavior results from how selective attention is channeled and distributed. The results are presented in the form of propositions and contribute threefold to the current state of the field as found in the literature: (1) the internal antecedents of organizational searches are extended by external antecedents, including the notion of outside-in problemistic searches and external threats (Chen and Miller 2007; Rhee, Ocasio, and Kim 2019); (2) the search components *selection* and *intensity* are transferred from the individual to the organizational level (Li et al. 2013); and (3) different attention structures between large and small firms are identified from an ABV. Logistics managers will profit from the insights into what drives LSPs' technology search behavior, as the findings will enable them to allocate resources more effectively.

The paper is structured as follows. Section A.2 provides an overview on the existing knowledge on LSPs' technology searches from an ABV and considers the potential size effects. Section A.3 presents the research methodology in depth. The results of the within- and cross-case analyses are outlined in Section A.4. Section A.5 contains a discussion of the results with regard to the existing search literature as well as literature on innovation management at LSPs. The paper ends with some remarks on limitations and future research.

A.2 Literature review

A.2.1 Technology searches at logistics service providers

In prior work, a search is defined as “the controlled and proactive process of attending to, examining, and evaluating new knowledge and information” (Li et al. 2013, 893). The variety of a firm’s search activities can thus be very broad, including the search for market opportunities (Gruber, MacMillan, and Thompson 2013), the search for competitors to imitate (Sharapov and Ross 2019), or the search for innovations (Snihur and Wiklund 2019). The present study focuses on one specific type of search for innovations—the search for *technological* innovations (hereafter, technology searches). Technological innovations are defined broadly, encompassing “the generation of a new product, service, or production process technology” (Magelssen 2020, 5). If these innovations relate to logistics services—no matter whether they are internally or externally oriented[50]—they are called technology-based logistics innovations (hereafter, technological innovations) (Flint et al. 2005). The focus is on hybrid solutions as a combination of physical and digital components, as this is a fast-growing category of technological innovations that is typical for the provision of services in today’s industry 4.0 environment (Barrett et al. 2012, 2015; Hofmann and Osterwalder 2017).

LSPs are a specific type of service company that carry out any kind of logistics service on behalf of others (Delfmann, Albers, and Gehring 2002). According to the literature, LSPs have long been considered to be particularly non-innovative (Busse 2010; Busse and Wallenburg 2014). The potential explanations for this are manifold and include restrictive contracts with customers (Cichosz et al. 2017), a special supply chain position between the customer and the customer’s customer (Selviaridis and Spring 2007), high dependency on customers from many diverse industries (Bolumole, Frankel, and Naslund 2007), and a very operations-driven culture throughout the whole industry (Esper, Fugate, and Davis-Sramek 2007). Nevertheless, an unprecedented “technology push” is currently gaining momentum and is forcing LSPs to deal primarily with technological innovations. This makes LSPs an ideal unit of observation against the back-

[50]Internally-oriented logistics innovations are typically concerned with the improvement of operational processes, while externally-oriented innovations aim to meet customer needs more effectively (Flint et al., 2005).

drop of this study: The exploration of technology search drivers in former low-technology service firms (Goldsby and Zinn 2016). By contrasting LSP-specific difficulties with innovation management in general and the need to cope with a growing number of technologies, challenges regarding the effective allocation of resources for technology searches are predestined.

In the literature, search activities have been classified along different dimensions, which are assigned to search selection and search intensity in the following (Li et al. 2013). Search selection refers to *where* firms search. Studies taking this perspective distinguished three different contrasting pairs of searches: (1) local vs. distant (sometimes also referred to as internal vs. external); (2) broad vs. narrow; and (3) familiar vs. unfamiliar. Regarding the first contrasting pair, it has been shown that firms tend toward local and simple search activities (Cyert and March 1963; Ahuja and Katila 2004). The second contrasting pair opposes exploration (broad searches) and exploitation (narrow searches). To be most effective, there should be a balance between exploratory and exploitative searches (March 1991; Sahay, Gupta, and Mohan 2006). The third contrasting pair draws on the familiarity with the search terrain, also referred to as knowledge distance (Rosenkopf and Almeida 2003). It has been shown that firms searching further away from their knowledge base introduce new products faster (Katila 2002). Search intensity refers to the *investment* in search activities as well as to the *duration* of the search. On the organizational level, scholars used R&D spending to operationalize search intensity and found positive effects on firm innovation (Cohen 1995; Greve 2003). Search intensity thus also impacts innovation success.

Technology searches at LSPs have rarely been investigated. Flint et al. (2005) showed that customer orientation predominates throughout the early innovation stages at LSPs. The search for innovation opportunities is often triggered by clues from the customer. Search activities are used to intensify customer contact and to get a better understanding of the customer's business model. This is important not only for concentrating on what the customer currently values, but particularly on what he or she is expected to value in the future. These qualitatively-derived insights into the customer role in search activities at LSPs were quantitatively confirmed by a later study (Flint, Larsson, and Gammelgaard 2008). However, to date, the customer's impact on search selection and intensity has remained unclear. Furthermore, the literature shows that technological innovations at LSPs are often not the result of deliberate search efforts. Sometimes experimentation or serendipity yield innovations as well (Flint, Larsson, and Gammelgaard 2008; Busse and Wallenburg 2011). Additionally, the search for technological innovations might also be guided by the customer's dissatisfaction with the current service (Wagner 2008).

Due to the scarcity of LSP-specific literature on the antecedents of technology searches, insights from innovation management at service firms in general are transferred to the logistics context. Thereby, categories of the drivers for technology search activities at LSPs are derived, as follows:

- *Customer-related drivers of searches*: Services are simultaneously produced and consumed (the uno actu principle) and thus per se are very customer-oriented (Cowell 1988). While information technology might "help to remove the synchronization of time and location between service provider and customer" (Hipp and Grupp 2005, 520) in some industries, the asset intensity of logistics services always implies physical touch points with the customer (Hofmann and Lampe 2013). Therefore, the customer can be expected to play a major role in the technology search behavior of LSPs.
- *Market-related drivers of searches*: Service products are intangible (Neu and Brown 2005). Thus, there is no possibility of establishing a temporary monopoly through the patent protection of a technological innovation (Hipp and Grupp 2005). This lowers the attractiveness of a first-mover strategy and increases the attractiveness of imitative search behaviors, particularly in financially-restricted industries such as logistics (Deepen et al. 2008). For this reason, the relationship between competitor technology adoption and focal LSP search behavior should be explored further.
- *Technology-related drivers of searches*: For technological innovations at LSPs, technological knowledge must be supplemented with equally-as-important non-technological knowledge (e.g. organizational knowledge, marketing knowledge, etc.) (Busse and Wallenburg 2011). The opposite side of this argument highlights the service firms' distance to technological knowledge, thus inhibiting LSPs from dealing with high levels of technological complexity. Thus, it can be assumed that technology characteristics have an influence on LSPs' search behavior.

A.2.2 An attention-based view on technology searches at logistics service providers

In order to further approach the antecedents of technology searches at LSPs, it is important to understand the cognitive processes behind search activities. The search for technological innovations is based on information-processing mechanisms (Rhee and Leonardi 2018). A search requires the attention of the responsible person because it is a human capability (Li et al. 2013). Scholars agree on the definition of attention as "noticing, encoding, interpreting and focusing of time and effort by organizational decision-makers" (Ocasio 1997, 189). But the cognitive capabilities of decision-makers are limited, which is why not all stimuli are attended to (Simon 1947; Joseph and Ocasio 2012) and attention can be viewed as a scarce resource (March and Shapira 1992; Gavetti et al. 2012). Theorists on the behavioral firm have established the notion that both individual cognitive processing and structural influences on the attention of decision-makers prejudge organizational action—in the present case, technology searches (March and Simon 1958; Cyert and March 1963; Cohen, March, and Olsen 1972; March and Olsen 1976). In his ABV, Ocasio (1997) took up this perspective and developed the argument that firm behavior results from the channeling and distribution of decision-makers' limited attention. He derived a model of situated attention and firm behavior, explaining how the processing of issues at the individual level is transformed into organizational reactions by decision-makers. Drawing on an ABV, the present paper focuses on organizational attention; a socially-structured pattern of individual decision-makers' attention (Ocasio 1995).

To date, scholars have rarely applied an ABV to explain search behavior, although this perspective—as with research on cognitive processes in general—is considered to be enriching for the understanding of searches at both the firm and the individual level (Li et al. 2013). If an ABV is taken, the search consequences are studied rather than the antecedents (Monteiro 2015; Rhee and Leonardi 2018; Scalera, Perri, and Hannigan 2018). Notwithstanding, the few insights on the antecedents are a valuable starting point for the present study. Chen and Miller (2007) scrutinized internal antecedents of search intensity. Situational antecedents contain aspirations (a problemistic search if aspirations are not met), slack (a slack search if there are excess resources), and bankruptcy. The ABV helps to motivate them, as the focus of attention is always dependent on the firm's situation (Ocasio 1997; Chen and Miller 2007; Posen et al. 2018). If a firm fails to meet its performance targets, for example, it will be willing to intensify its problemistic searches for new technologies. Rhee et al. (2019) also drew on the fundamental relationship between internal aspirations and search behavior (a problemistic search). In the complex setting of hierarchical business groups, an ABV is used to explain the cognitive accessibility of firm performance and R&D investments to group-level managers as a moderator on the effects of a missed aspirational level on search intensity. Barreto (2012) criticizes the emphasis in most existing studies on problemistic and slack searches. He highlights how organizational attention can be stimulated both by internal (e.g. problems arising from missing the envisaged performance level) and external (e.g. opportunities for market expansion) environmental factors (Ocasio 1997).

Following these insights and arguing from an ABV perspective, the external and internal search environments have a considerable role to play in explaining why firms attend to some stimuli and not to others in specific situations (Ocasio 1997). While internal environmental factors are quite well understood (problemistic and slack searches), only one selected external environmental factor has been scrutinized to date (market attractiveness) (Barreto 2012). Especially for service firms, there might exist other, more relevant factors. Having shown the importance of the customer for technology initiation at LSPs, for instance, it is likely that the customer will attract substantial attention during a search. However, the implications for the search behavior of LSPs are not yet understood. Furthermore, it is shortsighted to focus exclusively on opportunities (e.g. market attractiveness) as external antecedents of searches. Ocasio (1997) stated that the issues that a firm is confronted with can belong to the "categories of problems, opportunities, and threats" (1997, 194). Prospect theory suggests that potential gains (equivalent to opportunities) and potential losses (equivalent to threats) are valued differently by individuals (Kahneman and Tversky 1979). Thus, there is every reason to assume that opportunity-driven factors from the external search environment have different effects on organizational search behavior than threat-driven external factors from the search environment do, so that the latter need to be further understood in any case.

A.2.3 The role of firm size for technology searches at logistics service providers

As firm behavior is the result of complex and interrelated attentional processes (Simon 1947), the relationship between external aspects of the search environment and search behavior is impacted by the internal factors of the search environment (Barreto 2012) (see Figure A - 1). Above all, internal attention structures govern the allocation of decision-makers' attention focus (e.g. search selection), as well as the time and effort (e.g. search intensity) put into their activities (March and Olsen 1976; Ocasio 1997). Structural attention regulators encompass resources, dominant search principles, the involved people, as well as the structural positions in the firm (Ocasio 1997). These regulators differ considerably between large and small firms, as outlined below:

- *Resources*: These consist of the bundle of tangible and intangible assets that a firm can dispose of to conduct its search activities (Wernerfelt 1984). From a financial perspective, it is widely accepted that the absolute amount of R&D spending (search intensity) often grows proportionally with firm size (Cohen and Klepper 1996). To understand technology search behavior, however, the question of what these resources are used for is more exciting. Recent research indicates that firm size also has a significant impact on R&D composition (Choi and Lee 2018). In other words, firm size is relevant for both search selection and intensity.
- *Dominant search principles*: These refer to the formal and informal principles regarding how decision-makers act, interact, and interpret things during a search (Ocasio 1997). The dominant search principle is closely related to the attentional perspective of the firm. The attentional perspective is embedded in top-down cognitive structures (e.g. prior firm experience with a technology) and impacts how decision-makers attend to environmental stimuli during searches (Ocasio 2011). Drawing on analogous conclusions from strategic decision-making, the decisions of large firms were found to be scrutinized and tested to a much higher extent than those in small firms were (Eisenhardt and Zbaracki 1992; Liberman-Yaconi, Hooper, and Hutchings 2010). The technology search behavior therefore moves closer toward rationality than it would do in small firms, which might, for example, be more sensitive to threats than to opportunities as external search antecedents (Jackson and Dutton 1988).
- *Involved people*: These comprise of the people who undertake searches. They are relevant for organizational search behavior because decision-makers are selective regarding what will attract their attention (Joseph and Ocasio 2012; Monteiro 2015). The role of individual people in terms of their attention allocation depends on their position, with CEOs and the top management team as the most important

players (Cho and Hambrick 2006; Ocasio 1997). In large firms, higher levels of formalization decrease the influence of individual people's attention allocation on search behavior. Small firms are more often subject to the discretion of dominant, individual top executives (Liberman-Yaconi, Hooper, and Hutchings 2010; Kammerlander and Ganter 2015).

- *Structural positions*: These are manifested in the functions of decision-makers and the interrelationships with other internal or external positions. Together with the dominant search principle, the structural positions exert influence over the way in which decision-makers think and act during technology searches (Ocasio 1997). Large firms tend to have a clear organizational assignment for search activities and sometimes even operate their own R&D department as a service firm (Hipp, Tether, and Miles 2003; Cichosz et al. 2017). Small firms might search more opportunistically and cannot draw on internal technological knowhow.

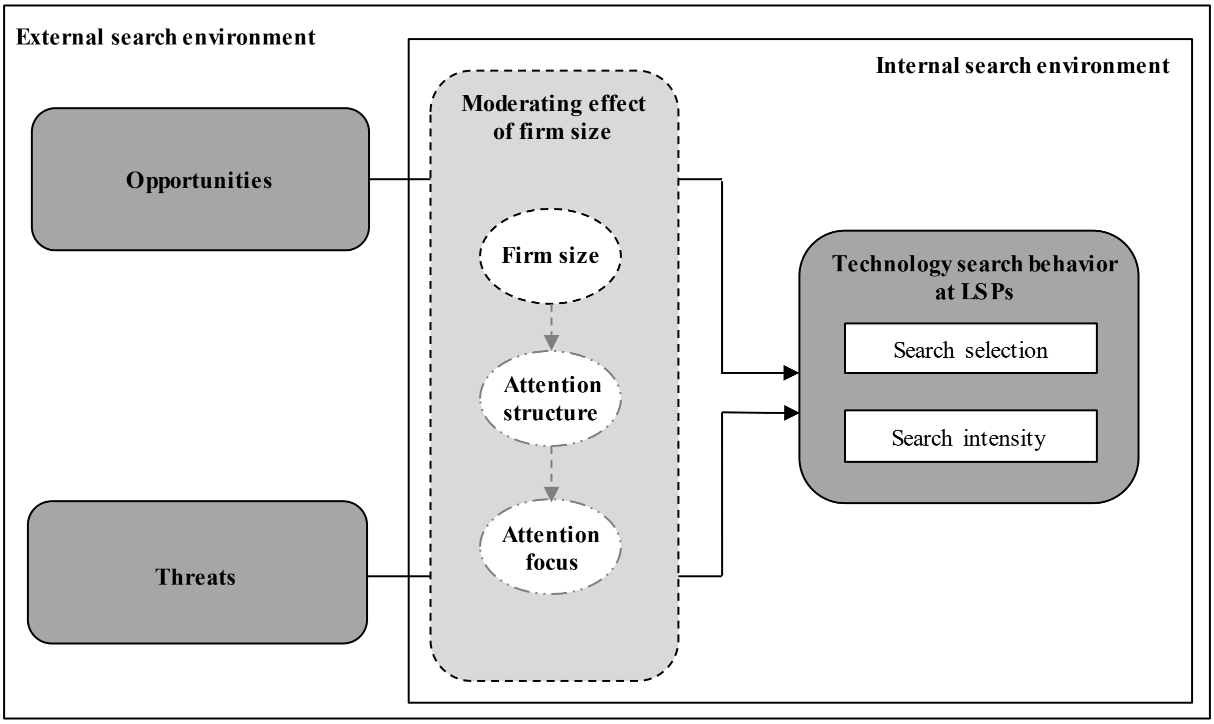

Figure A - 1. Overview of the interrelation of factors from the external search environment, factors from the internal search environment, and the technology search behavior at LSPs

Although aspects such as firm culture, ownership structure, or the level of formalization might play a much greater role for technology search behavior than firm size in individual cases, it has been shown that there is an impact from firm size on the attention structures that govern search activities. This is very important because the majority of service firms in general (Hipp and Grupp 2005) and of LSPs in particular (Evangelista and Sweeney 2006; Evangelista, McKinnon, and Sweeney 2013) is small. More than half of the people working in transport services are employed by small- and medium-sized enterprises (Eurostat 2009). Consequently, firm size has been proven to impact LSPs' innovation management (Busse and Wallenburg 2014). The concrete role of firm size for technology search behavior, however, is still unexplored.

A.2.4 Summary of the literature review

The literature review reveals that the concept of organizational searches is further gaining in importance due to the proliferation of new technologies and has become decisive for the competitiveness of service firms such as LSPs. To date, the search behavior of service firms has hardly been investigated, which is why the effective allocation of resources for search activities today is opportunistic rather than well-considered at most LSPs. The ABV provides a valuable perspective through which to understand the antecedents of search behavior in general as well as the potential effects of different attention structures in large and small firms. By scrutinizing the impact of external search aspects on the search behavior of LSPs and the moderating effect of firm size as an internal search aspect, this paper contributes to theory elaboration.

A.3 Methodology

A.3.1 Overall approach

Considering the under-explored nature of the phenomenon under study, the author applied an inductive research approach based on case studies (Eisenhardt 1989; Eisenhardt and Graebner 2007). The ABV (Ocasio 1997) is used as the theoretical basis for the investigations, framing firm search behavior as the result of how decision-makers' attention is channeled and distributed. Joseph and Wilson (2018) have outlined the value of case studies for the exploration of the complexities of attention. Therefore, various contributions have used this method to examine attention patterns (Rerup 2009; Joseph and Ocasio 2012; Vuori and Huy 2016). In order to identify commonalities of large firms, commonalities of small firms, and—most importantly for the research objective of this paper—differences between large and small firms, a comparative case study design based on theoretical sampling is applied (Eisenhardt 1989).

A.3.2 Study design, case selection, and sampling

The technology search behavior of LSPs is the main unit of analysis, while decision-makers from top management and those with technology-screening functions are interviewed to make the attention structures during technology searches observable (the unit of observation). In accordance with prior work, the author followed a theoretical sampling logic (Glaser and Strauss 1967; Eisenhardt 1989) and applied a two-step sampling approach (Seawright and Gerring 2008). In a first step, homogeneity was ensured so that comparability between the cases was given to a certain degree. The basis for this was the selection criteria developed from the literature (Meredith 1998; Bastl, Johnson, and Finne 2019).

- *Criterion 1—Comparable attentional perspective*: The attentional perspective refers to a firm's cognitive structures that create awareness for relevant stimuli and is equal to the dominant firm strategy (Ocasio 2011). All sample firms had to exhibit a clearly stated openness toward technological innovations (e.g. in their annual report) so that a comparable awareness for technological innovations could be assumed.
- *Criterion 2—Hybrid technological innovations*: Hybrid technological innovations exhibit higher levels of complexity than either standalone hard- or software solutions (Barrett et al. 2015). The complexity of a technological innovation can be expected to impact organizational attention allocation during searches because decision-makers are bounded in terms of their attentional capacity and have to search selectively (Ocasio 1997; Monteiro 2015). Thus, the cases included in this study were all confronted with innovations from this category in order to avoid distorting effects.
- *Criterion 3—Organizational assignment of technology searches*: Having a clear organizational assignment for technology searches is an indicator for at least two important aspects: (1) an LSP's affinity for technological innovations and (2) the

regular conduct of technology search activities (Rohrbeck and Gemünden 2011; Cichosz et al. 2017). As small firms are also part of the sample, a technology search does not necessarily have to be conducted by a separate function. It is sufficient that at least one person is officially responsible for search activities.

- *Criterion 4—Basic logistics provider*: The specializations of LSPs have sharply increased throughout the past few years (Mathauer and Hofmann 2019). Some market players, for instance from contract logistics, are closer to manufacturing firms than to the traditional view of LSPs (Liu and Lyons 2011). The companies incorporated in this study therefore all gain more than 70% of their revenue from basic logistics services including transportation, transshipment, and storage logistics.

The second sampling step evolved during the course of the research. Initially, the author intended to observe the antecedents of technology search behavior in one relatively homogenous group of firms sampled according to the above-stated criteria. However, patterns emerged in the data suggesting differences between large and small firms. For this reason, the initial framework was extended to the moderating effect of firm size, and sampling was adjusted in order to capture comparable subgroups of large and small firms (Eisenhardt and Bourgeois 1988; Eisenhardt 1989). This two-step approach yielded a sample that was—at least to a certain degree—both homogenous and heterogenous.

A.3.3 Data collection

Several data sources were incorporated in this study: (1) semi-structured interviews with firm executives; (2) informal follow-up interviews; and (3) archival material on the firm[51] and on the technology under study.

Semi-structured interviews were conducted in seven firms. In total, 16 in-depth interviewees are included in this study (see Table A - 1). All of the interviewed people had at least 7 years of industry experience and held senior positions such as CEOs, CIOs, COOs, Heads of R&D, Heads of Logistics, etc. Therefore, they were qualified to provide

[51] If there was no publicly available archival material for small firms, the interviewees were requested to provide internal archival material.

in-depth interviews on technology searches. At three of the four large firms, the interviews were conducted with at least one person from the corporate level and one person from the business level. This approach increased diversity and helped to reach theoretical saturation (Eisenhardt 1989). The structure of small firms did not allow for the inclusion of interviews across hierarchies. Still, at least two perspectives were incorporated on the search processes in order to avoid convergent retrospective sensemaking (Eisenhardt and Graebner 2007).

The semi-structured interviews had five sections (see Appendix A.8.1). First, the interviewees' backgrounds and roles were determined, with a special focus on their industry experience and their experience with past technology projects. Second, a detailed description of the technology search process was elicited, deepening the insights into attention allocation during initiation through follow-up questions. Third, technology search behavior was discussed for one selected technological innovation. The attention on external opportunities and threats could thereby be worked out in detail. Fourth, questions on negative experiences were incorporated. The fifth section contained, if necessary, questions that arose during the interview or from the additional case material. The interviews lasted between 45 minutes and 2 hours. Whenever necessary, informal follow-up calls or emails were used to complete the picture.

The author has taken several steps to further ensure data validity. Interview techniques were deliberately applied to increase the probability of accurate information (Hannah and Eisenhardt 2018). Furthermore, event-tracking proved valuable, because the participants enumerated their technology searches in a step-by-step manner and could even recall events from years before. All of the questions were posed in an open way, triggering the narrative flow of the interviewees before digging deeper with the help of follow-up questions (Strauss 1987). Last but not least, anonymity was guaranteed to encourage the interviewees to speak openly (Kownatzki et al. 2013; Hannah and Eisenhardt 2018).

To avoid retrospective biases, secondary data supplemented the semi-structured interviews. On the one hand, publicly-available documents were sifted through such as annual reports, internet sites, and online databases. On the other hand, internal firm documents (e.g. technology search process overviews, technology radars, etc.) found their way into the study. The various data sources helped to triangulate the findings, which is highly recommended for qualitative research (Strauss 1987; Yin 2017).

A.3.4 Data analysis

The data analysis started with a data-synthesis stage to enable comprehensive descriptions for each case to be written down (Eisenhardt 1989; Hannah and Eisenhardt 2018). Whenever details were missing, secondary data or follow-up calls and emails helped to close these gaps in our understanding. After having developed an understanding for each case separately, the data were coded following the three-step approach of Glaser (1978). First, open coding involved the inductive grouping of sentences or phrases into codes and phrases. Second, selective coding ensured that the focus remained on the categories that were directly related to the topic. Third, theoretical coding included the creation of interrelations among the codes and the linking of them to theoretical constructs. Data coding was used as a pre-stage for the following cross-case analysis based on tables. Appendix A.8.2 contains selected interview extracts and the assigned codes. To identify similarities and differences between large and small firms, pairwise comparisons based on the codes from the prior analysis step were undertaken. This tactic ensured that even subtle aspects were considered (Eisenhardt 1989). As an extension, the whole groups of large and small firms were analyzed separately first before contrasting them to refine the insights from the pairwise comparisons. This process was accompanied by reconciliations with prior literature in an iterative fashion (Eisenhardt and Bourgeois 1988).

Table A - 1. Case overview

Cases	Size	Firm description	Technology description	Participants (no.)	Total (no.)	Additional data sources on technology searches
L1	L	Internationally operating logistics group offering the full spectrum of logistics services, with a particular emphasis on the courier, parcel, and express mail business segments	Innovative optimization tool for package density; maximal usage of carton and pallet space via more effective selection and arrangement of packages based on size and weight	Head of Business Development & Account Management (1); Vice-President of Innovation & Trend Research (1)	2	• Company-related (212 pages) ○ Reports ○ Company presentation • Technology-related (99 pages) ○ Trend reports ○ Press releases
L2	L	Nationally operating postal service provider with further business areas in logistics, bus transport, and financial services	Temperature logger for manipulation-proof temperature data recording and transmission; the data is stored in a cloud encrypted by blockchain technology	Head of R&D (1), Head of Autonomous Delivery & IoT & Blockchain (1), Head of IT Strategy & Innovation (1)	3	• Company-related (131 pages) ○ Reports ○ Company presentation • Technology-related (187 pages) ○ Internal technology radar ○ Internal technology search process ○ White papers ○ Physical testing of technology ○ Product videos ○ Webpage of technology provider
L3	L	National market leader and provider of standard logistics services, including general cargo, partial and complete loads, combined transportation, and warehousing	3D-camera-based system capturing cargo sizes automatically when entering or leaving the warehouse	CIO (1), Member of the Board and Head of Logistics (1), Project Manager IT (1)	3	• Company-related (27 pages) ○ Reports ○ Press articles • Technology-related (14 pages) ○ Product descriptions ○ Product video ○ Webpage of technology provider
L4	L	Standard logistics service provider with a national focus and business fields covering general cargo, temperature-controlled transport, and car logistics	Smartphone equipped with an app for process optimization in car logistics; tons of paper are saved as the vehicle preparation configurations ordered by the customer are digitally stored and remotely accessible	Business Development Manager (1), Project Manager App Development (1)	2	• Company-related (28 pages) ○ Reports ○ Press articles ○ Company video • Technology-related (20 pages) ○ Physical testing of technology ○ Internal documents on app development ○ Webpage of technology provider

Table A - 1 (continued)

Cases	Size	Firm description	Technology description	Participants (no.)	Total (no.)	Additional data sources on technology searches
S1	S	Provider of standard logistics services for European customers, encompassing transportation, warehousing, and handling, with additional activities in contract logistics and consulting	Collaborative robots for the automation of commissioning processes; requirements are particularly high due to the filigree goods that have to be commissioned hand in hand with employees	CEO (1)	1	• Company-related (80 pages) o Reports • Technology-related (137 pages) o Press releases o Technical articles o Product descriptions o Webpage of technology provider
S2	S	Niche provider of standard transportation services and additional business fields including express transportation and temperature-controlled logistics	Alternatively-powered van for temperature-controlled transportation with different temperature zones and real-time access to temperature data for the customer	CEO (1), COO (1), Project Manager (1)	3	• Company-related (18 pages) o Company presentation • Technology-related (70 pages) o Product descriptions o Whitepaper
S3	S	Regional standard logistics service provider complementing its service portfolio with event logistics and customs clearing	Mobile data-entry system to optimize scanning during loading and unloading processes of general cargo transport	Member of the Board and Head of Logistics (1), CEO (1)	2	• Company-related (26 pages) o Internal reports • Technology-related (32 pages) o Product descriptions o Product videos o Webpage of technology provider

Notes: Firm size: L, large (revenue > 250 m EUR); S, small (revenue ≤ 250 m EUR)

A.4 Results

A.4.1 Within-case analysis

Case L1. L1 is a globally-operating logistics group and is among the largest of the LSPs in the world. Technology searches are organizationally anchored in a separate function and this includes both trend research activities and direct customer interaction in so-called innovation centers. Top management aimed at positioning L1 as the industry's innovation leader and provided extensive resources for search activities. The technology search under study was concerned with an optimization tool, where 3D-camera technology newly allowed for an increase in packaging density. The main trigger was the expected potential for market expansion, which both impacted search selection and search behavior. The trend research team increased the scope of the start-ups that were interviewed to better grasp the available solutions on the market. Furthermore, the team was allocated more time for the search to set the groundwork for a pilot study. With regard to general technology search behavior, a synthesis of the interviews yielded positive customer perceptions, market expansion, and the threat to business segments as antecedents of increased search selection. Search intensity was positively triggered by customer problems, direct competitor adoption, and technology uncertainty.

Case L2. L2 is a national market leader for postal and logistics services. Having a long history as a nationalized postal services provider, the interviewees stated that the company had an image problem in the market. Thus, the technology search behavior was generally driven by the principle of using new technologies to positively impact the perceptions of the company held by its customers. From an organizational point of view, technology searches are part of the group innovation function, but this is divided among a start-up screening function and adjacent further functions. The observed technology search was concerned with a blockchain-secured temperature-tracking device for the shipment of pharmaceutical and other temperature-sensitive products. This technological innovation was driven by the potentially positive perceptions of the market participants. There were no fixed return targets, although both search selection (interviews with blockchain experts from different branches) and intensity (involvement of internal specialists) increased. Besides customer perceptions, the interviews revealed that search selection was generally triggered by the opportunity for market expansion and by threatened business segments. Adding to that, the search intensified if the customer presented with a concrete problem, if direct competitors adopted technological innovations, or if a technology development was characterized by high levels of uncertainty.

Case L3. L3 is national market leader in the field of standard logistics services. The interviews indicated that technological innovations are considered to be necessary for achieving the self-imposed targets and to defend the company's competitive position. The CIO is responsible for search activities and acts mostly freely in defining the terms for search selection and intensity for his employees. The studied technology search was triggered by operative problems with selected customers. As their data on cargo dimensions were often insufficient, a system that could automatically and quickly capture cargo sizes with the help of cameras was searched for. To avoid long-term implications regarding the profit margin, the search intensity for a technological solution to the problem was increased. The CEO personally granted an extra budget to avoid losing any time. In consequence, both the breadth of interviews with technology providers (search selection) and the effort by the internal IT department (search intensity) increased. More generally, L3's search selection was positively associated with customer problems, positive customer perceptions, market expansion, and technologies that threatened existing business segments. The search intensity thus increased when L3's competitors adopted technologies or when L3 was faced with uncertain technology development.

Case L4. L4 has a long history as a national standard LSP with additional business fields of temperature-controlled transport and car logistics. Project managers within specialist departments are encouraged to spot technological innovations so that the salespeople are able to present up-to-date solutions to the customers. This high level of customer orientation was an omnipresent search principle and could also been encountered throughout the studied case example. The specifically examined technology search was concerned with the introduction of smartphones in combination with an app to optimize cleaning processes. As the customer expected L4 to become more digital and to save paper, search selection and intensity were extended. The responsible project manager had to access new technology suppliers that had not yet worked with L4. Furthermore, resources were made available in order to form a project team. The interviews further revealed that specific problems of customers, the opportunity for market expansion, and technological threats to existing business segments typically anteceded increased search selection at L4. The search intensity was additionally enhanced following technology adoption by its competitors and uncertain technology developments.

Case S1. S1 provides standard logistics services as well as consulting in the field of supply chain and logistics management. The encountered search principle was clearly directed toward future capabilities. In other words, the CEO wanted to avoid missing out on technological innovations that could jeopardize S1's key business segments. It is for this reason that the technology search that was investigated was concerned with automization technologies. Developments in robotics decrease the competitiveness of all LSPs with personnel-intensive and therefore expensive commissioning process. Thus, S1 increased both its search selection and intensity directed at this field. Having been planned as a pilot project that was also to be rolled out to other sites in the future, the search selection was very broad, even involving approaching its competitors in order to find the most promising solution. Furthermore, the management board granted an additional budget because it feared exposing the entire (personnel-intensive) site to the risk of possible closure if the process was too slow. More generally, S1's search selection was further increased by customer problems, the opportunity for market expansion, and direct competitors who had adopted a specific technology. The search intensity sometimes even increased due to technology uncertainty. This reflected a very future-oriented technology approach.

Case S2. S2 is a regional niche service provider specialized in express transport and food logistics. Its dominant search principal, which can be found in the firm strategy as well, is focused on solving problems for customers. Although the interviews indicated that S2 is more frequently than ever concerned with new technologies, search activities were "the top" part of the COO's job. As S2 did not possess technology-specific knowhow and only had limited resources, the search behavior was only conducted situationally. The technology search under study was geared toward an alternatively-powered, temperature-controlled van with low emissions, several temperature zones, and real-time access to temperature data for the customer. This van needed to help the customer to meet emission goals. To identify an appropriate technological solution, the search selection had to be broadened. The customer was even asked to suggest suitable providers. The search intensity could not be specified precisely because there was no formal project in place for this search. Nevertheless, it became clear that the search intensity increased as soon as the customer made its wishes known. From the interviews, it emerged that direct competitors and the threat to business segments also increased both search selection and behavior. Interestingly, the opportunity for market expansion and technological uncertainty had negative effects on search behavior. Against the backdrop of the limited resource allocation, the danger of dispersal would be too high.

Case S3. S3 is a regional standard service provider that complements its service portfolio with customs clearing. Being active in a highly competitive market, the search for technological innovations follows the principle of maintaining competitiveness. The Head of Logistics is responsible for technology searches, but he coordinates all search activities closely with the other Members of the Board. The observed technology search was centered around a mobile data-entry system. Large competitors were already using this technology, but S3 wanted to signal to its customers that small LSPs could work with such a system as well. Consequently, S3 extended its usual search radius and contacted new technology providers, former colleagues from the same industry, and other people from its personal network. As this was one of the largest technology projects in S3's history, the Head of Logistics also received a more extensive budget. Having been interviewed on other antecedents of general search behavior, customer problems and threatened business segments could be identified as positively impacting search selection and intensity. As was found for S2, market expansion opportunities and technology uncertainty also had a deterrent effect on the search behavior of S3. The following Table A - 2 provides a comparative overview of the cases included in this study.

Table A - 2. Comparison of the cases included in this study

Case	Structural attention regulators				Antecedents of search selection		Antecedents of search intensity	
	Resources	**Dominant search principle**	**People involved**	**Structural positions**	**Opportunities**	**Threats**	**Opportunities**	**Threats**
L1	Extensive – Technology search is not directly linked to monetary success; testing is structurally rooted	Market expansion – Technology search as basis to expand the market	Top management targets – Technology specialists lead search activities; top management just sets targets	Single function search approach – Search is conducted by a specialist function	• Positive perception by customer (+) • *Market expansion (+)*	• Threat to business segment (+)	• Customer problem (+) • Positive perception by customer (+) • *Market expansion (+)*	• Direct competitor (+) • Threat to business segment (+) • Technology uncertainty (+)
L2	Extensive – Technology search is not directly linked to monetary success; testing is structurally rooted	Customer perception – Technology search as basis to improve image with customers	Top management targets – Technology specialists lead search activities; top management just sets targets	Multiple function search approach – Search is conducted by various specialist functions	• *Positive perception by customer (+)* • Market expansion (+)	• Threat to business segment (+)	• Customer problem (+) • *Positive perception by customer (+)* • Market expansion (+)	• Direct competitor (+) • Threat to business segment (+) • Technology uncertainty (+)
L3	Moderate – Technology search is encouraged, but only if a case is available; testing is sometimes observable	Market expansion – Technology search as basis to expand the market	Top management involvement – CIO leads search activities; direct coordination with CEO	Single person search approach – Search is conducted by one person	• *Customer problem (+)* • Positive perception by customer (+) • Market expansion (+)	• Threat to business segment (+)	• *Customer problem (+)* • Positive perception by customer (+) • Market expansion (+)	• Direct competitor (+) • Threat to business segment (+) • Technology uncertainty (+)
L4	Moderate – Technology search is encouraged, but only if a case is available; testing is sometimes observable	Customer perception – Technology search as basis to improve image with customers	Top management information – Specialist department leads search activities; CEO is informed about search	Multiple person search approach – People from specialist departments are encouraged to search	• Customer problem (+) • *Positive perception by customer (+)* • Market expansion (+)	• Threat to business segment (+)	• Customer problem (+) • *Positive perception by customer (+)* • Market expansion (+)	• Direct competitor (+) • Threat to business segment (+) • Technology uncertainty (+)

Table A - 2 (continued)

Case	Structural attention regulators				Antecedents of search selection		Antecedents of search intensity	
	Resources	**Dominant search principle**	**People involved**	**Structural positions**	**Opportunities**	**Threats**	**Opportunities**	**Threats**
S1	Moderate – Technology search is encouraged, but only if an application case is available; testing is sometimes observable	Maintaining future ability – Technology search as basis to meet technological threats	Top management information – Specialist department leads search activities; CEO is informed about search	Multiple person search approach – People from specialist departments are encouraged to search	• Customer problem (+) • Market expansion (−)	• Direct competitor (+) • *Threat to business segment (+)*	• Customer problem (+) • Market expansion (−)	• Direct competitor (+) • *Threat to business segment (+)* • Technology uncertainty (+)
S2	Restricted – Technology search for good cause only; no testing	Customer problems – Technology search as basis to solve individual customer problems	Top management involvement – COO leads search activities; direct coordination with CEO	Single person search approach – Search is conducted by one person	• *Customer problem (+)* • Market expansion (−)	• Direct competitor (+) • Threat to business segment (+) • Technology uncertainty (−)	• *Customer problem (+)* • Market expansion (−)	• Direct competitor (+) • Threat to business segment (+) • Technology uncertainty (−)
S3	Restricted – Technology search for good cause only; no testing	Adoption by direct competitors – Technology search as basis to stay competitive	Top management involvement – Head of Logistics leads search activities; direct coordination with CEO	Single person search approach – Search is conducted by one person	• Customer problem (+) • Market expansion (−)	• *Direct competitor (+)* • Threat to business segment (+) • Technology uncertainty (−)	• Customer problem (+) • Market expansion (−)	• *Direct competitor (+)* • Threat to business segment (+) • Technology uncertainty (−)

Italic letters = Dominant antecedents in the observed case

A.4.2 Cross-case analysis

External opportunities as antecedents for technology search behavior

Opportunity for a positive perception by the customer. The opportunity for a positive perception by the customer emerged from the data as to how LSPs expected their customers to view the LSPs' innovation activities in terms of the company image. Thereby, the customer has a passive role and the LSPs (pro-)actively trigger technology searches. All LSPs underlined the importance of being seen as innovative market actors in times of increasing competition. Interestingly, only large LSPs adjusted both their search selection and intensity to align with the expected customer perceptions. L1, for example, cooperated with new research partners in order to comprehensively search the promising field of sustainable packaging technologies. The search behavior of the other large LSPs was also significantly driven by customer perceptions. The following quotes serve as an illustration:

> People always saw us as the nationalized, dusty postal services provider. How shall we convince new customers with such an image? Then drones came up, and we jumped directly onto it. Although we did not earn money with it, the opportunity was unique. And now, people directly associate us with this technology. (L2, Head of Autonomous Delivery)

> Whenever there is a chance to improve the customer's picture of us with the help of a new technology, the search focuses on it. (L3, Head of Transport)

The technology search behavior of the investigated small LSPs, in contrast, was only partly affected by customer perceptions. They would intensify technology searches whenever they expected a positive image to be created with the customer. However, the location of the searches remained the same. The following quotes serve as an illustration:

> We cannot afford to adopt technological innovations just for image reasons. Why should we therefore go and search for such technologies? […] If we have one in focus anyway, we dig deeper there. Otherwise not. (S2, Project Manager)

> The small LSPs also work with the small shippers. For these customers, an innovative image is less important than classical values such as reliability. (S3, Member of the Board and Head of Logistics)

Therefore, the author derives the following proposition and related moderating effect:

> *Proposition 1:* The opportunity for a positive perception by the customer antecedes the technology search behavior of LSPs.
>
> *Moderators of Proposition 1*: The relationship between a positive perception by the customer and the technology search behavior of LSPs is moderated by firm size, so that large firms increase search selection and intensity, while small firms increase search intensity.

From an ABV, the customer is an important part of the external decision environment (Ocasio 1997) and contributes to the understanding of organizational searches (Barreto 2012). This study goes beyond direct customer influence on search behavior (e.g. customers approaching LSPs with a specific problem) and provides evidence that even the expected perceptions by the customer drive the search behavior of LSPs. It is difficult to assess the customer's perception in the course of a technological innovation and, according to the interviewees, it is often based on past experiences. Research on firm behavior has strengthened the role of past organizational activities for the selection of new ones (Cyert and March 1963; March and Simon 1958), and this study provides further evidence for it.

Opportunity for solving a customer problem. The opportunity for solving a customer problem emerged from the data as search activities that aimed to find technological innovations for problems with which the customer approached the LSPs. It differs from the opportunity for positive customer perceptions because the customer actively triggers search activities. All LSPs included in this study frequently encountered this situation. However, differences became apparent between large and small LSPs. Large LSPs were confident regarding where they searched and did not perceive the problem-related interaction with the customer as a chance to broaden the search selection. After having suggested technological innovations to the customer, large LSPs merely intensified their search on the most promising ones. The following quotes serve as an illustration:

> Running after the client just to get things done in his sense does not work. We have defined a clear procedure regarding how to identify technological innovations […]. The customer is only one source where we search, and he cannot rule out the others. But we listen carefully. If there is a technology that has the potential to solve a customer problem, we invest in a better understanding of it. (L1, Vice-President of Innovation & Trend Research)

> We perceive ourselves as market leaders. The customer asks us how we would approach a problem, and we design a solution with the help of technologies. We usually have these technologies already on our radar, but we deepen research efforts if there is a demand from the customer. (L2, Head of R&D)

The small LSPs behaved differently, as customer problems directed their attention to technological solutions that they had not had to deal with before. In cases S2 and S3, the customers were even encouraged by the LSP to suggest potential technological innovations or technology providers they could talk to. As a result, the customers took an active role in search selection. For example, S2 was provided with suggestions for a suitable temperature-controlled van that met the customer's emission goals. As soon as it was clear where to search, available resources were bundled to intensify search activities. L4 was the only large LSP that behaved similarly to the small ones in this regard due to its problem-oriented business philosophy. The following quotes serve as an illustration:

> We know that others might do it differently. But we see this as a win–win situation if the customer helps us with the technology search. On the one hand, he receives what he expects. On the other hand, we save time and money. (L4, Business Development Manager)

> To be honest, we do not have another option than to involve the customer in the technology search. We lack knowledge and experience. (S2, COO)

Therefore, the author derives the following proposition and related moderating effect:

> *Proposition 2:* The opportunity for solving a customer problem antecedes the technology search behavior of LSPs.

> *Moderators of Proposition 2:* The relationship between the opportunity for solving a customer problem and the technology behavior of LSPs is moderated by firm size,

so that large firms increase search intensity, while small firms increase search selection and intensity.

Prior research has already studied problems as an antecedent for organizational search behavior (Chen and Miller 2007; Baumann, Schmidt, and Stieglitz 2019; Rhee, Ocasio, and Kim 2019). This type of problemistic search was inside-out-oriented (e.g. not meeting internal financial goals). Given that the present study focuses on LSPs as one specific type of service firm, decision-makers' attention allocation on the customer problems is hardly surprising (Wang, Zhao, and Voss 2016). Nevertheless, this is the first empirical contribution to find "outside-in problemistic search behavior" and therefore it substantially contributes to the search literature.

Opportunity for market expansion. The opportunity for market expansion emerged from the data as the chance to create new revenue streams in the existing market with the help of technological innovations. Launching a new-to-the-market service, however, requires resources, knowhow, and a critical size. The cases clearly exhibited a relationship between market expansion and search behavior, but with different signs depending on firm size. All large LSPs stated that they would increase search selection and search intensity if they saw the chance for market expansion. L1, for example, intensified its search efforts around the technology-based optimization of packages because they saw the chance to create a new standard tool for the industry. L2 and L3 behaved comparably, which is illustrated by the following quotes:

> Market expansion is extremely important for us. We really get a lot of resources from above in the search for technologies that have the potential to expand the market. Obviously, this impacts where we search and at what intensity. (L2, Head of IT Strategy & Innovation)

> We are talking about the holy grail of technological innovations now. Searches will directly focus on them with as much resources as we can afford if we really see the potential for market expansion. (L3, CIO)

Interestingly, the small LSPs in our sample were deterred from the market-expanding potential of technological innovations. All of them pointed to their resource allocations and their strategic positioning. According to them, a small LSP would not have the possibility to push such an innovation until market maturity and thus should better not try to. This might bring the advantage of avoiding costly mistakes that a first mover is likely to make. As a result, both search selection and intensity were reduced in these cases. The following quotes serve as an illustration:

> I am convinced that there are great use cases of blockchains with revolutionary potential for logistics. This is the result of my first search on the topic. But do I now start to broaden my search or with more effort? No. We could not implement such a solution anyway. (S2, CEO)

> We often came across such technological innovations [that provide the possibility for market expansion]. But there is a lot of financial risk about them. In such a case, we let it stay on the radar and put our feet up. Let the big ones spend money on it; a follower strategy is often smarter. (S3, CEO).

Therefore, the author derives the following proposition and related moderating effect:

> *Proposition 3:* The opportunity for market expansion antecedes the technology search behavior of LSPs.

> *Moderators of Proposition 3:* The relationship between the opportunity for market expansion and the technology search behavior of LSPs is moderated by firm size, so that large firms increase search selection and search intensity, while small firms decrease search selection and intensity.

Market expansion as an antecedent for search behavior has also been identified in earlier research efforts (Barreto 2012). The findings confirm that (1) market expansion positively impacts search behavior in large firms (with slack resources) and that (2) this positive effect deflagrates in small firms (with scarce resources). Regarding the latter point, the present paper goes even further and shows a potential reversal of the direction of the effect.

External threats as antecedents for technology search behavior

Threat of a direct competitor adopting a technology. The threat of a direct competitor adopting a technology emerged from the data as the technology adoption announcement by an LSP of comparable size and with a comparable business model to the LSP under study. Reflecting the competitive market surroundings in the logistics industry (Hofmann and Osterwalder 2017), such announcements impacted the search behavior of all investigated LSPs. L4, for instance, intensified searches on blockchain initiatives right after its biggest rival in the market had published a press release on a pilot project. The impact on search behavior was more comprehensive for small than for large LSPs. The reason behind this is the holistic search approach of the examined large LSPs. It would be more of a coincidence than a rule that a competitor would launch something that the large LSPs had not yet dealt with. The following quotes serve as an illustration:

> I have never been surprised by a competitor. (L1, Vice-President of Innovation & Trend Research)

> What makes us special is that we are searching so broadly and do many things at the same time. […] Our technology radar is full of technologies; there is nothing we have not yet dealt with. I don't think that any of our competitors would be able to launch something we have not yet considered. (L2, Head of Autonomous Delivery)

When small LSPs hear about a technological innovation by a competitor, the implications regarding their search behavior are different. The small LSPs in the sample did not strive for a dominant market position, but rather occupied a niche. Therefore, it is usual for them for competitors to launch a technological innovation that they have not uncovered with their previous search efforts. As a reaction, competitors have an influence on both search selection and intensity at small firms. This is reflected in the following quotes:

> From our side, it is something positive if the competitor makes us aware of a certain technology. I mean we can never have everything in view. Let the others make the first mistakes. It's good for us. (S2, COO)

> Sometimes we find out about an innovation [the competitor] brought to the market. There are two things we do then: First, we carefully watch. Second, we deal with the technology if we did not do so before. This also allows us to assess whether the technology is relevant for us. (S3, Member of the Board and Head of Logistics)

Therefore, the author derives the following proposition and related moderating effect:

> *Proposition 4:* The threat of a direct competitor adopting a technological innovation antecedes the technology search behavior of LSPs.

> *Moderators of Proposition 4:* The relationship between the threat of a direct competitor adopting a technological innovation and the technology search behavior of

> LSPs is moderated by firm size, so that large firms increase search intensity, while small firms increase search selection and intensity.

This finding is in line with Ocasio (1997), who postulates threats to be equally relevant for attention attraction than opportunities and problems are. However, threats have neither been dealt with from an ABV on the organizational level in general nor for technology searches. While Vuori and Huy (2016) already proved that the threat of competitors attracted attention at the individual level, this study adds empirical material for organizational attention allocation to the threat of competitors during technology searches.

Threat of business segment substitution. The threat of business segment substitution emerged in the data as the potential of a technological innovation to jeopardize the profitability of an LSP's core business segment. All LSPs included in this study feared such technologies, for which there are numerous examples in logistics: self-driving trucks, drones, robotics, etc. S1, for instance, is active in contract logistics and provides extensive commissioning services. These activities are very personnel-intensive, which is why S1 had to outsource parts of the business to Poland. The developments in robotics could lead to a substitution of human commissioners and the whole site is at risk. In response, its technology search behavior was clearly focused on automation technologies. No significant evidence occurred in the data that small and large firms would behave differently—neither for search selection, nor for search intensity. The following quotes serve as an illustration:

> In all asset-intensive businesses, it does not matter whether you miss a trend. Even in 50 years, physical things have to be transported from A to B. The entry costs for the physical systems are so high, a new competitor cannot afford to enter the market. We call it: "Keep the […] machine running." However, in digital businesses, you have to be very careful. Believe me that we are searching at full speed on the technologies that Uber and Amazon are applying. (L1, Vice-President of Innovation & Trend Research)

> We know about the importance of automation for our business and are facing this trend with humility and respect. It is on the top of our agenda to directly search for automation technologies. (S1, CEO)

Therefore, the author derives the following proposition and related moderating effect:

> *Proposition 5:* The threat of business segment substitution due to a technological innovation antecedes the technology search behavior of LSPs.

> *Moderators of Propositions 5:* The relationship between the threat of business segment substitution due to a technological innovation and the technology search behavior of LSPs is moderated by firm size, so that both large and small firms increase search selection and intensity.

For situations involving financial pressure, scholars showed that organizational and individual attention is directed to this problem and the accompanying search activities are expanded in every direction (both selection and intensity) (Cyert and March 1963; Levinthal and March 1981; Rhee, Ocasio, and Kim 2019). The above finding contributes to this debate, because similar effects were found for the external threat of business segment substitution. Thus, it can be concluded that there are external antecedents of search behavior that follow the same attentional mechanisms as selected internal antecedents do. In both described cases, the long-term survival of the company is at stake.

Threat of technological uncertainty. The threat of technological uncertainty emerged from the data as the perceived uncertainty about the future development of technological innovations. There was clear evidence for a relationship between technological uncertainty and search behavior across all cases. Large LSPs viewed this threat more as an impulse to deal with a technology with a higher intensity. Technology selection followed a standard procedure anyhow, but intensity increased with the difficulties in estimating the future development of a technology. L2 listed the example of blockchain technology, where the R&D department had absolutely wanted to explore the topic in depth, as branch experts were in disagreement as to whether the technology was just a short hype or would sustainably impact how logistics is done. The following quotes serve as an illustration:

> [L2] was among the first ones in logistics who considered blockchains as relevant for the industry. Our technology selection, as you refer to it, was successful. Especially the exchange with start-ups contributed to our understanding of the topic. However, nobody—probably even today—can assess how the story will go on. Therefore, we devoted more resources to the topic and also the long-term cooperation with [blockchain start-up] was initiated. (L2, Head of R&D)

> Topics are particularly interesting for us if we do not yet know today where the journey will end the day after tomorrow. (L3, Head of Logistics)

Technology uncertainty had the contrary effect in all small LSPs but S1. There, the CEO set out a strategy that explicitly demanded the examination of the technologies of tomorrow. S2 and S3 showed that such a level of future orientation is the exception rather than the rule for this company size. In the latter two small LSPs, especially rapidly changing technologies were consciously excluded from the search activities. The following statements provide reasons for this:

> For us it's extremely difficult to assess when we should go for a certain technology and when we should wait. If we have no clue how the technology will develop in the future, it is a clear sign for us to keep our hands off this technology. (S2, Project Manager)

> Look around. Does this look like a future labor? Obviously not, because we are doing standard logistics services. With our firm size, you can't afford to invest resources in technologies which are still too far away and we can't assess how they will develop in the next few years. (S 3, Member of the Board and Head of Logistics)

Therefore, the author derives the following proposition and related moderating effect:

> *Proposition 6:* The threat of the technological uncertainty of a technological innovation is related to the technology search behavior of LSPs.

> *Moderators of Proposition 6:* The relationship between the threat of the technological uncertainty of a technological innovation and the technology search behavior of LSPs is moderated by firm size, so that large firms increase search intensity, while small firms decrease search selection and intensity.

The perception of technological uncertainty as a threat is a widely known inhibitor to technological innovation (Bao 2009). This paper provides more differentiated evidence from an attentional perspective. The selection of the issues that decision-makers attend to is shaped by various factors, including situational characteristics, the interactions with other people involved, and the structural determinants of attention (Ocasio 1997). Explanations for the aforementioned finding can be derived from the latter factor. The attention structure is significantly impacted by the relevance an organization assigns to a certain issue. All large LSPs and one small LSP (S1) explicitly stated that they wanted to deal with future technologies, which was consequently reflected in the attention distribution during searches. The small LSPs had the directive not to burn their fingers on new technologies. Therefore, technological uncertainty ultimately had other effects on search behavior at small LSPs. Figure A - 2 summarizes the findings of the case study in the form of a conceptual framework.

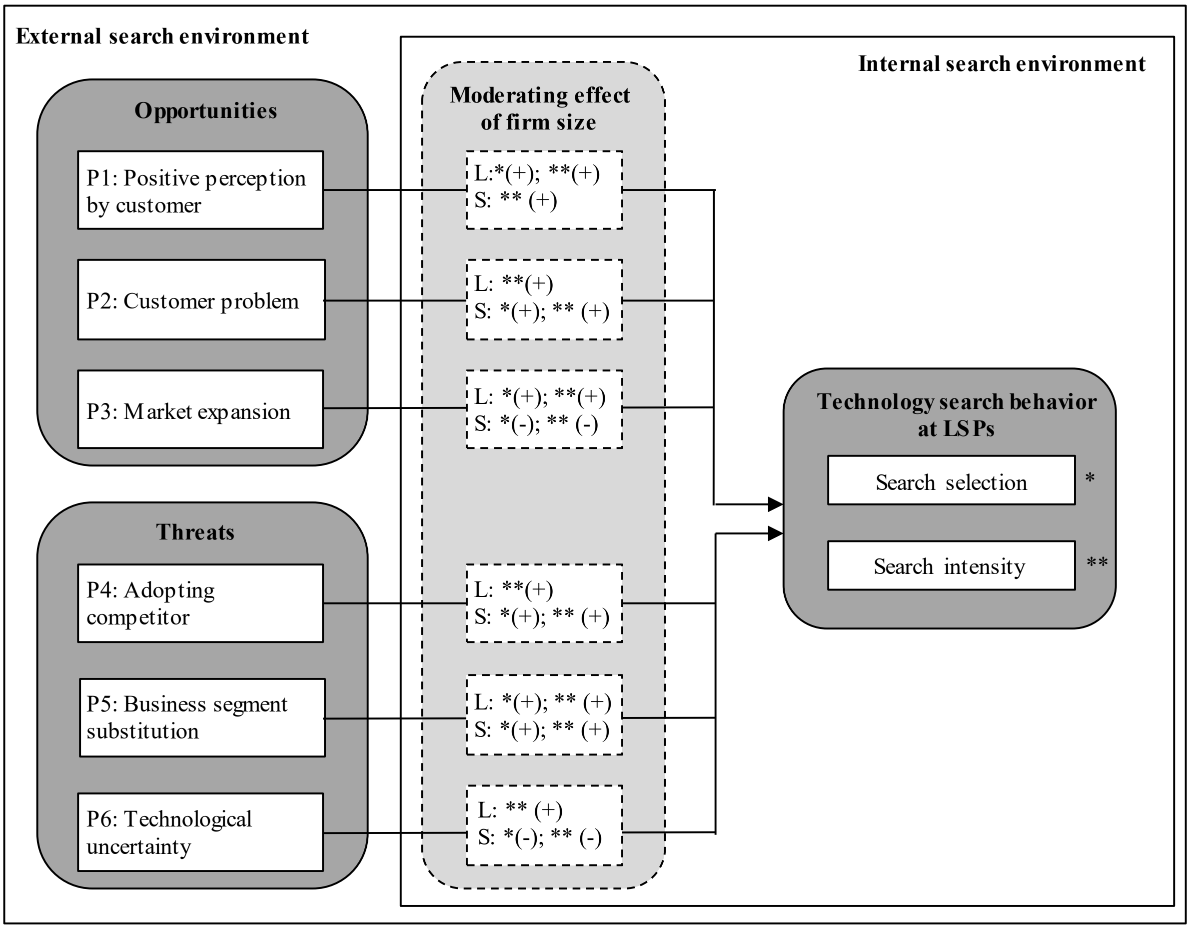

Figure A - 2. Overview of the results

A.5 Discussion

Based on a comparative case study of seven LSPs, this paper revealed the external antecedents of technology search behavior and the moderating role of firm size from an ABV. With regard to *RQ1*, the paper finds that technology search antecedents from the external search environment can be assigned to two categories: opportunities and threats. Opportunities encompass customer-related and market-related factors; namely, positive perceptions by customers, solving customer problems, and market expansion. Threats include market-related and technology-related factors, which are competitors adopting a technology, business segment substitution, and technological uncertainty. While the listed opportunities and threats all antecede technology search behavior, their effect is moderated by firm size. With regard to *RQ2*, it can thus be concluded that firm size matters for both the breadth (search selection) and the depth (search intensity) of technology searches; depending on the specific antecedent, firm size might even lead to a change of sign regarding these two dimensions of search behavior. If a technological innovation involves high levels of uncertainty, for example, it attracts all the more attention from large LSPs that will intensify their search efforts. Small LSPs' search behavior, however, is based on different attention structures that lead to a decrease in search selection and intensity in this example. Therefore, the way in which LSPs channel and distribute the attention of decision-makers is decisive for the understanding of the relationship between external search antecedents and technology search behavior. As such, the findings of this study particularly contribute to (1) the search literature that integrates insights from an ABV and (2) the logistics management literature that tries to understand the innovation activities of LSPs.

By elaborating an ABV, this research highlights the attentional structures that underly organizational searches. It enhances the search literature in three respects. First, the current limitation on the internal aspects of the search antecedents, more specifically on inside-out problemistic searches and slack searches, is overcome (Chen and Miller 2007; Rhee, Ocasio, and Kim 2019). The only known external search antecedent from the literature, the opportunity for market expansion (Barreto 2012), can be confirmed and extended by customer-related antecedents. As the problems of customers were found to impact technology search behavior, this paper adds the notion of outside-in problemistic searches to the current debate on problemistic searches (Gavetti et al. 2012; Posen et al. 2018). Furthermore, threats were found as a new category of external factors that antecede technology searches. This category is in line with Ocasio (1977), who states that problems, opportunities, and threats are drivers of organizational attention. This is the first study to find empirical evidence on the role of external threats on technology search behavior. Second, Li and colleagues (2013) identified two separate attention components of managerial searches: search selection and intensity. This study takes up these search dimensions and transfers them to the organizational level. Thereby, a more nuanced discussion of attentional processes in organizational searches becomes possible. Third, differences between large and small firms have not yet been investigated from an ABV. The present study showed that attentional structures differ considerably depending on firm size and it has provided empirical evidence for the implications with regard to technology search behavior.

Literature on the management of LSPs profits from new perspectives on the under-researched phenomenon of technology search activities. The findings of this paper attest that the customer has an important role at the front end of innovation activities, which is in line with previous findings (Flint et al. 2005; Flint, Larsson, and Gammelgaard 2008). However, the argumentation is based on attentional mechanisms that impact what decision-makers search for and at what intensity. This study is among the first to introduce an attentional perspective in the logistics management literature, and the value of understanding attentional processes becomes visible in view of the results. It was shown, for example, that the opportunity for market potential and the threat of technological uncertainty negatively impacted the technology search behavior of small LSPs. Considering the high prevalence of small LSPs in the logistics market, this paper adds new explanatory approaches regarding why the logistics industry might be significantly less innovative than other service industries are (Wagner 2008; Busse 2010).

The stated theoretical contributions of this study are complemented by important managerial implications. Technology searches at LSPs, especially when it comes to small firms, are often more opportunistic than actively managed (Cichosz et al. 2017). In both cases, understanding the drivers of attention is very valuable in order to improve search activities and prevent purely reactive behavior. This study provides insights into concrete opportunities and threats that antecede search behavior and highlights the accompanying attentional processes. Adding to that, decision-makers who are concerned with the search for technological innovations may not be aware of the different components of search behavior; namely, the breadth of the search (search selection) and the depth of the search (search intensity). Knowing that triggers from the external firm environment can impact these search components differently increases the possibility of managing the components of technology searches more deliberately. Thus, this study helps to understand how to allocate resources for technology searches more effectively. This is particularly valuable for industries such as logistics, where the resource allocations are particularly low due to low profit margins (Deepen et al. 2008). The comparison of small and large LSPs delivers additional value for practitioners. Depending on their firm size, search strategies can be pursued that contrast with what direct competitors do. Thereby, new possibilities for a competitive advantage evolve.

A.6 Limitations and future research

While the present study offers various insights, it is also subject to limitations. First, the results are derived from the perceptual assessments of both concrete search activities on specific technological innovations as well as general statements on technology searches. The author tried to mitigate the methodological effects, for example, through the incorporation of different perspectives and a wide range of additional archival material (Eisenhardt 1989). However, more objective and more extensive research is required in order to confirm the findings. Second, all sample firms stem from the logistics industry. Although this study consciously focused on service firms from former low-technology environments, there are peculiarities that might impede the generalization to other industries. For example, LSPs are known for an operative-driven culture (Esper, Fugate, and Davis‐Sramek 2007), their dependency on single customers (Bolumole, Frankel, and Naslund 2007), and their unique position between the customer and the customer's customer (Selviaridis and Spring 2007). It can only be assumed as to whether the presented findings would also show up in other service industries. Third, the study is limited by the relatively small sample size in combination with the high specificity of technological innovation projects. Although significant differences between large and small firms emerged from the data, these differences might diminish in larger subgroups. Additionally, technology projects are very difficult to compare due to their individual nature. The author attempted to reduce these effects by the strict application of the sampling criteria (Bastl, Johnson, and Finne 2019), but a certain amount of bias cannot be excluded.

This research would benefit from more research on the interpretation mechanisms to classify external search antecedents as either opportunities or threats (Jackson and Dutton 1988), as the categorization by the interviewees was not further scrutinized. For example, examining the implications of ambivalently-interpreted external stimuli for technology search behavior could be equally important, but has not yet been addressed (Plambeck and Weber 2009, 2010). Furthermore, a similar study in another industry context would help to complete the picture of search antecedents. The data hinted at the opportunity for improved interorganizational cooperation and the threat of negative adoption examples from the industry as further antecedents, but there was not enough evidence for incorporating them as well. Especially the former one could help to advance the literature on interorganizational technology adoption in supply chain management (Lyytinen and Damsgaard 2011). Finally, firm size was the only internal aspect of the search environment this study focused on. Future studies should consider further aspects as well, for example, firm culture (Min, Zacharia, and Smith 2019).

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A.8 Appendix

A.8.1 Extract of the interview guideline

1. **Personal background**
   a. Please outline your professional career in short.
   b. How many years of professional experience do you have in the logistics industry?
   c. What is your current position in the company and what tasks does it involve?
   d. In how far are you involved in technology search activities?
   e. How would you assess your level of experience regarding technology search activities?

2. **Technology search in general**
   a. What are the steps and sequence of the technology search process at your firm?
   b. Who participates in search activities and who determines the search principles?
   c. How are the search activities formally organized?
   d. Where do you search for technological innovations (search selection)?
   e. How long do you research for technological innovations (search intensity)?
   f. What resources do you dispose of for technology search?
   g. What triggers search activities at your firm?
   h. How do customer-related/market-related/technology-related factors impact search behavior (search selection vs. search intensity)?
   i. Could you please assign the aforementioned aspects to the categories of opportunity and threat?

3. **Technology search in specific**
   a. Please describe a (hybrid) technological innovation you have recently adopted so that we can refer to it with the following questions.

b. What was the initial trigger for dealing with this technology?
c. What other factors triggered the technology search activities (customer-related/market-related/technology-related)?
d. How did the aforementioned factors impact search behavior (search selection vs. search intensity)?
e. Could you please assign the aforementioned factors to the categories of opportunity and threat?

4. Negative experiences

a. Could you please describe the technology search process of a less successful example?
b. What went differently regarding the antecedents of search?

5. Varia

A.8.2 Overview on selected quotes and the coding

Quotations from the interviews (selection)	**Selective Codes**	**Theoretical codes**
"Our search activities are not directly linked to a monetary target. In a group like ours, there are certainly enough resources available for this." (Head of autonomous delivery & IoT & blockchain, L2)	Resources	Structural attention regulators
"I always come from the market, always from the benefit, always from the customer. That is the main idea." (CIO, S1)	Dominant research principle	
"Every search for a new technology must be driven by the aim to create a win-win situation. We want to profit, but the customer should profit as well." (Business development manager, L4)		
"I have the full responsibility for technology search at out firm. Once a year, we additionally have a future workshop with the whole board." (Member of the board and head of logistics, S3)	People involved	
"We have a specialist function called […]. They are concerned with the whole topic of trend research, including the search for specific technologies." (Vice president innovation & trend research, L1)	Structural positions	
"It is important to have competence centers for technology, for example, IoT. In case I attend to a related technology, I send it over to them. Without having specific knowhow, you would search endlessly." (Head R&D, L2)		
"Technology search is something we do for the customer and not for us. The client often tells us where to search, especially if he has a specific use case for which a solution is expected." (CEO, S2)	Problem of customer	Antecedents of search selection
"Automation is what we focus on, because we think it has massive consequences for logistics. Therefore, we are talking to as many people as possible on this topic." (CEO S1)	Threat of business segment	
"We do this professionally, so that the competitor normally does not have adopt technologies we have not thought of before. But for sure, if he announces adoption, we check whether we really considered every aspect of the technology in our search process." (Head of IT strategy & innovation, L2)	Direct competitor	Antecedents of search intensity
"We have done far too little for our image in the past. This is true for the whole industry. Therefore, we invest a lot for technologies that have the potential to improve our image at the customer." (Head of autonomous delivery & IoT & blockchain, L2)	Positive perception by the customer	
"The customers expects you to change and develop in some way. And you need just that kind of thing, even if it doesn't change our world." (Project manager app development, L4)		

B. Study B: Technology adoption by logistics service providers

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The purpose of this paper is to reveal the effects of different technology access modes on the successful integration of technological innovations. From the perspective of logistics service providers (LSPs), theoretical and managerial implications for the process of technology adoption are discovered. The paper provides a structured literature review of the state-of-the-art in technology adoption by LSPs. Drawing on the innovation diffusion theory (IDT) and absorptive capacity, the explorative case study research includes systematic analyses of ten technology projects conducted by seven different LSPs. The findings illustrate that the technology access modes (make, buy and ally) prejudge the success of the integration process in terms of technology acceptance, as well as process quality, speed and costs of integration. This relationship is moderated by technology-, firm-, environment-, and relation-related factors. The paper is limited by its qualitative research approach, only seven different LSPs were addressed. Furthermore, the scope of the investigated technologies is broad but not exhaustive. For practitioners, research indicates that the way LSPs access technologies is highly related to a successful integration process. Therefore, the paper provides practical support for improving technology adoption. As the link between LSPs' technology access strategies and a successful integration process has been largely neglected thus far, this paper is the first contribution addressing this research gap. In this context, IDT and absorptive capacity are discussed for application to technology adoption in supply chain management research.

Keywords: Digitalization, firm size, technology sourcing, case study research, technology innovation, make-or-buy decisions, technology assimilation.

B.1 Introduction

Several market developments are forcing logistics service providers (LSPs) to continuously adopt new technologies. First, the nature of logistics services has changed. Outsourcing as a main trend in supply chain management (SCM) impacts LSPs' service portfolios (Busse and Wallenburg, 2011). To improve customer service levels, existing offer spectra reach far beyond transportation and warehousing and include, for example, logistics management, order processing or additional IT services (Evangelista et al., 2013). Second, global markets exert ever-increasing competitive pressure. LSPs require new sources of competitive advantages (Lin and Lin, 2014). Technologies can help improve an LSP's competitive standing by aiding service innovations or improving existing logistics solutions (Lin, 2008). Third, digitalization is leading to increasingly shorter technology innovation cycles and new competitors, such as marketplace platform providers (Arnett et al., 2018; Hofmann and Osterwalder, 2017). To avoid missing out on the latest developments, a company must constantly scrutinize its level of technology.

Despite a growing body of research on technology adoption in logistics and SCM (Gunasekaran et al., 2017; Asare et al., 2016), logistics managers still struggle with managing this process (Busse and Wallenburg, 2011). One possible explanation can be found in the concept of technology adoption itself. This term is often defined very broadly, encompassing the generation, development and implementation of new technologies (Patterson et al., 2003). However, technology adoption in a strict sense is only one part of a superordinate technology assimilation process. Technology assimilation at the firm level starts with the identification and evaluation of technological innovations in a pre-adoption stage. It is characterized by the motivation and willingness to adopt (technology acceptance). This phase is followed by the actual adoption of a technology through accessing and integrating it, including the technology access mode. Routinization in a post-adoption stage brings the technology assimilation at the firm level to an end (Zhu et al., 2006; Rogers, 1962). Challenges occurring within and between the technology assimilation process stages are largely ignored in the literature. For example, the influence of internal or external technology access modes on the process of technology integration has remained unexplored thus far (Gnekpe and Coeurderoy, 2017).

Additionally, it is frequently neglected that LSPs are confronted with various industry-related specifics concerning technology assimilation, ranging from a lack of technological know-how (Wagner, 2008), an operations driven way of working (Sauvage, 2003) or low educational levels of the workforce (Lai et al., 2005; Lin and Jung, 2006) to a special position in the supply chain between customers and customers' customers (Selviaridis and Spring, 2007). It is supposed (but has not been sufficiently examined) that these peculiarities impact the choice of certain technology access modes and the subsequent integration process. To address the indicated deficiencies, the present paper examines the following research questions:

> *RQ1:* From an LSP perspective, in how far do technology access modes impact the success of the integration process?
>
> *RQ2:* From an LSP perspective, which factors moderate the relationship between technology access modes and the success of the integration process, and how can these factors be clustered?

To answer the research questions, this explorative study starts with a review of the literature on LSPs' handling of technological innovations. Germain et al.'s (1994) and Lin's (2008) logistics technology typologies are discussed and condensed into a logistics technology classification scheme. Drawing on the findings from previous research of Zhu et al. (2006), this paper derives a general process for assimilating technological innovations and shows that – especially against the backdrop of the digital transformation in supply chains – a multi-stage, industry-specific process for assimilating technology is necessary but does not exist. Following Eisenhardt (1989b) and Yin (2017), ten exploratory case studies of technology assimilation projects in seven internationally operating LSPs are used to derive propositions and to extend the process stage of technology adoption for the service provider context. The findings are discussed with regard to selected LSP characteristics (firm size, owner structure and scope of services).

From a theoretical perspective, the paper follows an eclectic approach and makes use of the innovation diffusion theory (IDT) (Meyer and Goes, 1988; Rogers, 1962) and absorptive capacity (ACAP; Cohen and Levinthal, 1990; Zahra and George, 2002) as theoretical lenses for the investigation. The IDT is employed due to its seminal contributions for understanding innovation adoption behavior (Oettmeier and Hofmann, 2017). ACAP is widely considered a key capability to successfully process knowledge obtained from external sources and therefore, should be included in a study on technology assimilation (Liu et al., 2013). Other theoretical work, such as the resource-based view (RBV) (Wernerfelt, 1984) or the technology acceptance model (TAM) (Davis et al., 1989), might be relevant. However, due to the increasing criticism of the application of RBV in SCM research (Bromiley and Rau, 2016) and the TAM's focus on willingness and motivation to adopt technology (Davis et al., 1989), the IDT and ACAP were regarded as better suited for the present paper as this research starts after organizations have decided to adopt a technology. The paper is structured as follows: as a starting point, the following section provides a literature review of LSPs and technological innovations as well as the general technology assimilation process. This overview concludes by identifying current research gaps addressed by the guiding research questions. Section B.3 presents the applied research method and the conceptual framework of the paper in detail. Section B.4 contains the empirical results for the case study analyses, which are scrutinized for selected LSP characteristics. Section B.5 discusses the theoretical and managerial contributions, the limitations of the study and potential directions for future research.

B.2 Literature review

B.2.1 LSPs and technological innovations

LSPs are a specific type of organization that carry out logistics services on behalf of others and therefore, have a special position within the supply chain (Delfmann et al., 2002; König and Spinler, 2016; Selviaridis and Spring, 2007). Literature yields various concepts for the term LSP. The following distinction is the most common: second-party logistics service providers (2PLs) are a synonym for carriers hauling products (Sink et al., 1996). Third-party logistics service providers (3PLs) own physical assets and provide all types of logistics-related services (Zacharia et al., 2011). Fourth-party logistics service providers (4PLs) subcontract other service providers, have a coordinating role and do not own physical assets (Win, 2008). As the sample for the present paper includes 2PLs and 3PLs, the understanding of LSPs is limited to these two manifestations in this paper. Apart from these general concepts for LSPs, additional differentiation criteria can be derived from literature, such as firm size, owner structure or the scope of services (Evangelista et al., 2013; Hofmann and Lampe, 2013). It stands to reason that different types of LSPs exhibit differences in dealing with technologies. The resulting impact on the technology assimilation process has remained unclear thus far.

The integration of various technologies is referred to as digitalization, a superordinate concept (Glas and Kleemann, 2016). Although technologies are a necessary pre-condition for digitalization, they do not have to be digital. As most current technological innovations in logistics have a digital component, the present paper does not investigate pure analog technologies (e.g. manual lift trucks for intra-logistics). Technological innovations encompass “the technological development of an invention combined with the market introduction of that invention to end-users through adoption and diffusion” (Garcia and Calantone, 2002, p. 112). Such a process typically has minimal complexity and is organized as a project.

Technological innovations vary in degree of intensity, with incremental (provide new features and improvements to existing technologies) and radical characteristics (establish a new technological paradigm) as two extremes of a continuum (Anderson and Tushman, 1990). Findings show that LSPs are much more focused on incremental innovations than on radical ones (Busse and Wallenburg, 2011). This may be due to the nature of service providers that adopt rather than generate new technologies (Wallenburg, 2009). The present paper examines “moderate” innovations, which are classified in between radical and incremental innovations and account for the majority of all innovations (Garcia and Calantone, 2002). These innovations are not necessarily new to the market but are new to the firm. Adding this relativity criterion takes into account that innovation effects always depend on the existing organizational context and the technologies in use (Nagy et al., 2016). Included in the study are product (e.g. a digital booking platform in wagon-load freight transportation) and process innovations (e.g. a new transportation management system).

In the context of technology assimilation by LSPs, only a few authors tried to find a classification for technologies in the logistics industry. Germain et al. (1994) chose a coarse distinction between logistics hardware (e.g. optical scanners) and logistics software (e.g. order entry). The product–service customization trend had not yet been incorporated. Another classification originates from Lin (2008), who identified four categories of technological innovations in the logistics industry: data acquisition (e.g. bar code systems), information (e.g. electronic data interchange), warehousing (e.g. computeraided picking systems) and transportation (e.g. global positioning systems) technologies. However, the categories appear outdated when considering today's integration level of technological solutions. Today, technological innovations typically consist of various components. Firms have to decide whether the combination of standard components is sufficient or customization is necessary (Hoetker, 2005). As this logic is truly independent from the application area of the technology, this paper provides the following classification:

- *Customized hardware*: Hardware technology that is adapted to the customer's needs, e.g. trucks with a special superstructure;
- *Standardized hardware*: Hardware technology that is be accessed "off the shelf" by anyone, e.g. an electric forklift;
- *Customized software*: Software technology that is adapted to the customer's needs, e.g. an individually tailored transport management system; and
- *Standardized software*: Software technology that is be accessed "off the shelf" by anyone, e.g. a warehouse management system.

For classifying technologies in this ideal-typical scheme, the dominant dimension (hardware vs software; customized vs standardized) is decisive in each case.

The majority of studies are limited to the adoption process of standardized software technologies at a general level (Gunasekaran et al., 2017; Lai et al., 2008). Evangelista et al. (2013), for example, show that information and communication technologies (ICT) help diversify service portfolios through value-added services. The level of adoption depends on the firm size and structure. In addition to ICT's role in service innovation, Lai et al. (2008) showed positive effects on the cost structure and service quality of LSPs. Hardware technology has traditionally received little attention in logistics research, because buying trucks or charge carriers could not be seen as technology projects in an analog world. Through digitalization, hardware solutions are undergoing "technologization" and have gradually become high-tech products with disruptive potential for LSPs, which is why hardware technology should be included in technology adoption research.

B.2.2 Assimilation of technological innovations

The IDT (Meyer and Goes, 1988; Rogers, 1962) and ACAP (Cohen and Levinthal, 1990; Zahra and George, 2002) contribute to understanding of organizational assimilation of technological innovations. According to Rogers's (2003) IDT, innovation diffusion mainly depends on specific innovation attributes (relative advantage, compatibility, trialability, observability and complexity). ACAP is concerned with a "firm's ability to recognize the value of new information, assimilate it, and apply it to commercial ends" (Cohen and Levinthal, 1990, p. 128). Reconceptualizing the seminal work of Cohen and Levinthal, Zahra and George (2002) suggested that absorptive capacity has two dimensions: potential ACAP (the firm's receptivity to acquiring and assimilating external knowledge) and realized ACAP (the capability of transforming and exploiting that knowledge). Both theories can be applied at the individual and organizational level.

Drawing upon the IDT and ACAP, the assimilation process of technologies at the firm level can be defined as a series of stages from a firm's pre-adoption evaluation of a special technology ("initiation phase") to the actual adoption of the technology ("access phase") until its integration as part of the value chain activities in the post-adoption stage ("integration phase"). At the network level, the post-adoption phase also includes the interorganizational technology distribution to the next downstream company ("technology transfer") and the diffusion from the initiating firm along the entire supply chain ("technology diffusion"). As this study takes a firm focus, the network level is excluded. Previous research efforts mostly did not distinguish between technology assimilation and technology adoption, neglecting the pre- and post-adoption stages (Chan et al., 2012). However, treating the assimilation process of new technologies as an undivided phenomenon limits our understanding and the reliability of results (Gnekpe and Coeurderoy, 2017). Thus, the present paper focuses on technology adoption as part of a superordinate technology assimilation process – assuming that upstream and downstream process stages might influence the actual adoption. The three phases of technology assimilation at the firm level are explained.

Initiation phase. Sticking to the IDT, the technology assimilation process starts with developing an initial awareness and evaluation of the technological innovation (Rogers, 1962). The overarching motivation for triggering this process is an envisaged balance among the perceived benefits of the technology, the firm's technological endowment ("technology push") and market expectations ("customer pull"). The decision about to adopt a technology depends on the degree of problem fit. Logistics and supply chain literature identifies cost savings (Lin and Ho, 2008), the development of digital business models (Hofmann and Osterwalder, 2017), competitive pressure (Wagner, 2008) or individual customers' wishes (Busse andWallenburg, 2011) as typical reasons for assimilating technological innovations.

Access phase. The second stage in the process encompasses the decision about how to access a technological innovation (Rogers, 1962). For doing this successfully, potential ACAP is needed. It refers to a firm's capability of valuing and acquiring external knowledge (Zahra and George, 2002). Due to the access phase's central position in the technology assimilation process, this phase is interrelated with all other phases and plays a key role in the overall success of the process. This phase triggers the actual technology adoption and therefore, is the starting point for the present study. Literature provides different possibilities for accessing technologies ("access modes"), which can be subdivided into make, buy or ally:

- *Make*: firms develop new products or services internally on their own that are customized to the firms' needs (Wagner, 2008; Gnekpe and Coeurderoy, 2017).
- *Buy*: firms buy software or hardware technology "off the shelf" or buy customized software or hardware technology (Tsai and Wang, 2009).
- *Ally*: firms enter into strategic alliances (Borah and Tellis, 2014) or into cooperative participation in technology suppliers (Hagedoorn, 1990). Hostile takeovers were not included in the study due to the technology suppliers' lack of willingness to cooperate. Similar to make strategies, alliances usually involve customized products or services.

Integration phase. The technology assimilation process ends with the integration of the new technology and its use in the post-adoption stage (Zhu et al., 2006). Successful integration requires realized ACAP to leverage the absorbed knowledge (Zahra and George, 2002). A distinction can be made between two dimensions of integration success: success of the integration process and company and market success. Because it takes years until technology projects translate into company success, the latter is excluded from this study. In an SCM research, four central components of successful technology integration processes can be identified: acceptance of innovation (Hazen et al., 2012), the quality of the integration process (Devaraj et al., 2007), speed of integration (Busse and Wallenburg, 2011) and integration costs (Devaraj et al., 2007). The second through fourth components are internal; the first component refers to acceptance by employees (internal) and acceptance by customers and/or other collaboration partners (external).

To further complete the conceptual model of technology assimilation, factors influencing the process must also be considered. In the adoption literature for LSPs, the technology-organization- environment (TOE) framework (Tornatzky et al., 1990) is dominant for clustering moderating factors (Lin, 2008). Research on moderating factors of the technology access and integration phases in the logistics context does not exist, although scholars regard those assimilation stages as particularly worth studying (Zhu et *al.,* 2006). Especially in the supply chain context, the TOE dimensions should be extended with an inter-firm perspective (Grossmann, 2004). From the technology adoption perspective of an LSP, this encompasses deliberate cooperative relationships with technology (service) providers and customers, including the customer's clients and suppliers. In contrast, environment-related factors refer only to companies the LSP is not directly related to concerning technology adoption (e.g. competitors). Important dimensions of the relation-related factors in literature are power (Zhang and Dhaliwal, 2009) and trust (Asare et al., 2016).

B.2.3 Summary of the literature review and research gaps

Overall, the literature review shows that several peculiarities of the logistics industry require LSP-specific research on the adoption of technological innovations in the digital age. However, studies that focus clearly on technologies (and not on technological implications for business models) are scarce and undifferentiated. An analysis of existing literature reveals three research gaps:

1. In the studies of new technologies in logistics, standardized software technologies are overrepresented, limiting understanding of current developments in hardware and hybrid technologies. Thus, this study includes hardware and software solutions.

2. There is no knowledge on the multi-stage technology assimilation process of LSPs, differentiating among initiation, access and integration phases, including the access modes make, buy and ally. For deepening the scientific discussion, the first research question focuses on the relationship between the access and integration phases.
3. Moderating factors of technology assimilation in logistics are most often reduced to the TOE framework, neglecting relation-related characteristics. Thus, a structured examination of industry-specific impact factors on single technology assimilation process stages promises to expand the knowledge frontier. That is the aim of the second research question.

B.3 Methodology

B.3.1 Study design and conceptual framework

This study follows an explorative approach. The aim is a valuable contribution to the scientific discussion through formulating propositions. As research on this phenomenon is still emerging from the perspective of LSPs, this paper applied a multiple case study design according to Eisenhardt (1989b) and Yin (2017). Furthermore, the IDT (Rogers, 1962) and ACAP (Cohen and Levinthal, 1990; Zahra and George, 2002) are used as a theoretical basis. LSPs' technology adoption as part of their technology assimilation process is the main unit of analysis and therefore, chosen as the perspective for the case studies. All semi-structured interviews were conducted in seven organizations for one or two different technology assimilation projects per company (see Table B – 1). Overall, findings from 23 in-depth interviews that lasted from 90min to 4 h are included in the study. To reduce biases and get an unfiltered picture of the respondents' experience during technology assimilation, an unsuccessful project (S1b) was included in the sample (Mena et al., 2013). Persons in different positions, such as CEOs, COOs, CIOs, project leaders, software developers, business engineers and technology providers, were interviewed. Interviews were conducted via phone only if geographic distance did not allow for a physical visit. Following the encounter, interviewees received a copy of the transcript to ensure correctness.

To guide the investigations to answer the research questions, a conceptual framework was derived (see Figure B - 1). The primary focus is the relationship between the access phase and the integration phase, as the research gaps reveal a lack of empirical knowledge on this second half of the technology assimilation process. The potential impact of different technology access modes in the literature on the success of the technology integration process was investigated. As there is every reason to assume that this process is moderated by different factors, they are included in the conceptual model. Overall, the proposed conceptual model is ideal typical. LSPs do not always undergo this process deliberately; occasionally, it is rather emergent (Mintzberg and Waters, 1985).

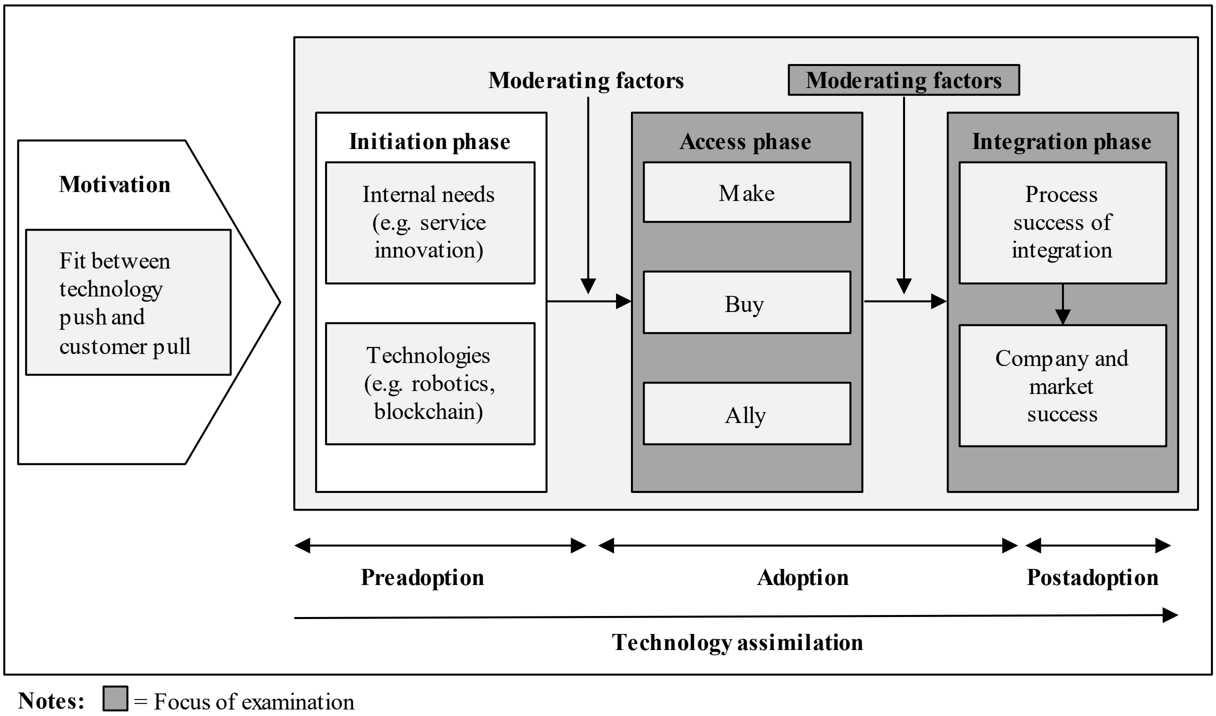

Figure B - 1. General framework of technology assimilation at the firm level[52]

B.3.2 Case selection and sampling

The intersection between technology access modes and integration success was examined in logistics companies. This focus on LSPs is appropriate due to their increasing technological opportunities for providing new or enhanced services in the digital age (Marchet et al., 2009). Furthermore, previous studies carved out various industry-

[52] Own illustration based on Zhu et al. (2006).

Table B - 1. Case overview

ID	Description	Type of technology	Firm Origin	Firm Size	Owner structure	Scope of services	Interview partner	No.
L1	Contract logistics provider co-developing intelligent robotic solution for dynamic commissioning	Customized software	G	L	FB	ALP	Business development manager; technology supplier	2
L2a	Rail freight transportation provider implementing a digital customer interface for transparency in the transportation chain	Customized software	CH	L	NFB	BLP	Business development manager; head of IT products; head of strategy	3
L2b	Rail freight transportation provider co-developing an automated coupling system to reduce staff needs for shunting	Customized hardware	CH	L	NFB	BLP	Business development manager, head of strategy	2
L3a	Postal services provider operating a local platform for same-day shopping	Customized software	CH	L	NFB	BLP	Business development managers (both)	2
L3b	Postal services provider buying the majority of an IT startup specialized in last-mile delivery	Customized software	CH	L	NFB	BLP	Head of smart urban logistics, technology supplier	2
M1	Groupage freight and general cargo provider introducing pioneering transport management system	Customized software	G	M	FB	BLP	Divisional manager IT; project manager IT	2
M2	Diversified LSP introducing mobile application for facilitating processes of car logistics	Customized software	CH	M	FB	ALP	Chairman of the Board of Directors and COO; project manager app development; marketing manager	3
M3	Diversified LSP co-developing own parcel management software	Customized software	CH	M	FB	BLP	CIO; project manager IT	2
S1a	Niche specialist buying vehicles with special superstructure	Customized hardware	G	S	FB	BLP	CEO; COO; technology supplier	3
S1b	Niche specialist buying a standardized dispatching software	Standardized, industry-specific software	G	S	FB	BLP	CEO; COO	2

Notes: Firm origin: CH, Switzerland; G, Germany. Firm size: L, large (revenue >1bn EUR); M, medium (1bn EUR>revenue >250m EUR); S, small (revenue <250m EUR). Owner structure: FB, family business (decision rights controlled by one family >50 percent and one family member in management or on supervisory board); NFB, non-family business (decision rights controlled by one family <50 percent and/or no family member in management or on supervisory board). Scope of services: BLP, basic logistics provider with transportation, transhipment and storage logistics >70 percent of revenue and value-added services <30 percent of revenue; ALP, advanced logistics provider with value-added services >30 percent of revenue and transportation, transhipment and storage logistics <70 percent of revenue peculiarities, such as a more reactive than proactive role in terms of technology (Perego et al., 2011). These insights suggest that the whole LSP technology assimilation process differs considerably from that of other industries.

As technological innovations are the focus, case selection was limited. Each technology project was double checked for its newness to the individual market and the companies' lack of familiarity with the technologies. Furthermore, hardware and software projects were included for comparability (Lin, 2008). In accordance with Eisenhardt (1989b) and Seawright and Gerring (2008), case selection followed a two-step analytical sampling approach. In the first step, companies with a homogeneous origin (German-speaking region of Europe to ensure a comparable legal setting) and a recognizable openness to new technologies were selected. Companies that trust new technologies are thought to exhibit deliberate technology assimilation behavior (Lippert and Forman, 2006). In the second step, companies that differ in terms of firm size (small, medium and large), owner structure (family business, non-family business) and scope of services (focus on basic core processes, focus on value-added services) were chosen. The two-step process ensures that a sample is (to a certain degree) homogeneous and heterogeneous. Thus, the cases can be compared but generalizable results obtained (Eisenhardt, 1989a). An overview of the cases is provided in Table B - 1.

B.3.3 Data analysis

For analyzing the collected data, Strauss and Corbin's (1990) qualitative analysis was applied. This procedure is particularly suitable when rich unstructured information is available. The first step was a within-case analysis to better understand the chosen technology access modes and the implications for the integration process. By considering insights from the transcribed interviews, company websites, official company documents and site visits, data triangulation was applied. Then, a cross-case analysis was conducted to identify generalizable patterns among cases. Aspects of the technology assimilation process that appeared to be most promising for future research were chosen and are presented. This step examined the role of moderating factors, which were expected to influence the impact of technology access modes on a successful integration. To ensure transparency of the coding process, Table B - 2 presents selected extracts from the interviews and the categories the quotes were assigned to before they were structured at the code level.

Table B - 2. Selected data codes and categories

Quotations from the interviews (selection)	Category	Code
"We do not exclude anything [access mode]. However, acquiring a technology supplier is quite unlikely" (L1)	Access modes	Available range of access modes
"For us [a small transportation company], there is a very limited range of available access modes. We can choose between buying either standardized or customized technological solutions and allying with a strategic partner" (S1a)		Access mode choice
"For our specific problem, there is no standardized hardware solution on the market. Since we do not have the capabilities to develop something on our own, a strategic alliance with the technology supplier was the only possible access mode for us" (L2b)		
"Few software solutions on the market are suited for our core business [consolidated freight and general cargo] […]. New solutions entail new technologies, but lack of functionality and triability. […]. We therefore had to partner and co-develop an own solution" (M1)		
"The most important dimension of technology integration in our case [buying a majority stake in an IT startup] was acceptance—both internal and external acceptance" (L3b)	Impact of access mode on integration process	Acceptance of innovation
"Internal acceptance of new technologies is a problem for us, especially for bought software solutions. Our truck drivers, for instance, want to have a truck and no computer" (M3)		Quality of integration process
"In my career, I never experienced that we bought a software, installed it and it worked satisfactorily" (M2)		Speed of integration process
"There is a trade-off between speed and quality of integration […]. We were very fast [with the development of an own parcel software], but our quality was a catastrophe" (M3)		Costs of integration Process
"Make strategies for customized software solutions can be twice as fast as buying standardized components and adjust them to own requirements" (L3a)		
"Do I have to give an answer? […]. We will probably never find out whether the acquisition was worth the money […]. Since the company valuation of a start-up is very difficult, costs are a major topic for this technology access mode" (L3b)		
"Trialability is a main driver of the integration process. If there is not yet a pilot available, we initiate an own pilot project. However, the technology needs to be in such a stage of maturity that we see a use case" (L1)	Moderators	Technology-related factors
"The ratio between costs and expected benefits is a main driver for the whole project" (L2a)		Firm-related factors
"The compatibility with our existing IT-infrastructure is one of the main reasons why we develop our own parcel software" (M3)		Environment-related factors
"Market pressure is generally high […]. There are many competitors, many service providers that can easily be substituted and start-ups doing business differently with the help of new technologies" (L1)		Relation-related factors
"Supply chain management is about sharing information, which can sometimes even be confidential. Thus, we are highly interested in trustful relations with our customers and consignees" (M1)		
"The technology supplier's trust was very important in our case because the takeover has not started from one day to the next. Instead, we successfully worked together for years and had checked various options for the future quite early" (L3b)		

B.4 Results and discussion

B.4.1 Correlation between technology access modes and a successful integration process

Buy strategies. Research revealed a relation between the access mode choice and a successful integration process for LSPs. All case interviewees attested that buying standardized solutions is the fastest and most cost-efficient way to access new technologies. For hardware technologies, L2b, M2 and S1a followed a standardized process from evaluation to integration. Software projects normally do not allow such high standardization and entail feedback loops in the integration phase. The M1 divisional manager IT stated the reason for this: “Software projects are never finished.” Nevertheless, all the interviewees from cases that involved customized software acknowledged that – if there is a standardized software solution for the specific problem available on the market – integration is easier and quicker than for customized solutions. The L2a head of IT summarized: “If I can buy a reliable piece of standardized code on the market, I am always cheaper.” Integrating customized IT solutions, however, is expensive and can take time. In contrast, buying customized hardware technologies is considered to be not very different from buying standardized hardware. S1a provided evidence from buying trucks with a special superstructure for temperature-controlled goods, which did not take longer than buying trucks without customized features. Aggregating these findings, the following propositions can be made:

> *Proposition 1*: From an LSP perspective, buying standardized technological innovations (hardware and software) is positively associated with a fast and cost-efficient integration process.

> *Proposition 2*: From an LSP perspective, buying customized hardware technological innovations is positively associated with a fast and cost-efficient integration process. This relationship does not hold for customized new software technologies.

Ally strategies. Whenever a customized technological product is not available on the market, companies must exploit different access modes to (co-)develop a suitable solution. Strategic alliances were the most common technology access strategy, chosen by L1, L2b, L3a, M1 and M2 for their customized hardware and software projects. Asked about the implications of strategic alliances for the integration process, four out of five achieved a high-level integration quality. This quality is reached because the technology supplier is usually an established market player that had developed similar solutions for the logistics industry. Furthermore, employees often accompany such projects over years and build fruitful relationships. In contrast to buying stakes in a technology supplier, the costs of strategic alliances are much easier to estimate. M1 was an exception with low integration quality, and high costs as downsides of its ally strategy. The divisional manager of IT explained, "We lost a lot of money because of bad technology supplier choice and further delays in the process." Accumulated experience reduces the downsides of ally strategies. L1, L2b and M2, for example, ally quite often and have already developed routines. Thus, the following proposition is suggested:

> *Proposition 3*: From an LSP perspective, entering into a strategic partnership to co-develop technological innovations is positively associated with a cost-efficient integration process and high process quality.

Estimating integration speed and costs for technology access through participation in a technology supplier is very difficult. The L3 head of urban logistics said, "Although we now have immediate access to the technology, the integration process will take time […]. Since there is the option to increase the participation [from 51%] to 100%, another integration process might follow." Concerning the expected costs, he added, "We will probably never find out whether the acquisition was worth the money." However, there is a positive impact on innovation acceptance and process quality. Internal acceptance originates from thorough internal evaluation and selection processes that simultaneously ensure high process quality. External acceptance is facilitated through the target company's existing customer base. The L1 business development manager explained, "We successfully worked together and co-developed a satisfying product. The high acceptance of our solution supported our decision to participate in the company." Thus, the following proposition is formulated:

> *Proposition 4*: From an LSP perspective, participating in a technology supplier to access technological innovations is positively associated with high innovation acceptance and process quality.

Make strategies. Compared to the participation example of L3, make strategies, as executed by L2a and M3, foster quick technology integration. The head of IT products at

L2a explained, “Preparation is everything. We developed a very clear concept for our aspired solution. Everybody was committed and worked at full speed to reach the common goal.” In the case of M3, the interviewees agreed that only the complete development of the proprietary parcel management software allowed them to stay on time, because harmonizing standardized components would have taken too long. Time restrictions, however, negatively impacted the final results. Although both projects reached “go-live status” just within a year, there was still much work to improve the solutions. Furthermore, L2a and L3 exhibited high employee involvement and conducted extensive customer analysis to meet market needs. As a result, internal and external innovation acceptance surpassed expectations. Similar to participation in technology suppliers, the overall costs were very difficult to estimate. This finding was emphasized by the M3 CIO: “I just have no idea what the whole project will actually cost us at the end.” This leads to the following proposition:

> *Proposition 5*: From an LSP perspective, developing proprietary technological innovations is positively associated with high innovation acceptance and fast integration.

B.4.2 Moderating factors

Technology-related factors. The case study research furthermore indicates that the effects of technology access modes on a successful integration process are context-dependent. The first group of relevant moderating factors is technology-related. The divisional IT manager of M1 emphasized the role of technology: “Our company chose a strategic alliance for developing a new transportation management system and faced two great challenges on the way to integration success: Trialability and complexity of the technology. Trialability, because there was nothing comparable on the market before. Complexity, because our business [groupage freight and general cargo] demanded such a complex solution so that it took us more than 10 years to develop it.” The statement was supported by L1, S1b and M2. For the L1 business development manager, trialability of a technology was a necessary pre-condition for executing pilot projects quickly. For S1b, high complexity was mentioned as a reason for failure. Moreover, M2 improved the speed of its app development because around ten apps had been developed, and trialability increased every time. This finding is in line with Rogers (1962), who also identified trialability and complexity as important technology attributes for the general adoption process. Moore and Benbasat (1991) reframed complexity as "ease of use," which can be understood as the opposite of complexity and is the main driver for innovation adoption at the personal level. Individuals are more likely to adopt a technology if the physical and mental effort of using the technology is low. Furthermore, in every case the adoption of a new technology was impacted by the ratio of costs and expected benefits. L2's head of strategy explained, "Our projects are driven by the desire to improve processes while saving costs at the same time. That is why we aim to support human resources with automated solutions." Rogers (1962) referred to this phenomenon of innovation adoption as relative advantage in his IDT. Against this backdrop, the following proposition is formulated:

> *Proposition 6*: From an LSP perspective, the effects of technology access modes on the success of the integration process are moderated by complexity, trialability and the relative advantage of the technological innovation, so that the first impairs and the latter two enhance process success dimensions (acceptance, process quality, speed and costs).

Firm-related factors. For successful technology integration, firm-related factors are important. As the qualification of the workforce is an "evergreen topic" in logistics research (Busse and Wallenburg, 2011), interviewees' similar statements were not surprising. The project manager IT of M1 stated, "There is a lack of qualified people. At the moment, we do not have enough experts to service our new [transport management] system. That is why developing a custom solution is not possible." Additionally, the integration level of technological solutions is rising, particularly for software solutions. According to the S1 CEO, lacking compatibility was the main reason for the project's failure: "If you have dispatching software which does not go hand in hand with the other systems needed, stopping the project is the only remaining option." Across all cases, compatibility with the existing infrastructure and qualified employees were essential for project success. Therefore, the next proposition is derived as follows:

> *Proposition 7*: From an LSP perspective, the effects of technology access modes on the success of the integration process are moderated by technological compatibility and employee qualifications, so that process success dimensions (acceptance, process quality, speed and costs) are enhanced.

Environment-related factors. The interviewees' reflections often referred to the external environmental settings in which the companies operate; thus, the second group of moderators is called environment-related. The M3 CIO stated, "Our competitive landscape changes extremely fast, and the parcel business is becoming ever more important. We were afraid of missing this dynamic development and decided to enter the market. […] However, the whole thing could only work with the help of the most cutting-edge technology available." This statement reflects environmental uncertainty, which typically provokes a feeling of vulnerability and openness to new technologies to change this situation (Patterson et al., 2003). In addition to M3, L3a and S1a provided evidence for the impact of an uncertain environment on technology adoption. Although L3 was not sure about the implications of marketplace platforms on its business model, the firm launched its own digital marketplace. The L3a pilot project is a typical example of service diversification with the help of new technologies. Similarly, S1a used technological innovation as an answer to the increasing industrialization of services and strengthened the provider's unique selling proposition. The COO said, "Our market faces high levels of consolidation at the moment and small service providers can easily be substituted. We bought these trucks to preserve our unique service portfolio with the help of new technologies." In some cases, the technology projects must be seen less as an answer to an uncertain general market than as a direct reaction to competitors. The head of smart urban logistics at L3b rephrased it sententiously: "We pushed the participation because we knew that it would take us too long for catching up with them [the technology supplier] by developing a custom solution. It was a question of competition." Another example is M2, which introduced a new app to expand competitive standing. The app did not provide new service offerings but improved internal processes. In contrast to these examples, L1, L2 and M1 saw themselves as undisputed market leaders regarding the technology projects and did not act because of competitive reasons. Nevertheless, competitive pressure should impel integration success dimensions in any case. Thus, the environment-related findings are summarized as follows:

> *Proposition 8*: From an LSP perspective, the effects of technology access modes on the success of the integration process are moderated by environmental uncertainty and competitive pressure, so that process success dimensions (acceptance, process quality, speed, costs) are enhanced.

Relation-related factors. The most important dimensions of moderating factors from literature (technological, organizational and environmental factors) have been discussed (Tornatzky et al., 1990). However, this study identified a fourth cluster of moderators that have a substantial effect on the observed relationship in a supply chain context: relation-related factors. They can be split into the two dimensions, power and trust, referring to the relationship between LSPs and their customers, the supply chain partners of their customers or technology suppliers. The S1 COO gave an example of power exerted by the customer: "Our technology adoption process was very fast. The customer dictated us the requirements for the truck, and we bought a truck customized to his wishes." This logic was strengthened by the M3 project manager, who emphasized their clients were the focus of all business activities. The power depends on the client's strategic relevance, which is regularly reflected in the client's share of turnover. However, having potential power does not always imply that it is actually exercised (Asare et al., 2016). Trust is another essential aspect of successful technology integration processes. The L2a business development manager, for instance, outlined that external acceptance of new technologies was supported by considering customer needs and building a trustful relationship. In this case, the initial technology project idea was first discussed with the customer. This process also included several meetings with the customers of their customers to ensure interoperability along the supply chain. An example of a trustful relationship with the technology supplier is L1. The LSP and the supplier emphasized their sound cooperation and explained that working hand in hand is a necessary precondition for fast adoption of technology. These findings can be aggregated in the following proposition:

> *Proposition 9*: From an LSP perspective, the effects of technology access modes on the success of the integration process are moderated by power and trust, so that process success dimensions (acceptance, process quality, speed and costs) are enhanced.

Figure B - 2 provides a final overview. The moderating factors are located in the LSPs' technology adoption process.

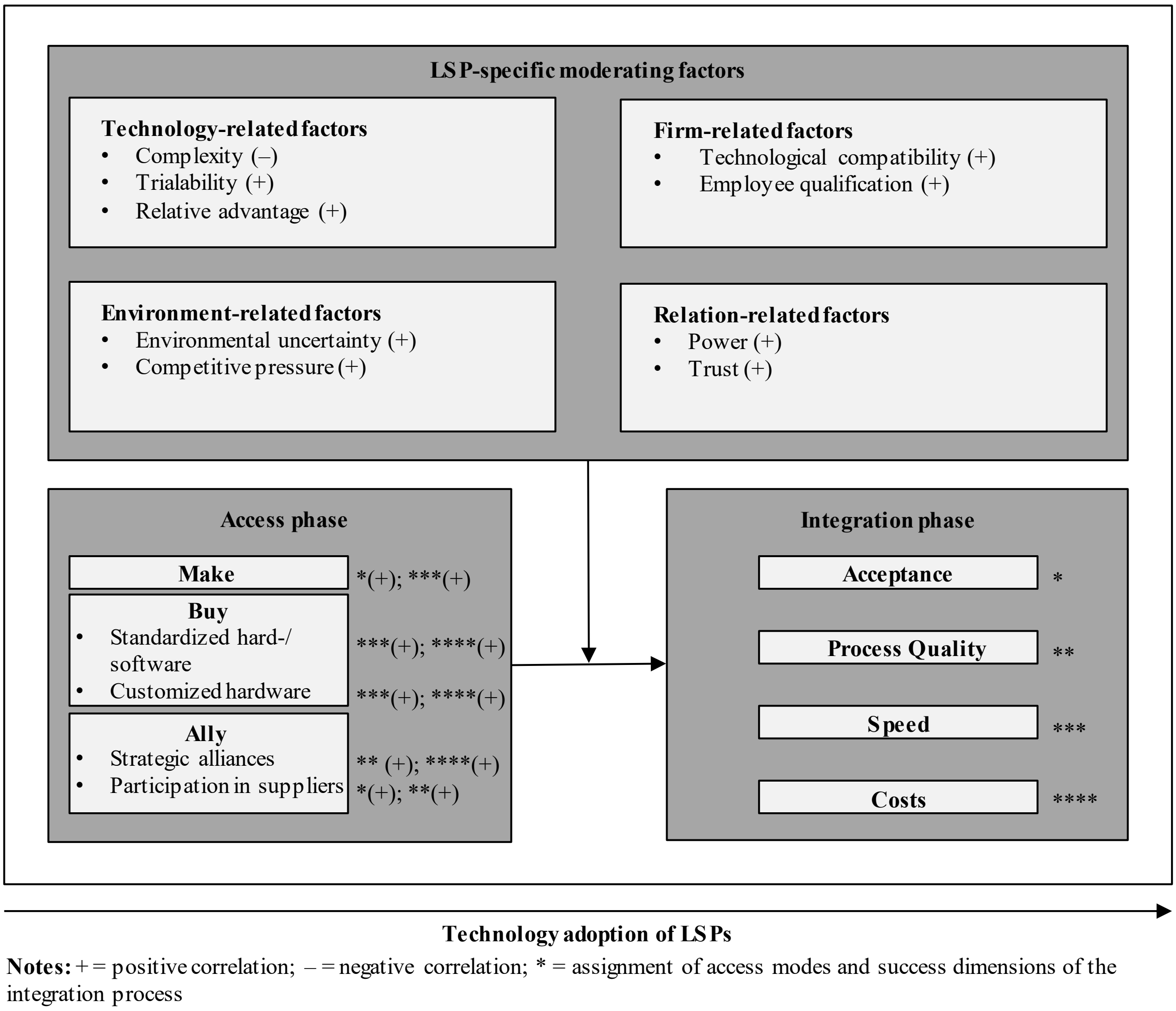

Figure B - 2. Overview of the refined technology adoption process of LSPs

B.4.3 Discussion

This section discusses selected LSP characteristics (firm size, owner structure and scope of services) against the backdrop of the findings, deriving new insights into LSPs' technology adoption process.

Firm size. The LSPs were large, medium and small in size. Previous studies yielded results for a positive relationship between firm size and technology adoption in logistics (Marchet et al., 2009). The present empirical results reveal one reason behind this and provide a new explanatory approach. This paper concluded that size effects especially influence LSPs' ACAP. According to the interview statements, only large firms were financially powerful enough to choose among all technology access modes. Medium-sized firms had to forego participation in technology suppliers. Small LSPs were forced to either buy solutions or ally with a strategic partner. Large- and medium-sized LSPs exhibit higher ACAP. Dealing with different technology access modes increases receptivity to acquisition of external knowledge (potential ACAP) and the capability of exploiting that knowledge (realized ACAP). Thus, P4 and P5 cannot be applied unreservedly to small LSPs. Size differences also impact the moderating effects. Existing research provides evidence that the main barriers to technology adoption by small- to medium-sized LSPs are reluctance to change and insufficient human and financial resources (Evangelista and Sweeney, 2006). Thus, it can be concluded that to integrate technological innovations successfully firm- (P7), environment- (P8) and relation-related factors (P9) are even more important for small- to medium-sized LSPs than for large LSPs.

Owner structure. Another distinctive feature of the sample companies is the owner structure. Five of seven firms are family businesses, where the family is the majority stakeholder and has a leading management role. Research on innovation management in family businesses has shown that family involvement plays a crucial role in innovation processes and can be split into two drivers (Chrisman et al., 2015): ability (discretion to innovate) and willingness (disposition to innovate). This study showed that family-managed LSPs are characterized by a very pronounced ability to innovate. In S1 and M3, the owner directly initiated the technology assimilation project (almost) independently and had a dominant role in the technology assimilation process. Willingness to innovate was apparent in family and non-family businesses but was manifested differently. For non-family businesses, the disposition to innovate was explicitly stated, and impulses came from within the company. The family businesses, however, exhibited a more emergent technology assimilation process. Stimuli for innovation regularly came from outside the company. One reason for this behavior was the strong customer focus, which was amplified through good personal and trustful relationships between the firm owner and the customer. Summing up, especially relation-related factors (P9) impact technology adoption by family businesses.

Scope of services. Last, the scope of services varied for the companies in this sample. There were firms focused on basic logistics processes (basic logistics provider) and firms that mainly provided value-added services (advanced logistics provider). In this sample, the basic logistics providers mostly aimed at process improvements to save money and time (with the exception of L3 striving for service innovation). This observation is supported by findings of Lai et al. (2008), who showed that the main motivation for 3PLs to build up IT capabilities is cost savings through increasing efficiency and effectiveness. Therefore, it can be concluded that two groups of moderators are especially important to companies focused on transport, transshipment and storage logistics: technology-related factors (to reduce complexity on the technological side; P6) and firm-related factors (to increase the probability of a successful integration from the firm side; P7). Providers of value-added services regularly exhibit different motives for technology adoption with strategic differentiation more important than cost savings (Evangelista et al., 2013). That is why environment-related factors (to gain a competitive advantage; P8) and relation-related factors (to offer cutting-edge services based on new technology tailored to customer needs, P9) are especially important to these providers.

B.5 Conclusion

The goal of the paper was to examine potential effects of technology access modes on the success of the integration process from the LSP perspective. As this relationship had largely been uninvestigated in technology adoption and logistics research, possible moderating factors were also included in this study (Gnekpe and Coeurderoy, 2017). Regarding *RQ1*, the findings of the exploratory empirical analysis of LSPs indicate that technology access modes prejudge the successful integration of new technologies. Differences were detected for make, buy and ally strategies in terms of innovation acceptance, as well as process quality, speed and costs of integration. For buying strategies, a distinction should be made between not only hardware and software technologies but also customized and standardized solutions. The stated implications are context-dependent, with technology-, firm-, environment- and relation-related factors as moderator clusters for answering *RQ2*.

From a theoretical perspective, the research sheds light on technology adoption by LSPs from a technology assimilation perspective (Zhu et al., 2006). With the application of IDT (Meyer and Goes, 1988; Rogers, 1962) and ACAP (Cohen and Levinthal, 1990; Zahra and George, 2002) at the organizational level, three general process stages of technology assimilation were identified: initiation, access and integration. Thus, the research stream of technology adoption is given more depth, and the pre- and post-adoption stages become visible (Chan et al., 2012). Furthermore, the dominant TOE framework for clustering moderating factors in the logistics industry (Lin, 2008; developed by Tornatzky et al., 1990) was extended by an important category for supply chain research on technology adoption: relation-related factors, which encompass power and trust (Asare et al., 2016). Thus, the general technology assimilation process was refined for LSPs' adoption of technological innovations. Attention must be paid to the ideal-typical character of the process, which can be highly emergent in practice (Mintzberg and Waters, 1985). The findings must always be reflected against the specific application context. As this discussion highlights, LSP characteristics like firm size, owner structure and scope of services must be considered for technology adoption projects.

From a managerial perspective, results can influence decision making concerning access strategies for technological innovations in the logistics industry and foster understanding of technology adoption mechanisms. LSPs should be aware that the integration process is different depending on whether they choose a make, buy or ally strategy. Make strategies involve high innovation acceptance and speed. Buy strategies are cost-efficient and fast, but only for hardware and standardized software. Implementing customized software is much more time-consuming. Accessing technological innovation by participating in a technology supplier triggers innovation acceptance and the integration process quality. Buying a stake in a company, however, takes time, and the financial scope is difficult to assess.

The explanatory impact of the study is limited by the small sample size, the high specificity of individual technology projects and the focus on a few moderating effects. Moreover, 4PLs were excluded from the study; thus, the findings can be applied only to 2PLs and 3PLs and do not cover the promising area of asset-free business models. The insights from the paper can serve as a starting point for future research. The implications of technology access modes for a successful integration process should be verified quantitatively. Furthermore, the relationship between the initiation and access phases of technology assimilation must be examined. Finally, the moderators in these first assimilation phases (initiation and access) are as unknown as the interplay of factors moderating the whole process.

B.6 References

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C. Study C: Vertical interorganizational technology diffusion: Principal–agent cascades in logistics

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This study examines the critical and rather neglected role of multi-level principal–agent constellations for the vertical diffusion of technological innovations in interorganizational service chains (SCs). Thereby, the notion of principal-agent hierarchies is transferred from the intrafirm to interorganizational settings. Drawing on agency theory, the authors describe the evolving constellations as principal-agent cascades. The research approach is based on four deep-dive case studies, each of which represents one multi-level logistics service chain. Interviewees from all levels of the SC (shippers, third-party logistics providers (3PLs), carriers, and drivers) and additional data sources on the investigated technologies are included. The findings illustrate that three constellation-related aspects are associated with the occurrence of information asymmetries during interorganizational technology diffusion: diversity of technological innovations (technology characteristics), breadth of principal-agent cascades (technology-principal relationships) and depth-of principal-agent cascades (number of diffusion levels). Furthermore, the analysis reveals collaborative mechanism design, contracts reflecting the degree of technological interaction, as well as new forms of mutual monitoring as effective governance mechanisms to overcome information asymmetries. This paper thus is the first contribution to refine existing governance mechanisms from agency theory for individual levels in interorganizational technology diffusions.

Keywords: Information asymmetry, information and communications technology, logistics service providers, case study research, principal–agent cascades.

C.1 Introduction

Research on innovation diffusion has a long history in the social sciences, but it did not gain widespread attention until Rogers's seminal work in the 1960s (Rogers, 1962). His innovation diffusion theory (IDT) frames the phenomenon of innovation diffusion as a communication process with patterns of information transmission at its very core (van Oorschot, Hofman, & Halman, 2018). Therein, the terms "adoption" and "diffusion" are distinguished: While adoption is a process on the intrafirm level (or micro level), diffusion can be seen as a group phenomenon and it refers to the innovation spread in a broader social system, for example, in an industry (macro level) (Loch & Huberman, 1999; Rogers, 1962). After years of studying innovation diffusion relatively independently from the observed innovation (Bass, 1969; Mahajan & Peterson, 1978; Norton & Bass, 1987), the expansion of information systems has led to technological innovations and the accompanying challenges coming to the fore in diffusion studies (Cooper & Zmud, 1990; Swanson, 1994). As technologies are playing an ever-increasing role in staying competitive (Madsen & Leiblein, 2015), the application of IDT for the diffusion of technologies in business-to-business (B2B) contexts has increasingly gained in importance (Bowen, Frésard, & Taillard, 2017; Sood & Kumar, 2018; Wu, Cegielski, Hazen, & Hall, 2013).

Despite the continuous research interest in the diffusion of technological innovations, there are still issues that require clarification for a more complete understanding to be gained (Greenhalgh, Robert, MacFarlane, Bate, & Kyriakidou, 2004; van Oorschot et al., 2018). For instance, existing studies do not tend to distinguish between the different actors involved in technology diffusion (on a meso supply chain level). The decision-makers behind technological innovation adoptions are seldom the actual users (Lanzolla & Suarez, 2012). Considering the essential role of information transmission for the diffusion of technologies (Abrahamson & Rosenkopf, 1997; Davis, 1989; Rogers, 1962), potential disruptions to this process might stem from information asymmetries between the involved actors (Akerlof, 1970). With its focus on information distribution among business parties, agency theory can substantially contribute to the understanding of technology diffusion. However, its application in terms of technology diffusion remains limited, mostly only covering innovation strategy (Block, 2012; Hoskisson, Hitt, Johnson, & Grossman, 2002). As agency theory provides an explanatory contribution even for multidimensional business relationships, researchers from the discipline of logistics and supply chain management (SCM) still call for a greater use of this theory (Fayezi, O'Loughlin, & Zutshi, 2012; Wilhelm, Blome, Bhakoo, & Paulraj, 2016).

The ongoing vertical division of labor in combination with the trend toward short-term contractual arrangements has led to the prioritization of the study of service provision subcontracting (MacKenzie, 2008; Walsh & Deery, 2006) as many firms can only meet the ever-increasing customer demands by entering into such relationships (Evangelista, McKinnon, & Sweeney, 2013). Thus, some industries are known for their extensive use of subcontractors such as the construction (Brahm & Tarziján, 2014), tourism (Robinson, Martins, Solnet, & Baum, 2019), or logistics industries (Li, Wang, & Adams, 2009). The resulting nested vertical service chains (SCs) are challenging to manage (Ata & Mieghem, 2009), especially, for example, for logistics service providers (LSPs). When a shipper outsources some of its logistics activities to a third-party LSP (3PL), a veritable cascade of subcontracting relationships might be initiated: the 3PL hires a logistics intermediary, the intermediary a carrier, and the carrier maybe another carrier (Cui & Hertz, 2011; Rajahonka, 2013). Such subcontracting cascades complicate technology diffusion, because technology adoption by the initiator (e.g. 3PL) on the first level of the SC is not sufficient. Instead, the subcontractors also have to adopt the technology so that it reaches the user level and can be integrated within the service provision. Innovation diffusion appears to be considerably more complex in the services sector than earlier work might have suggested (Tether & Tajar, 2008), with LSPs frequently struggling in this regard (Busse & Wallenburg, 2011, 2014). This is problematic as LSPs are being increasingly confronted with technological innovations (Goldsby & Zinn, 2016; Mathauer & Hofmann, 2019), but face very low margins anyway (Cichosz, Goldsby, Knemeyer, & Taylor, 2017).

However, research on technology diffusion has widely neglected this vertical phenomenon. The most frequently studied horizontal interorganizational technology diffusion (e.g. Rogers, 1962, 2003) stresses the role of information for the horizontal spread of innovations, but is unable to explain vertical diffusion among affiliated companies. Horizontal intrafirm technology diffusion's explanatory contribution is also limited (e.g. Stoneman, 1981), as the risk associated with technology adoption can be massively reduced if experience with the technology already exists in other parts of the firm

(Fuentelsaz, Gómez, & Palomas, 2016; Simon & Lieberman, 2010). The literature on vertical intrafirm technology diffusion (e.g. Cooper & Zmud, 1990) covers similar problems relating to information asymmetry and governance, but solution mechanisms cannot be easily transferred to the interfirm context. Research on vertical interfirm technology diffusion (Iacovou, Benbasat, & Dexter, 1995; Premkumar, Ramamurthy, & Crum, 1997) has identified challenges and governance mechanisms to foster interfirm technology diffusion, but only in dyadic relationships. Within multi-level relationships, information asymmetry characteristics vary on every level (Wilhelm et al., 2016), so that both information-related challenges and governance mechanisms from one-to-one relationships do not straightforwardly align with multi-level constellations; thus, there is a need for in-depth research on the principal-agent constellations in vertical interfirm diffusions of technological innovations. This is stated in the first research question of the paper:

> *RQ1:* From a 3PL perspective, what are the principal–agent constellations under which technological innovations are diffused in vertical interorganizational settings?

The principal-agent constellations of vertical interorganizational technology diffusions can be exemplified with a three-level logistics SC (LSC). A shipper (principal) may instruct a 3PL (agent) to use a sophisticated smart container as a charge carrier and expects appropriate handling. The 3PL enters into a subcontracting relationship with a carrier and thereby also temporarily becomes a principal. If the consignee complains to the shipper that the goods have arrived with a damaged charge carrier, a tricky situation involving information asymmetry arises. This is particularly important for the 3PL, who occupies a key position in the LSC and has the power to design governance mechanisms to overcome the information asymmetries (Lieb, 2005). As these information asymmetries are always associated with inefficiencies and costs, agency theory suggests to establish appropriate governance mechanisms. Thus, the present paper pursues the following second research question:

> *RQ2:* From a 3PL perspective, how can information asymmetries of technological innovation diffusions in vertical interorganizational settings be overcome?

Following Eisenhardt (1989b) and Ketokivi and Choi (2014), the paper is based on case studies with abductive reasoning. The data stem from four different technological innovations in four multi-level LSCs. Agency theory (Jensen & Meckling, 1976) serves as a theoretical foundation, as it allows for the abovementioned information-related challenges of technology diffusions in affiliated firms to be grasped.[53] The results are presented in the form of observations and contribute at least threefold to the state-of-the-art in technology diffusion. First, the study is pioneering as vertical technology diffusions in interorganizational constellations with more than two levels are examined, allowing for the actual situation in today's SCs to be better understood and reflected. Second, agency theory is refined. Tirole's (1986) principal–agent hierarchies are transferred from the intrafirm to the interorganizational level to derive a principal–agent cascade for LSCs. Furthermore, sub-constellations within these cascades are examined, which contributes to more recent developments of the theory that are concerned with double (Child & Rodrigues, 2003; Wilhelm et al., 2016) and multiple principal–agent constellations (Aguilera, Marano, & Haxhi, 2019; Arthurs, Hoskisson, Busenitz, & Johnson, 2008; Hoskisson et al., 2002). Third, existing governance mechanisms are revisited for the interorganizational diffusion context. The implications are not only of theoretical relevance but will also help logistics professionals on a very concrete level to tackle information asymmetries that occur during technology diffusion, thus avoiding costly inefficiencies in their operations.

The structure of the paper is as follows: The next section summarizes the existing literature on information asymmetries in the course of technological innovation diffusion in LSCs. Detailed insights into the applied research method are provided in the Section C.3. While the outcomes of the case study analyses are presented Section C.4 and discussed in Section C.5, the paper ends with concluding remarks (Section C.6).

[53] Other theories such as institutional theory (DiMaggio & Powell, 1983) might also be relevant. However, as institutional theory traditionally focuses on a focal firm and more recent attempts to apply it to interfirm settings are controversial (Royston Greenwood et al., 2014), the authors consider agency theory as better suited for this study.

C.2 Literature review

C.2.1 Characterization of logistics service chains

LSPs comprise all firms that "perform logistics services on behalf of others" (Delfmann, Albers, & Gehring, 2002:204). In a typical constellation, a focal manufacturing firm (shipper) outsources its logistics activities to a 3PL (see Figure 2).[54] Instead of carrying out the contracted logistics activities on its own, the 3PL might enter into a subcontracting relationship. In road transport, for example, 3PLs usually draw on a large number of affiliated smaller carriers that take over the actual transport (Li et al., 2009). However, the SC does not necessarily stop at this point, as "tiering"—the use of subcontractors by subcontractors—can even be observed in the logistics services industry (Rajahonka, 2013). The result is a vertical hierarchy of firms referred to as a vertical LSC, which typically comprises the following actors (Cui & Hertz, 2011):

- *Shippers* outsource logistics services and therefore initiate the LSC (Roorda, Cavalcante, McCabe, & Kwan, 2010).
- *Third-party logistics service providers (3PLs)* focus on the effective coordination of clients, logistics intermediaries, and carriers to provide integrated services (Cui & Hertz, 2011).
- *Logistics intermediary firms* consolidate goods, but do not necessarily move physical goods from A to B. Examples of this type of LSP are freight forwarders or brokers (Hofmann & Osterwalder, 2017).
- *Carriers* strive for the efficient transport of physical goods and include, among others, trucking, shipping, or airline companies (Delfmann et al., 2002).
- *Drivers* carry out the operative transport. Since they have a high degree of autonomy and their concrete behavior is difficult to observe, they are regarded as separate actors (Hickman & Geller, 2005).

The 3PL takes a key role in any LSC constellation through directly serving the shipper and coordinating subcontractors at the same time (Lieb, 2005). Horizontal cooperation

[54] Fourth-party logistics service providers (4PLs) are other possible LSC actors. Their business model focuses on the asset-neutral coordination of service providers (Hofmann & Lampe, 2013; Stefansson, 2006). However, technology diffusion always implies investments in assets, which is why 4PLs are not of further importance for this study.

at each level of the LSC is also conceivable and increases the complexity in the logistics service provision even further (Cruijssen, Cools, & Dullaert, 2007; Ferrell, Ellis, Kaminsky, & Rainwater, 2019). Thus, the claim has been made for a reconceptualization of logistics management from a network perspective (Cui & Hertz, 2011; He & Liu, 2015). This complexity therefore calls for research that exceeds the single-firm focus to examine innovation at LSPs (e.g. Busse & Wallenburg, 2014). On the one hand, the characteristics of LSCs mean that innovation is an interfirm phenomenon (Lyytinen & Damsgaard, 2011; Tanskanen, Holmström, & Öhman, 2015). On the other hand, a distinction between the single actors is necessary because the LSPs' tasks depend on their position within the LSC (Cui & Hertz, 2011).

C.2.2 Types of technology diffusion in logistics service chains

If an innovation affects logistics-related services—independent from their degree of complexity—and is helpful to the external or internal focal audience, it is called a logistics innovation (Flint, Larsson, Gammelgaard, & Mentzer, 2005). Considering the increasing importance of technologies for logistics services (Hofmann & Osterwalder, 2017), the scope of this research is focused on technological logistics innovations (hereafter, technological innovations). A special emphasis is placed on hybrid solutions that combine a physical and digital component by integrating data collected from sensor-equipped hardware (e.g. a smart charge carrier). Hybrid innovations are typical of today's industry 4.0 environment and pose new managerial challenges due to the dynamic interrelations between physical and digital systems, with calls being made for more intense research on this innovation type (Barrett, Davidson, Prabhu, & Vargo, 2015; Barrett, Oborn, Orlikowski, & Yates, 2012). Furthermore, hybrid innovations match the presented idea of complex LSCs, as technological interoperability and data sharing among related companies are critical for the successful diffusion of these innovations to the affiliated subcontractors (Chen, Yen, & Chen, 2009).

To locate the phenomenon of technology diffusion in vertical LSCs within the existing research on technology diffusion, the literature has been divided into four fields: (1) horizontal intrafirm technology diffusion, (2) vertical intrafirm technology diffusion, (3) horizontal interorganizational technology diffusion, and (4) vertical interorganizational technology diffusion (see Figure C - 1).

(1) Horizontal intrafirm technology diffusion. This captures the spread of a particular technology within a firm. Mansfield (1963) and Stoneman (1981) substantially contributed to this stream, finding, among others, large differences in the intrafirm innovation diffusion speed. Additionally, the final degree of horizontal diffusion within firms varies; while an innovation may fully substitute the old technology in one firm, the same innovation may merely be a partial substitute in another (Battisti & Stoneman, 2003; Fuentelsaz, Gómez, & Palomas, 2009). Technology characteristics were found to impact horizontal intrafirm diffusion, for example, the complexity of a technological innovation (Attewell, 1992; Tornatzky, Fleischer, & Chakrabarti, 1990). However, information on the technology is less important than for the other technology diffusion types, as during the horizontal intrafirm diffusion process, it can be gathered on an ongoing basis; thus, technology adoption decisions are more profound and imply lower levels of risk (Attewell, 1992; Fuentelsaz et al., 2016; Simon & Lieberman, 2010). For LSPs, horizontal intrafirm diffusion is of particular importance as it allows for process improvements to be exploited for multiple customers (Grawe & Ralston, 2019).

(2) Vertical intrafirm technology diffusion. This concerns the actual intensity of use of the technology (Zhu, Kraemer, & Xu, 2006). Cooper and Zmud (1990) were among the first to recognize that technology diffusion is not over after several units of a firm have adopted the technology. Instead, employees must accept the technology so that it is incorporated into daily activities ("routinization") and organizational effectiveness can be enhanced ("infusion") (Cooper & Zmud, 1990). The organizational outcome is measurable, for example, in terms of productivity (Boothby, Dufour, & Tang, 2010). Additionally, greater vertical diffusion aligns with adjustments to the governance systems because agency problems become particularly relevant whenever diffusion has a clear top-down direction (Zmud & Apple, 1992). The vertical perspective on technology diffusion should always distinguish different user levels (Lapointe & Rivard, 2007). These intrafirm hierarchies are especially susceptible to information asymmetries (e.g. on the appropriate use of the technology), so that information plays—in contrast to horizontal intrafirm diffusion—a decisive role (Tirole, 1986). To overcome such information asymmetries in an SCM context, Hazen, Overstreet, and Cegielski (2012) identified formal guidance and training programs as effective activities.

(3) Horizontal interorganizational technology diffusion. The overwhelming amount of research on technology diffusion in B2B contexts is devoted to horizontal interfirm diffusion, which can be understood as the technology adoption of (independent) firms that operate in the same industry. Thus, the acquisition of the first unit of a technology by an adopting firm is of interest. The work of Rogers (1962, 2003) and Davis (1989) has exerted major influence on this stream. Rogers (2003), for example, found attributes of technological innovations (e.g. complexity) to impact the adoption rate, while Davis (1989) explained what assumptions (e.g. perceived usefulness) influence adoption decisions. Antecedents, consequences, and context factors have been well explored from a general (Knott & Posen, 2009; Zhu et al., 2006) and from a logistics or SCM perspective (Lin, 2008; Panayides & So, 2005). Framing interorganizational technology diffusion horizontally stresses the importance of available information on the innovation (Mansfield, 1961). Characteristics of the adopter and the competitive situation are also relevant (Giachetti & Lanzolla, 2016). As there are not necessarily any contractual relationships among the adopting firms, no agency problems evolve. Furthermore, the adopting firm does not have to incorporate the innovation completely in its internal processes (in contrast to vertical intrafirm diffusion), so that risk exposure is limited.

(4) Vertical interorganizational technology diffusion. This type of diffusion is the latest approach to studying technology diffusion and it became popular with the increase in interorganizational information systems in the 1990s. Various scholars have examined electronic data-interchange adoption, thereby unearthing a completely new diffusion setting; namely, an interorganizational constellation of affiliated companies dominated by the technology initiator. Iacovou et al. (1995) identified perceived benefits, organizational readiness, and external pressure as particularly relevant for this setting. Premkumar et al. (1997) found environmental, organizational, and innovation characteristics to determine interorganizational technology adoption. More recent studies from the field of logistics and SCM have yielded mixed results (Autry, Grawe, Daugherty, & Richey, 2010; Sternberg & Norrman, 2017). However, relative advantage, complexity, and compatibility are particularly important in such constellations. Furthermore, it is important to install mechanisms to overcome agency problems, especially in the supply chain context (Patterson, Grimm, & Corsi, 2003). However, the majority of existing articles only examine dyadic relationships (e.g. between a buyer and a supplier). Regarding the abovementioned multi-level constellations of today's SCs, this is not sufficient. Thus,

Lyytinen and Damsgaard (2011) call for research on “adoption units” (e.g. LSCs) to take into account the impact of multi-level constellations on technology diffusion. This is especially important for the diffusion of innovations in logistics and SCM, where multi-level interorganizational constellations are a constituent characteristic of the innovation context and effective mechanisms to overcome information asymmetries determine diffusion success (Cui & Hertz, 2011).

	Intrafirm	Interorganizational
Vertical	**(2) Vertical intrafirm technology diffusion** Refers to the use intensity of a technology within a firm (e.g. incorporation in daily activities) **Selected contributions** • Cooper & Zmud, 1990* • Zmud & Apple, 1992* • Lapointe & Rivard, 2007** • Beaudry & Pinsonneault, 2010** • Hazen et al., 2014*** • Hazen et al., 2012***	**(4) Vertical interorganizational technology diffusion** Refers to the directed distribution of a technology from one initiating to affiliated firms (e.g. in service chains) **Selected contributions** • Iacovou et al., 1995* • Premkumar et al., 1997* • Lyytinen & Damsgaard, 2011** • Autry et al., 2010***
Horizontal	**(1) Horizontal intrafirm technology diffusion** Refers to the spread of a technology within a firm (e.g. across departments) **Selected contributions** • Mansfield, 1961* • Stoneman, 1981* • Fuentelsaz et al., 2009** • Fuentelsaz et al., 2016** • Grawe & Ralston, 2019*** • Tanskanen, 2015***	**(3) Horizontal interorganizational technology diffusion** Refers to the (first) adoption of a technology by independent firms from the same population (e.g. in the same industry) **Selected contributions** • Rogers, 1962* • Davis, 1989* • Giachetti & Lanzolla, 2016** • Zhu et al., 2006** • Lin, 2008*** • Panayides & So, 2005***

Notes:
*Seminal foundations; **Selected contributions with general management orientation; ***Selected contributions with industry focus on logistics or supply chain management

☐ = Focus of the paper

Figure C - 1. Matrix of technology diffusion types with selected contributions from the innovation diffusion literature

Neither the insights from horizontal technology diffusion (both at the micro and macro level) nor the insights from vertical diffusion (micro level) are sufficient to guide the management of vertical interfirm technology diffusions. Horizontal intrafirm technology diffusion follows a different logic than vertical interorganizational diffusion does, as there are already experience values that make the process of horizontal intrafirm diffusion less risky (Grawe & Ralston, 2019). Horizontal interorganizational technology diffusion underlines the importance of information distribution (Rogers, 2003), but understands information as the first contact between the firm and the technology. It is obvious that information on the mere existence of a technology does not ensure its adequate use by affiliated firms, especially if the technology is sufficiently complex (Zmud & Apple, 1992). Thus, different mechanisms to govern information diffusion are required in the vertical interorganizational context. Last but not least, vertical intrafirm technology diffusion is concerned with comparable agency problems to vertical interorganizational diffusion, as user-level behavior might be difficult to observe. Despite this, vertical interorganizational diffusions are confronted by higher levels of risk. The initiating firm has less control over the users who are working for stand-alone firms, so that other effective governance mechanisms are needed.

Having indicated that vertical interorganizational technology diffusions combine challenges of agency and risk sharing from all other diffusion types, information asymmetry and a lack of governance structures are the key challenges. Thus, agency theory (Jensen & Meckling, 1976) appears to be especially suited for exploring this phenomenon. While there are various studies that use this theoretical perspective in a logistics or SCM context (Bolumole, Frankel, & Naslund, 2007; Cordes Feibert & Jacobsen, 2015; Heaslip & Kovács, 2019; Logan, 2000), its application in the field of technology diffusion is still missing.

C.2.3 Multiple principal–agent constellations and information asymmetries in logistics service chains

A principal–agent relationship is based on a contract in which the agent undertakes to perform a service on behalf of one or more principals (Jensen & Meckling, 1976). An agency problem occurs if the principal and agent have conflicting goals or if the principal faces difficulties in verifying appropriate behavior by the agent due to an asymmetric information distribution. The efficient design of contracts is considered to be a main lever to overcome agency problems through either behavior-oriented (e.g. salary) or outcome-oriented contracts (e.g. bonus–penalty models) (Eisenhardt, 1989a). As information about technological innovations has already been shown to be crucial for explaining their diffusion in firm networks (Mansfield, 1961, 1968), the present paper focuses on information-driven agency problems. Agency theory provides valuable insights to enable possible information asymmetries in complex service networks to be identified and overcome (Agrell, Lindroth, & Norrman, 2004; Heaslip & Kovács, 2019). It is assumed that agents will behave in such a way so that they will profit from the venture, whereas principals will not. Typically, there are four different types of information asymmetry in one-to-one agency relationships: (IA 1) hidden characteristics, (IA 2) hidden intention, (IA 3) hidden information, and (IA 4) hidden action. Each information asymmetry type is characterized by a different form of information advantage for the agent. For illustration purposes, Table C - 1 contains examples from the logistics context for each information asymmetry type as well as general governance mechanisms that the literature has yielded in order to overcome these asymmetries.

IA 1 hidden characteristics is the only mentioned information asymmetry type that typically occurs before entering into a contractual relationship (ex ante). Nevertheless, ex post situations for hidden characteristics are also conceivable; for example, if a principal selects between agents to carry out a technology pilot project and already does business with these agents. To avoid distorting the results due to special effects in the turbulent initiation and establishment phase of business relationships, this paper has a long-term focus and investigates ex post issues in established SCs (Bastl, Johnson, & Finne, 2019).

The nested character of LSCs, however, requires the consideration of constellations with more than two organizations, because there are role overlaps with firms being the principal in one relationship and the agent in another (Cheng & Kam, 2008). Recent theory developments take up this insight and model additional complexity that goes beyond one-to-one relationships, for example, making contributions to double (Child & Rodrigues, 2003; Wilhelm et al., 2016) or multiple agency scenarios (Arthurs et al., 2008; Child & Rodrigues, 2003). The notion of double agency is especially useful to explain triadic interorganizational constellations (particularly in SCM research). For instance, first-tier suppliers must comply with the standards of their customers (primary agency role) and have to ensure that these standards are passed on to their own suppliers (secondary agency role; Child & Rodrigues, 2003; Wilhelm et al., 2016). This approach is promising for understanding vertical interorganizational technology diffusions, as issues of information asymmetry and governance in vertically-dependent firms are considered.

Nevertheless, the double agency perspective is not sufficient to capture LSCs that usually include more than two vertical levels. The concept of multiple agency is more horizontally oriented, and covers, for example, situations in which one agent might serve several principals at the same time (Arthurs et al., 2008). Such constellations are also conceivable in LSCs. Thus, these insights need to be incorporated into this study, but are deficient in themselves to explain vertical interfirm technology diffusion.

Table C - 1. Overview on information asymmetry types and governance mechanisms in logistics service chains

Type / Feature	**Hidden charateristics (IA 1)**	**Hidden intention (IA 2)**	**Hidden information (IA 3)**	**Hidden action (IA 4)**	**Hidden transfer (IA 5)**
Description	The principal does not know the characteristics of the agent before entering into a business contract (Akerlof, 1970)	The principal has an information deficit concerning the intentions of the agent (Alchian & Woodward, 1987)	The principal can observe the action of the agent, but is unable to assess it due to an information deficit (Arrow, 1985)	The principal is unable to observe the actions of the agent; the result can be a moral hazard (Arrow, 1985)	The principal is cheated by several agents who make it their common cause to ignore, distort, or manipulate information (Tirole, 1986)
Time reference	*Ex ante/ex post*	*Ex post*	*Ex post*	*Ex post*	*Ex post*
Problem	Adverse selection	Hold-up	Moral hazard	Moral hazard	Side transfers
Examples for logistics service chains	Difficult for 3PL to assess the technological capabilities of the carrier when introducing a new pilot, e.g. knowhow of drivers	Difficult for 3PL to assess how the carrier might behave during technology use, e.g. specific investments in technological endowment of the carrier become risky	Difficult for 3PL to assess whether damage to the used technology is due to incorrect handling or low product quality, e.g. for smart charge carriers	Difficult for 3PL to assess whether the carrier uses technology in the best possible sense for the company, e.g. incorrect data capture for convenience	Difficult for 3PL to assess whether the intermediary and carrier have worked for a common cause, e.g. for covering up technology damage
Governance mechanism	Self-selection, signaling, screening	Collateral, vertical integration	Reward systems, self-selection, signaling, screening	Reward and monitoring systems, bonding	Short relationships, job rotation

Technology diffusions in LSCs from a vertical perspective always imply a hierarchical notion that is well established in agency theory. In his seminal work, Tirole (1986) recognized the emergence of three-level hierarchies within firms (principal/supervisor/agent model). He stressed the role of information distribution in vertical constellations and even found a new form of information asymmetry type called "hidden transfer" (IA 5). This phenomenon occurs if two or more parties make it their common cause to ignore, distort, or manipulate information for the principal. The results are monetary or non-monetary side transfers that need to be avoided. As established relationships are especially prone to hidden transfers, shortening business relationships is one proposed governance mechanism (Tirole, 1986).

This paper contributes to theory elaboration by taking up Tirole's (1986) multi-level approach and transferring it to the interorganizational setting of LSC constellations. As a result, principal–agent cascades emerge, which can comprise further sub-constellations. *Principal–agent cascades* extend the idea of double agency (Child & Rodrigues, 2003; Wilhelm et al., 2016) to vertical constellations with various consecutive firms in double agency roles. Each of the LSC's actors can be assigned to a level in the principal–agent hierarchy (see Figure C - 2):

- Shipper (primary principal) and 3PL (agent): The shipper instructs the 3PL to adopt a technological innovation. As technological innovations are not necessarily driven by the shipper, this level is called the zero level and can occur optionally.
- 3PL (secondary principal) and logistics intermediary (agent): The 3PL (1st level) instructs a logistics intermediary (2nd level) to adopt a technological innovation.
- Logistics intermediary (subsequent principal) and carrier (agent): The logistics intermediary (2nd level) instructs a carrier to adopt a technological innovation (3rd level).

If the shipper has no dominant role in technology diffusion, all subsequent designations need to be adjusted (the 3PL becomes the primary principal, etc.). This is the case for technological innovations such as a transport management system (TMS) initiated by a 3PL and just concerns the affiliated LSPs and not the shipper. All levels following that of the technological innovation initiator can be referred to as subsequent levels. A contract, if it exists, is usually concluded between the primary principal and her agent. Contractual stipulations among subsequent levels differ considerably and depend on the investigated case. Furthermore, the actual technology use normally (but not necessarily) takes place on the lowest level of the SC, which is why the designation "technology-user level" is introduced.

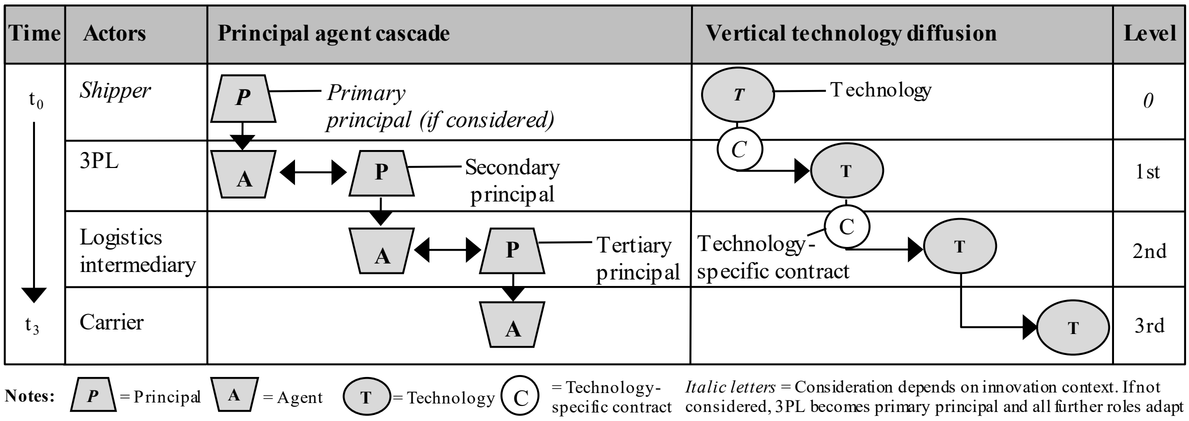

Figure C - 2. Actors of the logistics service chain and the corresponding ideal-typical principal–agent cascade

C.2.4 Technology diffusion within principal–agent cascades in logistics service chains

Principal–agent cascades are valuable for studying the challenges of vertical interorganizational technology diffusions in a more differentiated way. What is particularly helpful is the possibility of distinguishing between single levels because information asymmetry types might be differently pronounced at each level of the SC (Wilhelm et al., 2016). Furthermore, the distinct technology–principal relationships within principal–agent cascades can be worked out. Two sub-constellations are of special interest: one technology–multiple principal and multiple technology–one principal constellations (see Figure C -3). Besides, mixtures of these two may occur (one technology–one principal or multiple technology–multiple principal). However, since one technology–one principal constellations are the most trivial ones and multiple technology–multiple principal constellations combine the first two, the focus is on one technology–multiple principal and multiple technology–one principal constellations in the following.

One technology–multiple principal constellations refer to settings in which the agent offers services to more than one principal. This situation is challenging for both principal and agent. The more principals make use of an agent's services, the weaker the power position of each principal becomes. IA 2 hidden intention, for example, might feed distrust and undermine the business relationship. The principal could avoid investments in the agent ("hold-up"), because she might not be sure whether the agent really intends to develop a long-term business relationship or would prefer to opt for other principals (Saam, 2007). Conversely, the agent might face conflicting choices and has to select only one principal due to resource limitations (Arthurs et al., 2008; Hoskisson et al., 2002). The one technology–multiple principal constellation can be found quite often in LSCs. Carriers usually provide their services as a subcontractor to many different 3PLs, with implications for technology diffusion (Li et al., 2009).

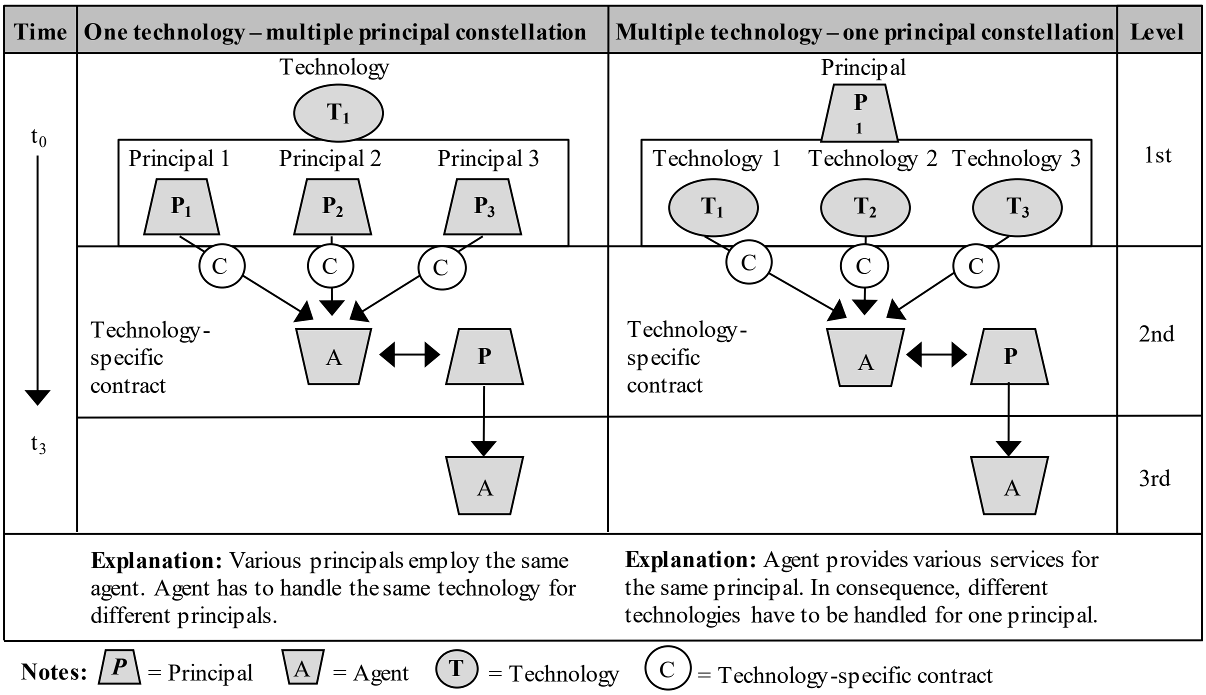

Figure C - 3. Different sub-constellations of technology–principal relationships in principal–agent cascades

Multiple technology–one principal constellations include settings where the agent adopts different technologies for the same principal. In such a situation, the principal and agent are normally both better off as it lowers information asymmetry. Adverse selection, for example, is less likely because the principal is already aware of the agent's characteristics when starting a new technology project. The same is true for IA 2, which loses in significance with the duration of business relationships. As both the dependence of the agent and the principal's chances of control rise in these constellations, the moral hazard is expected to decrease. Due to increasing technology intensity in logistics service provision, these constellations can be expected to further gain in relevance in the future (Goldsby & Zinn, 2016). One technology–multiple principal constellations and multiple technology–one principal constellations are not mutually exclusive; rather, they often occur together in practice. For this work, they are separated only for structuring reasons.

C.2.5 Summary of the literature review and research gaps

Overall, the literature review shows that the special character of LSCs requires LSP-specific research on vertical interorganizational technology diffusion. Present research on horizontal and vertical technology diffusion is not sufficient to grasp the information asymmetries of vertical interorganizational technology diffusions and to derive effective governance mechanisms. To date, no studies have examined information distribution by considering the different levels in the vertical SC beyond dyadic relationships. Furthermore, it is not yet clear how the characteristics of hybrid technologies impact information distribution among actors in the SC. Agency theory could be a valuable theoretical perspective to approach the phenomenon. However, the extension of the theory on principal–agent cascades with their sub-constellations of one technology–multiple principals and multiple technologies–one principal is necessary to mirror the complexity of LSCs. Following this notion, the present paper aims to fill these research gaps by empirically investigating different principal–agent constellations in interorganizational settings as well as the design of appropriate governance mechanisms for effective vertical technology diffusion in LSCs.

C.3 Methodology

C.3.1 Overall approach

Considering the underexplored nature of the studied research phenomenon, the present paper pursues a case study approach (Eisenhardt, 1989b). As the discoveries from observing the new phenomenon of vertical interorganizational technology diffusion did not match the prior theoretical insights, abductive reasoning is pursued and the as-is assumptions based on agency theory are extended. Therefore, abductive reasoning allows for the reconciliation of agency theory with the idiosyncrasies of the observed context, in particular in relation to principal–agent cascades (Alvesson & Kärreman, 2007; Ketokivi & Choi, 2014).

C.3.2 Study design, case selection, and sampling

Agency theory (Jensen & Meckling, 1976) serves as the theoretical foundation for the investigations because it provides explanatory approaches for the emergence of information asymmetries between business partners and a wide range of governance mechanisms to overcome them. The main unit of analysis is the 3PL initiating the technology diffusion, while all the actors in the vertical LSC serve as units of observation. In cases where the shipper is the initiator, the perspective changes for reasons of comparison. The technology diffusion initiator is therefore of special interest as he or she usually plays a dominant role in the design of governance mechanisms to overcome information asymmetries that occur in interorganizational technology diffusions.

Case selection followed a theoretical sampling logic to ensure that the unit of analysis was transparently observable (Eisenhardt, 1989b). Drawing on the approach of Bastl et al. (2019), criteria derived from the literature guided the selection of cases.

- *Criterion 1: Stability of relationships*. A focus on existing relationships reduces exposure to unforeseeable issues during the building phase of new relationships that might also impact technology diffusion. Furthermore, long-term relationships exhibit relational history, which can yield very valuable insights (Anderson & Narus, 1990; Bastl et al., 2019).
- *Criterion 2: Multi-level service chains*. To study vertical interorganizational technology diffusion, all case study firms had to be part of a multi-level SC in which the technological innovation initiator differed from the actual user. This is important because information asymmetries typically occur at the intersection between the levels of the SC. The existing technology diffusion literature often ignores the difference between those who make technology adoption decisions and the actual users (Lanzolla & Suarez, 2012).
- *Criterion 3: Hybrid technological innovations*. The SCs under study had to be faced with technological innovations that not only concerned the first-level cascade actor but subsequent actors as well. This is important in order to overcome

a single-firm adoption focus and to take into account the challenges of different SC constellations (Lyytinen & Damsgaard, 2011). As hybrid innovations gain in importance for service firms (Barrett et al., 2015) and are especially difficult to distribute (due to the necessary interoperability across the whole SC), the investigated technologies all stemmed from this category.

- *Criterion 4: Different governance mechanisms*. As this study, among others, aims to observe effective governance mechanisms to overcome information asymmetry during technology diffusion, SCs were chosen that already made use of governance mechanisms to tackle information asymmetry (Bastl et al., 2019; Mayer & Salomon, 2006).

C.3.3 Data collection

To start data collection, a key company had to be identified for every case that facilitated access to the other firms in the SC. In some cases, the technology provider was contacted first and served as a link to the LSC. In other cases, the first-level firm granted access to the entire SC. One second-level actor even turned out to be a suitable "gatekeeper," as its SC position enabled contacts to be made with up- and downstream actors. The first contact served to outline the sampling criteria and the necessity of including several actors in the multi-level SC. Afterwards, a person from the key company identified potential participating firms and approached them to clarify their willingness to participate. Having reached a preliminary agreement to participate, the research team approached these firms to explain the project and to ensure compliance with the abovementioned selection criteria (Bastl et al., 2019).

Before the interviews, companies were asked to provide informational material on the technologies under study. Then the authors gathered a diverse set of additional data sources on each technology, including product descriptions, product videos, and even podcasts (Vaskelainen & Münzel, 2018) (see Table C - 2). In a first step, this variety of data sources—in combination with the authors' industry-specific knowhow from various scientific projects in this field—allowed for an in-depth understanding of the technologies as such. Site visits involving physical contact with each of the technologies supplemented the initial analyses. In a second step, the insights from the technologies were used to pre-discuss the mechanisms of their interorganizational diffusion. This approach was necessary in order to incorporate the peculiarities of every technology diffusion in the interview guide.

The semi-structured interviews were conducted in ten organizations. In total, 36 interviewees have been included in this study (see Table C – 2). The authors systematically sampled for persons with a management perspective at the upper levels of the LSC and for persons with operational expertise at the technology user level. This approach allowed to adjust interview questions to the professional background of the interviewees in order to cover the full spectrum of technology diffusion from the initial technology adoption decision to operational technology use. In consequence, twelve interviews (with employed drivers) were very application-oriented, made use of a structured interview guide and lasted up to 30 minutes. All other interviews followed a semi-structured interview guide and lasted 60 minutes to two and a half hours, underlying their in-depth character. Questions were raised about the individual SC constellation, the diffused technological innovation, information asymmetry types at each level of the SC, and how and why governance mechanisms were used to overcome information asymmetries (see Appendix C.8.1). If the geographic distance did not allow for a physical visit, phone calls served as an alternative. By combining the insights from the interviews with publicly available information on the firms, additional data on the technologies, and observations from company visits, data triangulation was achieved (Choi & Hong, 2002; Vaskelainen & Münzel, 2018).

C.3.4 Data analysis

Drawing on Mantere and Ketokivi (2013), the case study design allows for the following research procedure: observation of the phenomena, explanation of their occurrence, and the derivation of rules (e.g. observations). This logic was ensured by applying the qualitative analysis approach by Glaser (1978): (1) open coding, (2) selective coding, and (3) theoretical coding. In a first step, sentences and phrases were inductively grouped into codes and categories to generate initial labels to the data. The second step helped to limit coding only to those categories that were related to the core categories and started after no new open codes had occurred. In a third step, the authors related the codes to each other and connected them to established constructs from theory. Appendix C.8.2 provides an overview of selected extracts from the interviews and the assigned codes.

All cases were first analyzed separately (within-case analysis) before detecting common patterns across cases (cross-case analysis).

Table C - 2. Case overview

Cases	Technology description	Size	Level	ID	Firm description	Participants (no.)	Total no.	Additional data sources on technologies
Alpha	Multifunctional handheld for the optimization of scanning during loading and unloading processes in local transport. Device is app-based and equipped with a GPS module (position detection) and a digital camera (documentation of damaged goods).	L	1	Alpha L1	Globally-operating LSP active in European road transport, air and sea logistics, food logistics, and contract logistics.	Business development manager (1), dispatcher (1)	2	• Physical testing on site • Product descriptions (98 pages) • Product videos • Webpage of technology provider
		S	2 & 3	Alpha L2a/3a	Diversified niche provider of logistics services, specialized in temperature-controlled goods, express delivery, and exhibition logistics.	CEO (1), COO (1), dispatcher (1), employed drivers (7)	10	
		S	2 & 3	Alpha L2b/3b	Regionally-operating LSP with haulage and stock management as main business segments.	Co-CEO (1), employed drivers (5)	6	
Beta	Temperature-tracking device to ensure high quality standards across the whole transportation and distribution process of pharmaceutical goods. It logs temperature data points during transport, which must be retrieved after the consignment has arrived. All data are stored in a cloud solution accessible to the shipper.	L	0	Beta L0	Pharma company focused on prescription medications, with a special focus on the condition of iron deficiency. In its field, it is the global market leader.	Supply & demand specialist (1)	1	• Interview with technology provider • Physical testing on site • Product descriptions (63 pages) • Product videos • Webpage of technology provider
		M	1 & 2	Beta L1/2	Transport and logistics provider for the pharma, medical, dental, and high-tech industry. Due to its focus on the healthcare sector, compliance with the highest regulatory demands is used to differentiate it from its competitors.	Member of divisional management healthcare (1), group leader warehousing (1), warehouse worker (1)	3	
Gamma	Smart container for the passively cooled transport of highly temperature-sensitive products. The solution guarantees temperature deviations below 0.1% and offers shippers the tracking of various status data that are stored in a blockchain-secured cloud. The containers under study are among the most reliable in the world.	L	0	Gamma L0	One of the largest pharma companies in the world with production facilities in North America, Asia, and Europe. The group's drugs focus on asthma, HIV/AIDS, malaria, depression, migraine, diabetes, and cancer.	Senior manager cold chain distribution (1)	1	• Interview with technology provider • Physical testing on site • Product descriptions (52 pages) • Product video • Podcast

Table C – 2. (continued)

Cases	Technology description	Size	Level	ID	Firm description	Participants (no.)	Total no.	Additional data sources on technologies
		L	1	Gamma L1	International logistics group that provides the full spectrum of logistics services, with a particular emphasis on the courier, parcel, and express mail business segments.	Process and quality compliance specialist (1)	1	
		S	2 & 3	Gamma L2/3	Local logistics service specialist that covers general cargo, temperature-controlled transports and warehousing, with certifications for dangerous goods, food, and pharmaceuticals.	Quality manager (1), employed drivers (5)	6	
Delta	Data-management platform to maintain competitiveness in standard logistics services and improve fleet management. The platform integrates one system for local transport (system 1) and one system for long-haul transport (system 2) with the existing TMS. System 1 is related to mobile scanners and includes, besides standard information on the freight, GPS data, a photo function, and the management of damage. System 2 is based on both a tablet and a box installed in the vehicle and can also access and transmit data from the digital tachograph such as data for the drivers or information on the vehicle. Further functions are messaging and real-time tracking information.	S	1	Delta L1	Medium-sized LSP with a focus on standard logistics services. Offerings cover general cargo solutions, warehousing, logistics consulting, as well as selected value-added services (e.g. transport insurance).	Member of the board (1), chief dispatcher (1), dispatcher (1), business development manager (1)	4	• Physical testing on site • Product descriptions (68 pages) • Product video
		S	2 & 3	Delta L2/3	Small LSP whose offered services include permanent local transport tours on behalf of medium-sized LSPs and—rather rarely—also directly for shippers. Besides general cargo (focal market sector), the building chemistry industry is served with special trucks.	CEO (1), driver (1)	2	

Notes: Firm size: L = large (revenue >1 billion EUR); M = medium (1 billion EUR > revenue > 250 million EUR); S = small (revenue < 250 million EUR)

C.4 Results

C.4.1 Case Alpha: Multifunctional handhelds

The LSC in Case Alpha consisted of a large and globally-operating 3PL on the first level (Alpha L1), two regional carriers on the second level (Alpha L2a and Alpha L2b), as well as their employed drivers (Alpha L3a and Alpha L3b; see Figure C - 4). Alpha L1 employed around 30,000 people, Alpha L2a/3a 150, and Alpha L2b/3b 60. The subcontractors did not work exclusively with Alpha L1 and find themselves in one technology–multiple principal constellations with many different 3PLs. The handling of handhelds is a widespread precondition to serve as a subcontractor in the logistics industry, even though the level of complexity between the handhelds varies considerably. In the present case, the diffusion of the handheld from Alpha L1 to Alpha L3a/b took approximately two weeks. Both subcontractors made use of further technologies in the course of their business relationship with Alpha L1 (multiple technology–one principal constellation). For instance, Alpha L1 provided core thermometers with which the actual temperature of the goods had to be checked at critical stages of the transportation process for temperature-controlled food. As Alpha L1 was the owner of the technology, Alpha L2a and Alpha L2b needed to sign a user contract including insurance.

The data from the handhelds were directly transmitted via 3G mobile internet from the local drivers to Alpha L1's subsidiaries. In fact, the subsequent LSC levels neither knew the exact amount of sent data nor what Alpha L1 (primary principal) intended to do with it (IA 2). This led to several presumptions being made by the carriers (e.g. a data-based comparison among subcontractors by Alpha L1) and by the drivers (e.g. personal surveillance during the day by Alpha L1) on how Alpha L1 might make use of the data (IA 4 and IA 5). At the same time, the user level profited from the increasing complexity of the handhelds that granted new opportunities to shirk (e.g. deliberately taking false photos to conceal the actual extent of transport damage). Such hidden actions (IA 4) were sometimes not even noticed because coalitions between the dispatchers and the drivers made control difficult (IA 5). To break up coalitions, rotating dispatchers was found to be an effective mechanism. Additionally, a unilaterally-designed malus system should have ensured appropriate technology use. Carriers had to comply with a scanning rate to avoid paying a contractual punishment (outcome-oriented contracts).

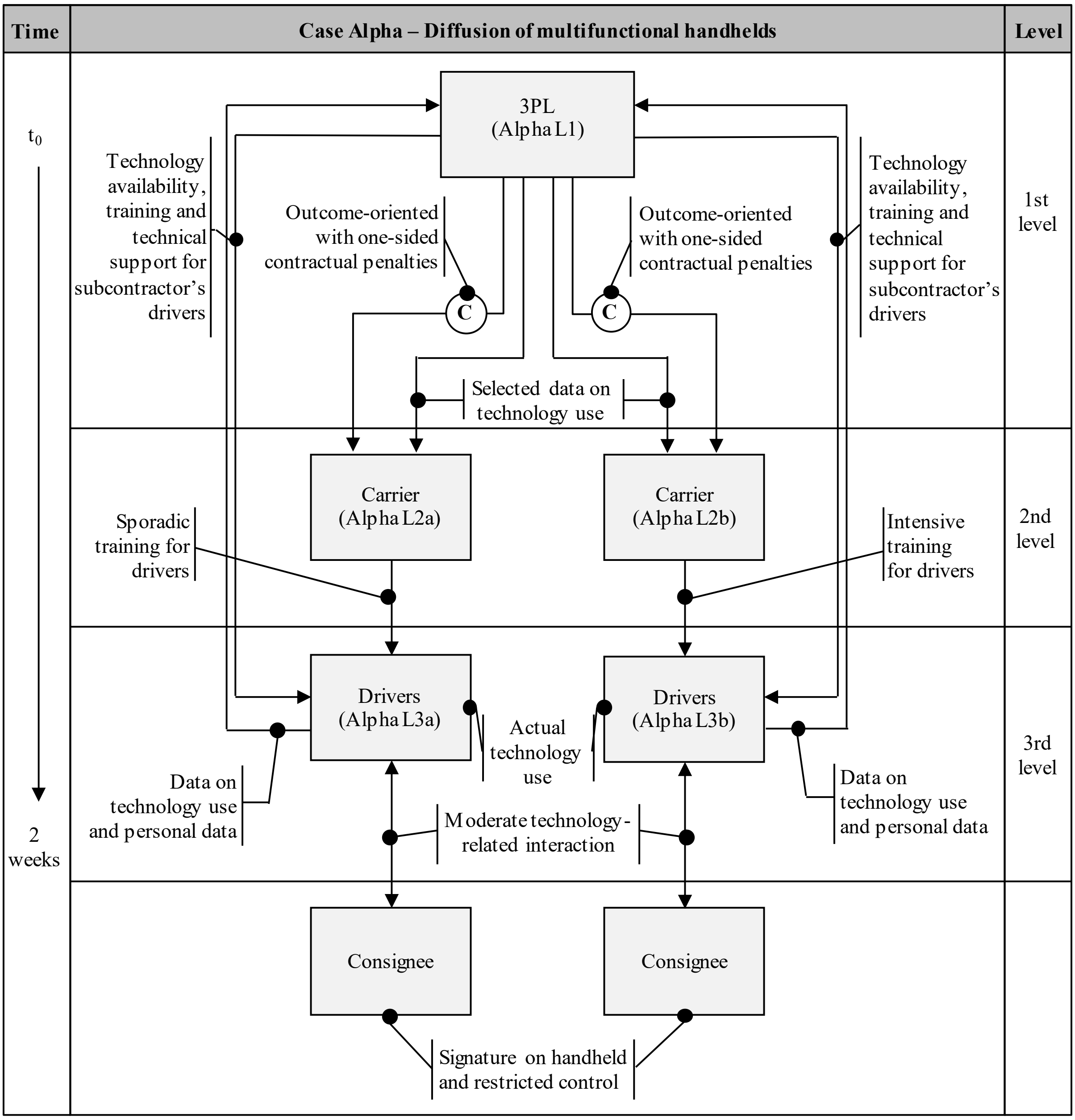

Figure C - 4. Overview of Case Alpha: Diffusion of multifunctional handhelds

C.4.2 Case Beta: Temperature-tracking devices

In Case Beta, the LSC comprised of a niche pharma company (Beta L0), an LSP specialized in the healthcare sector (Beta L1), and its warehouse employees (Beta L2; see Figure C - 5). Beta L0 employed 2,650 people and Beta L1/2 600 people. Beta L1/2 served as the long-term warehousing partner of Beta L0 for the whole of Europe. The produced goods were brought directly to one of Beta L1/2's warehouses, which prepared them for shipment all over the world. To do this, Beta L1/2 used various technologies for the same customer (e.g. packaging technologies such as covers or containers, trackers, etc.; multiple technology–one principal constellation). The observed temperature trackers were not typical for Beta L0 because regulations forced all pharma customers of Beta L1 to monitor the temperature along the whole transportation process with the help of trackers (one technology–multiple principal constellation). However, the diffusion process from Beta L0 to Beta L2 lasted three months in this case. Depending on the number of pallets per consignment, Beta L2 was responsible for starting the tracking devices, attaching the correct number of trackers to the pallets, and documenting the whole process. Furthermore, Beta L2 also handled the data-transmission process for loggers that were attached to incoming shipments. For data transmission, the device had to be connected to a computer and it automatically created a file with all the important information.

Dealing with similar technologies for many different customers (one technology–multiple principal constellation) granted Beta L1 an information advantage over Beta L0. Beta L1 knew the exact time needed to provide the tracker-related services, potential pain points in the process, and the technological competence required (IA 3). Beta L0 was aware of its adverse position and, in response, requested the joint design of standard operating procedures (SOPs). In the course of introducing new devices, Beta L2 had to write binding SOPs, which were reviewed by Beta L1 and finally approved by Beta L0. The SOPs were equivalent to a technology-specific contract. This helped Beta L0 to reduce IA 3 hidden information, as the process of technology handling became transparent. Furthermore, the secondary principal could not hide the actual level of technological knowhow. Besides the IA 3 problem, Case Beta was vulnerable to further information asymmetries. Already established governance mechanisms, however, had contributed to their elimination. For example, the warehouse employees had sometimes not started the trackers so as to be finished faster (IA 4). As the same employees were responsible for retrieving the data from incoming shipments in the meantime, they knew how meticulously the pallets were checked and what problems would arise in case a tracker had not been started. Simultaneously performing a control function thus helped to reduce hidden action. Moreover, it was made impossible for employees to cover up mistakes (IA 5) because the supervisors assigned to each customer team were changed regularly.

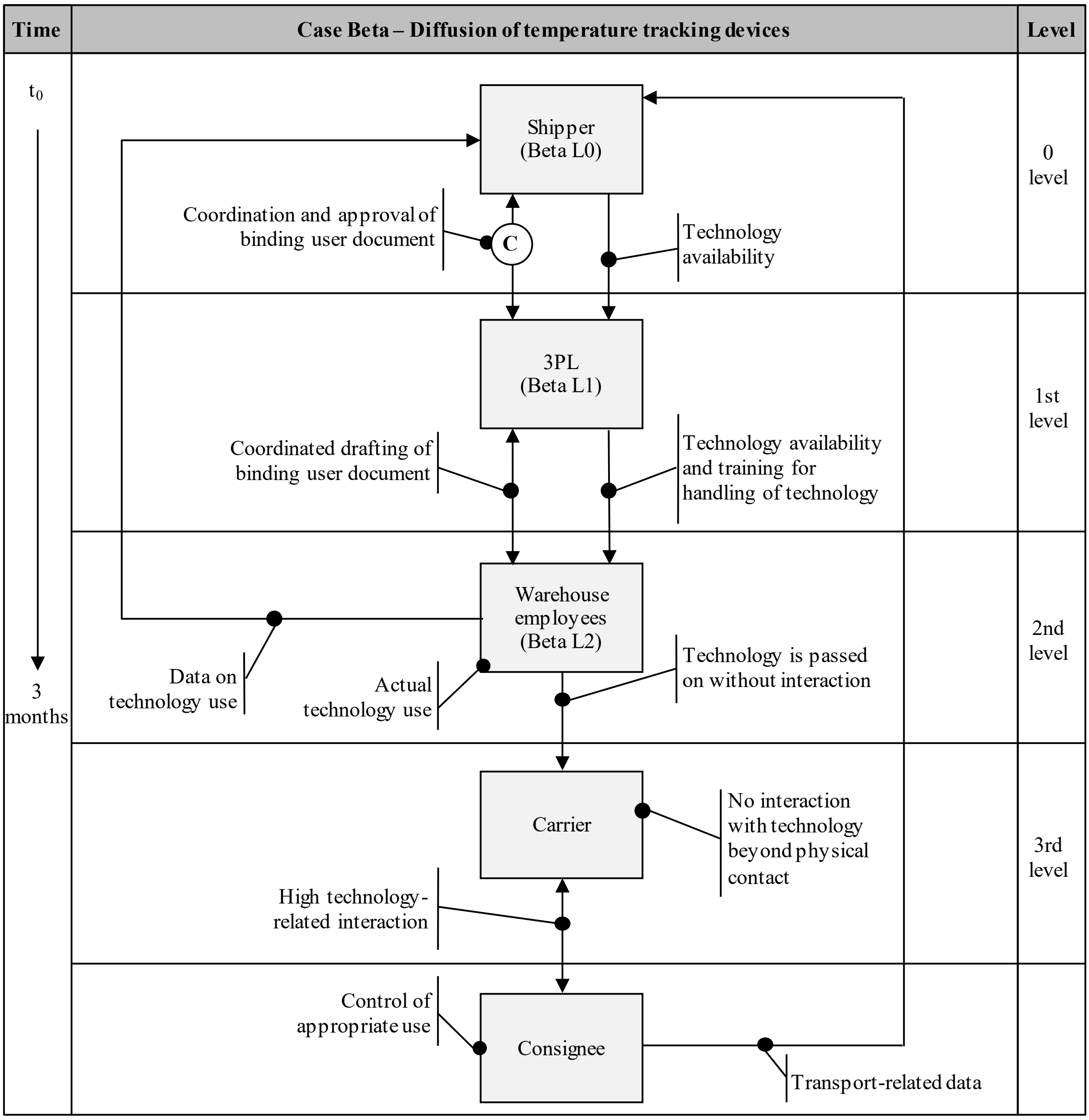

Figure C - 5. Overview of Case Beta: Diffusion of temperature-tracking devices

C.4.3 Case Gamma: Smart containers

The LSC under study in Case Gamma included a large pharma production company on level zero (Gamma L0), an international LSP responsible for the loading of the containers (Gamma L1) on the first level, a specialized small carrier (Gamma L2) acting as a freight forwarder on the second level, and employed drivers on the third level (Gamma L3) who transported the containers from Gamma L1's warehouse to the airport (see Figure C - 6). Gamma L0 employed 100,000, Gamma L1 500,000, and Gamma L2/3 approximately 120 employees. Gamma L1 was a long-term partner of L0 and was therefore involved in various logistics projects all over the world. This entailed both one technology–multiple principal and multiple technology–one principal constellations. Gamma L2/3 was specialized in the transport of temperature-controlled goods and was faced with various technologies for L1 (e.g. different temperature-controlled containers; multiple technology–one principal constellation), but handled smart containers for other pharma companies as well (one technology–multiple agent constellation).

Due to the complexity of the SC, the diffusion of the technology took half a year. The smart containers were owned by the technology provider, who also accounted for the conditioning (e.g. pre-tempering, safety checks, etc.) before each transport. Whenever the container passed a gateway (e.g. at the airport), data were transferred into a blockchain-secured cloud that could only be accessed by the shipper. This information advantage caused mistrust to arise in the subsequent SC levels. Although they assumed that the data were just used for temperature-tracking purposes by Gamma L0, a feeling of being controlled spread, especially on the user levels (IA 2 and IA 4). While no personal data were collected, conclusions about personal data could be drawn from the consignment-related data (e.g. working speed, rest breaks, etc.). With regard to technology handling, Gamma L0 had a lack of information on Gamma L1 (IA 3). Due to the newness of the smart containers, Gamma L0 had limited possibilities for comparing their handling among different LSPs. Furthermore, Gamma L1 acted as a service center for the technology provider, which required special certification to be allowed to undertake the pre-conditioning of all containers in this region. Comparable to Case Beta, Gamma L0 insisted on the joint design of SOPs to improve its own information position (e.g. to get an idea of the time needed for handling). The SOP replaced a separate technology-specific user contract in this case. As the LSC even had four levels, IA 4 hidden action and IA 5 hidden transfer were especially pronounced. Gamma L1 reported that it was never sure whether the damage to containers could be attributed to poor handling by Gamma L3 (IA 4) or to the poor quality of the containers, because Gamma L2 would, in case of doubt, stick to Gamma L3 (IA 5). However, being directly controlled by the consignee's warehouse significantly reduced IA 4 hidden action by Gamma L3.

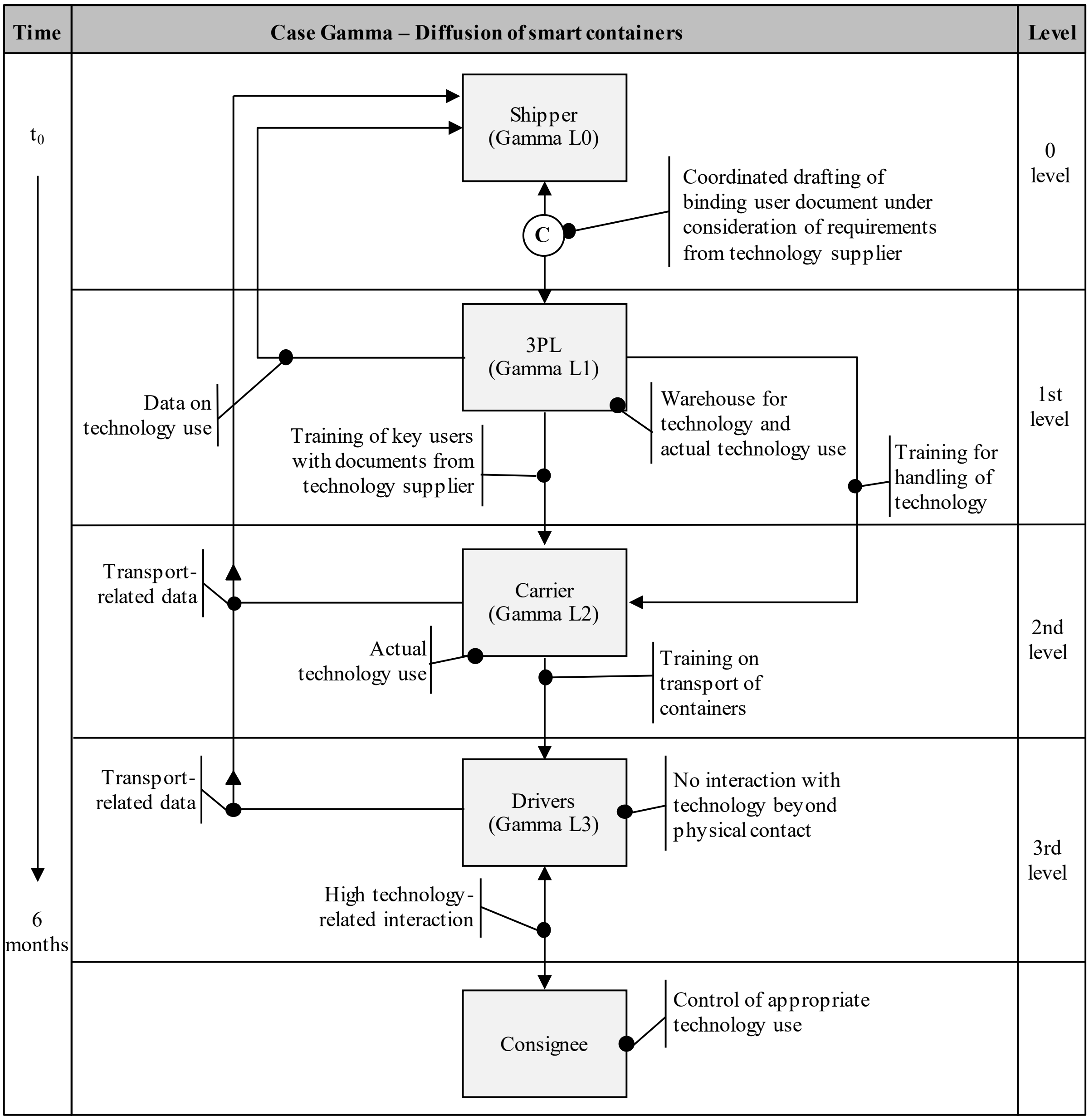

Figure C - 6. Overview of Case Gamma: Diffusion of smart containers

C.4.4 Case Delta: Data-management platform

The logistic SC of Case Delta encompassed a mid-sized 3PL providing standard logistics services (Delta L1), a small carrier operating as a local subcontractor for different 3PLs (Delta L2), as well as Delta L2's employed driver (Delta L3; see Figure C - 7). Delta L1 employed 650 people and Delta L2/3 16 people. Delta L2/3 served as a long-term subcontractor for Delta L1, but only handled the investigated technology (one technology–multiple principal constellation). This can be found frequently for subcontractors in the general cargo sector, whose use of technological innovations is often limited to individually-purchased vehicles and the technological equipment provided by the 3PL (e.g. handhelds). It took two months to implement the examined technology in this case.

Only system 1 (for local transport) of the data-management platform allowed for the application to be used by both subcontractors and employed drivers because it was related to mobile scanners. System 2 (for long-haul transport), in contrast, was based on a tablet and a box installed in the trucks that could only be made available to employed drivers. Information-related problems in terms of the technology had already arisen prior to the first pilot being launched. Delta L1 had difficulties in assessing the characteristics of subcontractors in order to select suitable pilot users (IA 1). Not having the possibility to draw on past experiences from other technological innovations complicated the choice of appropriate subcontractors. Thus, Delta L1 had to select pilot users based on non-technological characteristics such as the length of the business relationship or their reliability in daily business. By doing so, IA 2 hidden intentions were also unveiled. However, the formation of coalitions between Delta L2 and Delta L3 delayed the roll-out process (IA 5). Very often, Delta L2 complained about missing technology training for the employed drivers, while they obviously did not study the provided material sufficiently and were too time-constrained to scan all the shipments (IA 4). For this reason, Delta L1 introduced outcome-oriented contracts with financial punishments for inappropriate technology use (items not scanned, etc.). As noted, Delta L2 and Delta L3 had complained about Delta L1's non-transparent dealing with the data. Subsequent levels in the SC did not know what Delta L1 intended (IA 2) to do with the data (IA 3) and even feared that the data would be passed on to third parties (IA 5). An overview of the principal–agent constellation, the information asymmetry types, as well as governance mechanisms for each case is provided in Table C - 3.

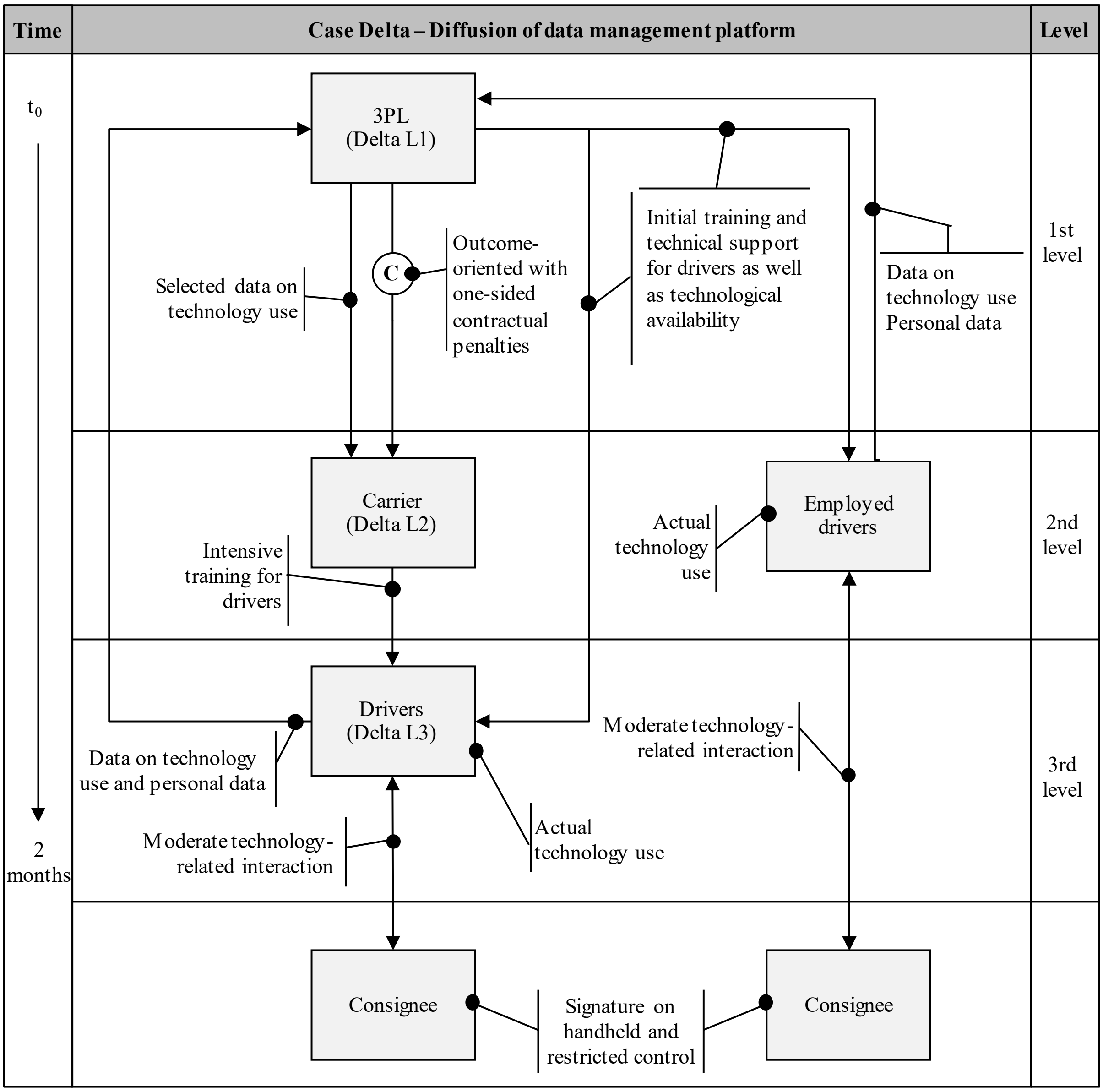

Figure C - 7. Overview of Case Delta: Diffusion of a data-management platform

Table C - 3. Comparison of the cases included in this study

Case	Technology characteristics and interaction	Principal–agent constellation	Applicable information asymmetry types (affected actors in italic letters)	Governance mechanisms (effectively governed level from a 3PL perspective)

Alpha	Multifunctional handhelds
	• Degree of data acquisition: High—wide-ranging data for behavior observation of the user level in the LSC
	• Degree of technological integration: High—new applications are regularly added
	• Degree of technological interaction:
	  o High (technology-user level)—handhelds accompany daily business
	  o Moderate (consignee)—just signs with restricted control
		• One technology–multiple principal constellation: Yes—carrier provides comparable service to different 3PLs
		• Multiple technology–one principal constellation:
		Yes—carriers uses various different technologies for same 3PL
			• IA 2: Yes
			Primary principal does not disclose to the others what it intends to do with the acquired data from the handhelds
			• IA 4: Yes
			Primary principal does not disclose to other actors of the LSC the degree to which the personal and general data from the handhelds is analyzed, e.g. to compare drivers
			The technology-user level profits from the increasing complexity of the handheld and finds new ways to shirk, e.g. by deliberately taking false photos
			• IA 5: Yes
			Primary principal does not disclose to the others when the data are transferred to third parties, e.g. to data-analysis specialists
			Subsequent levels of the LSC, e.g. the drivers and the dispatcher, form coalitions to cover up incorrectly entered information on consignments
				• Outcome-oriented contract with penalties for inappropriate technology use (technology-user level)
				• Rotation of people controlling agents (all subsequent levels)

Beta	Temperature-tracking devices
	• Degree of data acquisition: Moderate—selected data for behavior observation of the user level in the LSC
	• Degree of technological integration:
	Moderate—simple technology, but embedded in cloud infrastructure
	• Degree of technological interaction:
	  o Moderate (technology-user level)—just a few routine actions to start tracking
	  o High (consignee)—retrieves data and controls compliance with requirements
		• One technology–multiple principal constellation: Yes—3PL provides comparable service to different shippers
		• Multiple technology–one principal constellation: Yes—carriers use various different technologies for same shipper
			• IA 3: Yes
			Secondary principal deals with similar tracking devices for different customers and thus can appraise the whole diffusion process including pain points in advance
			• IA 4: Yes
			Technology-user level does not start the trackers carefully so as to be finished faster
			• IA 5: Yes
			Subsequent levels of the LSC, e.g. warehouse employees and drivers, form coalitions so that incorrectly attached trackers are not detected
				• Collaborative governance mechanism design (all subsequent levels)
				• Monitoring through quasi-principal role of consignee (technology-user level)
				• Monitoring through rotation of the principal's people (all subsequent levels)

Table C – 3. (continued)

Case	Technology characteristics and interaction	Principal–agent constellation	Applicable information asymmetry types (affected actors in italic letters)	Governance mechanisms (effectively governed level from a 3PL perspective)
Gamma	Smart containers • Degree of data acquisition: Moderate—selected data for behavior observation of the user level in the LSC • Degree of technological integration: Moderate—simple technology, but embedded in blockchain-secured cloud infrastructure • Degree of technological interaction: ○ Low (technology-user level)—no interaction beyond physical contact ○ High (consignee)—unloads containers and controls compliance with requirements	• One technology–multiple principal constellation: Yes—both 3PL and carrier provide comparable service to different firms • Multiple technology–one principal constellation: Yes—both 3PL and carrier use various different technologies for the same customer	• IA 2: Yes *Primary principal* does not disclose to other actors of the LSC how much analysis is carried out on the data from the smart containers, e.g. to draw conclusions on the performance of single actors in the LSC • IA 3: Yes *Secondary principal* simultaneously operates as a service center for the smart container producer and therefore already knows the relatively new technology better than the shipper does • IA 4: Yes *Technology-user level* accepts the damaged containers in order to be able to provide a service as quickly and cheaply as possible • IA 5: Yes *Primary principal* does not disclose to the others when data are transferred to third parties, e.g. to the technology provider in order to find ways in which to better control the subsequent levels *Subsequent levels* of the LSC, e.g. the carrier and the employed drivers, try together to cover up any transport damage	• Collaborative governance mechanism design (all subsequent levels) • Monitoring through quasi-principal role of consignee (technology-user level)
Delta	Data-management platform • Degree of data acquisition: High—wide-ranging data for behavior observation of the user level in the LSC • Degree of technological integration: High—new applications are regularly added • Degree of technological interaction: ○ High (technology-user level)—hardware constantly accompanies drivers ○ Moderate (consignee)—just signs without control	• One technology–multiple principal constellation: Yes—carrier provides comparable service to different 3PLs • Multiple technology–one principal constellation: No—carrier handles just the observed technology for the same 3PL	• IA 1: Yes *Technology-user level's* capabilities are difficult to assess by the primary principal because there is no prior experience from past projects in a comparable constellation • IA 2: Yes *Primary principal* does not disclose to the others what is intended for the platform data *Technology-user level* of the LSC has no interest in sharing the intentions as to why it makes itself available for a pilot test • IA 4: Yes *Primary principal* gathers driver-related data to improve the future choice of subcontractors (without them knowing it) *Technology-user level* of the LSC is too lazy to scan all items and consciously leaves out single consignments • IA 5: Yes *Primary principal* does not disclose to the others when data are transferred to third parties, e.g. to data-analysis specialists	• Outcome-oriented contract with penalties for inappropriate technology use (technology-user level)

Table C – 3. (continued)

Case	Technology characteristics and interaction	Principal–agent constellation	Applicable information asymmetry types (affected actors in italic letters)	Governance mechanisms (effectively governed level from a 3PL perspective)
			• IA 5: Yes *Primary principal* does not disclose to the others when data are transferred to third parties, e.g. to data-analysis specialists *Subsequent levels* of the LSC, e.g. the carrier and its employed drivers are covering for each other in terms of missing technology training in order to hide their inability to scan	

C.5 Discussion

C.5.1 Implications of technology characteristics on information asymmetries

Diffusion of data-acquiring technological innovations in principal–agent cascades. Information asymmetries might occur whenever the behavior of the agent is unobservable to the principal. Thus, all of the studied technological innovations were designed to exclusively acquire data on technology handling for the primary principal. The first level of Cases Alpha and Delta highlighted how the permanent tracking of the users' behavior (including GPS information, time for (un-)loading, or personal data) allowed them to comprehend and assess precisely whether the technology was being exploited in the best possible way. Additionally, the user level admitted that this high level of transparency had a deterrent effect on hidden action. Although this sounds good from the perspective of the primary principal, information asymmetries arose in another level of the LSC. The second level of Cases Alpha and Delta complained about being at the mercy of the first level regarding the handling of the data. This was also observable for Case Gamma, but to a lesser extent, as this case included considerably less extensive data (e.g. no personal data). Thus, the information asymmetry between the upper two levels in the SC had switched places, including IA 2 hidden intention (the secondary principal cannot judge whether the data handling by the primary principal is adequate), IA 4 hidden action (the secondary principal cannot observe exactly what is done with the data), and IA 5 hidden transfer (the secondary principal cannot observe whether data are shared with third parties). Hence:

> *Observation 1a:* Technological innovations that acquire usage data exclusively for the primary principal are negatively associated with hidden information and hidden action at the technology-user level.

> *Observation 1b*: Technological innovations that acquire usage data exclusively for the primary principal are positively associated with the hidden intention, hidden action, and hidden transfer of the primary principal.

Observation 1a supports the insights of the pertinent literature in this field. Eisenhardt (1989a) suggests that investment in information systems is one possible option to make agents' behavior observable and fight information asymmetries. Saam (2007), more precisely, explains information systems as a suitable means for preventing IA 4 hidden action. Information systems, however, are most effective in combination with control or incentive compensation systems. As could be presumed, the data provide no evidence for a negative effect of data-acquiring technologies on IA 1 hidden characteristics, IA 2 hidden intention, or IA 5 hidden transfer. In order to tackle IA 1 or IA 2, data that were acquired prior to the technology being used would be required. IA 5 does not often show up in the data as the data entry might already be distorted.

Observation 1b is reconcilable with existing research efforts but goes far beyond them. Perrow (1986) already noted that agency problems also exist on the principal side of the relationship. This is particularly relevant in the supply chain context, where interdependent relationships regularly entail changing roles; actors can simultaneously be an agent in one constellation and a principal in another (Fayezi et al., 2012; Wilhelm et al., 2016). The present study extends these findings by revealing the information asymmetry types that stem from exclusive data sovereignty at the first level of multi-level LSCs.

Diffusion of integrated technological innovations in principal–agent cascades. All the observed cases showed a tendency toward more integrated solutions. For example, the data-management platform in Case Delta had overcome a previous data limitation relating to the consignments, vehicles, and drivers. The software solution now allowed for text messages to be written to speed up communication between the dispatcher and the drivers, as well as among the drivers. However, the primary principal of the SC highlighted how difficult it was to control the intended use of this function. Drivers might have used this function to override the prohibition against private mobile phone use during transport for private messaging. The other cases yielded further examples of more potential sources of information asymmetry through integrated technology solutions. For example, a photo function had recently been integrated into the handhelds of Case Alpha in order to record cargo damage. However, numerous false photos had already been taken. Thus:

> *Observation 2:* The increasing integration of technological innovations is positively associated with hidden action and hidden transfer at the technology-user level.

Observation 2 refers to a phenomenon that could be suspected as being the case, but which has not yet been empirically supported. The linkage between technological characteristics and individual behavior has been studied by IS researchers for years (Karahanna, Straub, & Chervany, 1999; Venkatesh, Morris, Davis, & Davis, 2003). Goodhue and Thompson (1995) show that technology features and task requirements must "fit" well for optimal performance. The more integrated the technologies are, the more functions are available that exceed the requirements of individual tasks. This creates new opportunities to make mistakes or even to deliberately exploit individual new functions for one's own benefit. Assuming the opportunistic behavior of the agent (Eisenhardt, 1989a), new possibilities to shirk are exploited by the agent.

C.5.2 Implications of principal–agent constellations on information asymmetries

One technology–multiple principal constellations. All four investigated cases exemplified one technology–multiple principal constellations. From the perspective of the primary principal, these constellations can lead to an information deficit toward the agents. In Cases Beta and Gamma, the accompanying challenges became particularly explicit. Both shippers had long-term relationships with few LSPs that were each in full charge of the logistics activities of a selected part of the shippers' supply chains. The shipper in Case Beta, for instance, worked together with one LSP whose employees attached temperature-tracking devices to all products produced in Europe. Similarly, the shipper in Case Gamma had only a few LSPs whose employees loaded the smart containers and were responsible for their transport. In both cases, the LSPs provided the observed technology-handling service for many other customers. Consequently, the shipper did not have the same level of expertise that the LSP had in order to judge whether the technology was handled in the best possible way (IA 3 hidden information). This observation could also be made for Cases Alpha and Delta. However, as in both these cases the primary principal worked together with many different agents (as is typical for subcontracting in logistics (Y. Li et al., 2009)), this information deficit was less pronounced. Here, the primary principle had the possibility of comparing technology use between different agents. Thus:

> *Observation 3:* One technology–multiple principal constellations are positively associated with the hidden information of the secondary principal.

Observation 3 demonstrates that the particularities of LSPs have an impact on the occurrence of certain information asymmetries. Typically serving a wide range of customers from different industries with different technologies, LSPs are forced to transfer knowhow and processes between multiple customers (Liu & Lyons, 2011; Selviaridis & Spring, 2007). Thereby, efficiencies are realized and supply chain robustness can be achieved (Grawe & Ralston, 2019). Against the background of one technology–multiple principal constellations, LSPs will try to use a technology in the best possible way for them based on the existing experience from comparable technology projects with other customers. The result is an information advantage over the technology initiator, who has a less frequent chance of transferring technology knowhow from other customer projects.

Multiple technology–one principal constellations. Due to the increasing importance of technologies for the provision of logistics services (Hofmann & Osterwalder, 2017), LSPs frequently make use of different technologies for one customer. Consequently, all the observed agents but one (Case Delta) applied more than just the observed technological innovation for their principal. The principals of these cases—no matter on which LSC level—knew how to take advantage of this. For example, the primary principal of Case Alpha selected subcontractors for an initial technology pilot on the basis of their performance in previous technology projects. These subcontractors, in turn, used the pilot with their drivers who had the highest degree of technological affinity. The underlying logic behind this has run very obviously through all the cases. Besides the selected characteristics of the agents, multiple technology–one principal constellations can also contribute to revealing their intentions. The primary principal of Case Delta had a very clear overview of the carriers who really wanted to perform above average and of those who were not suited to testing a new technological innovation. Interestingly enough, multiple technology–one principal constellations were also seen as a chance by the agents. In Cases Beta and Gamma, the interviewees pronounced that their previous handling of new technologies might have impacted the decision of the primary principal to test further technologies with them. Therefore:

> *Observation 4:* Multiple technology–one principal constellations are negatively associated with hidden characteristics and hidden intentions at the subsequent levels.

Observation 4 introduces a new explanatory approach to the occurrence of IA 1 hidden characteristics and IA 2 hidden intentions during technology diffusion. Existing research with an agency perspective suggests certain aspects of principal–agent relations as a predictor for information asymmetry types, for example, the length of relationships (Lambert, 1983) and the associated level of trust (Ateş, Van den Ende, & Ianniello, 2015). Other scholars highlight the role of present governance mechanisms. Agents might, for example, prevent IA 1 by signaling with the help of certificates (Grinblatt & Hwang, 1989; Saam, 2007). This research shows that the characteristics of the technology–principal constellation allow conclusions to be drawn about expected information asymmetries. It thereby contributes to recent findings on innovation as a signaling mechanism (Hsu & Ziedonis, 2013).

C.5.3 Implications of principal–agent cascade levels on information asymmetries

Number of levels in principal–agent constellations. The observed principal–agent cascades in LSCs all had several levels: Three levels in Cases Alpha, Beta, and Delta, and four levels in Case Gamma. As shown in the literature review, IA 5 hidden transfers might occur whenever principal–agent cascades consist of more than two levels and agents have the chance to form coalitions (Tirole, 1986). Indeed, the cases with three or more levels were affected by this phenomenon. In Case Beta, coalitions exposed blind spots in the SC. The shipper as the primary principal had received images of all pallets to be shipped that had been equipped with temperature-tracking devices by the warehousing partner. These pallets sometimes arrived at the customer without a tracking device, although the freight forwarder should have had nothing to do with the trackers. Especially in exotic countries, they found that the trackers had been sold for cash. Less extreme examples were found for Cases Alpha and Delta, where the primary principals complained about the lack of distance between dispatchers on the second level and drivers on the third level in the SC. Individual consignments were listed as delivered on time, while dispatchers and drivers took a break together and the consignment had not yet been delivered. Last but not least, the secondary principal in Case Gamma confessed that deviations from the standard handling procedure were most likely all the way down in nested SCs (even beyond level 3), where selected agents might have developed a common cause. Thus:

Observation 5: An increasing number of principal–agent cascade levels during technology diffusion is positively associated with hidden transfers at the subsequent levels.

Observation 5 makes a valuable contribution to the scientific debate on principal–agent hierarchies, which to date have only been studied for the intrafirm setting. The rationale behind this remains the same for both interorganizational and intrafirm constellations: Whenever there are three or more levels in hierarchical relationships, two actors have the possibility of forming a coalition and of working toward a common cause to the detriment of the third actor (Tirole, 1986). To the best of the authors' knowledge, this is the first paper that adds empirical material to and confirms this connection in an interorganizational setting. Insights are expected to be especially relevant for the recent theory developments around double agency (Child & Rodrigues, 2003; Wilhelm et al., 2016). Therein, the challenges for companies being a principal in one constellation and an agent in another are incorporated, but a transfer to interorganizational constellations with more than two levels was unresolved.

C.5.4 Governance mechanism design to overcome information asymmetries

Active involvement of subsequent levels. An effective approach to tackle information asymmetries in LSCs is from active involvement from the top to the bottom levels. Cases Beta and Gamma exemplified this approach because their governance mechanisms were co-designed between the primary and secondary principals. After the technology adoption and diffusion decision had been taken by the primary principal, a process of governance design started. In both cases, the primary principal (supported by the technology provider) provided the secondary principal with information on the purpose of the technology diffusion, the regulatory stipulations to comply with, the relevant processes affected by the technology, the consequences of technology misuse, and various further aspects. The secondary principal had to study the information and translate it into a binding document that regulated the exact nature of the technology handling. This process was iterative until both parties agreed on the final document. For the primary principals, this procedure was perceived as helpful in order to understand the technology use in detail (in order to overcome IA 3 hidden information) and to ensure that there was no IA 2 hidden intention. Additionally, the secondary principal revealed its technological capabilities, so that there were no IA 1 hidden characteristics. The secondary principal used the process to combine signaling and self-selection. On the one hand, existing technological knowhow could be indicated. On the other, there was still scope for shaping the handling in a favorable way. What turned out to be very valuable for the relationship between the primary and secondary principals should also be applicable to the subsequent levels in the LSC. The other cases did not contain a cooperative element for the design of governance mechanisms. As both secondary principals in Cases Alpha and Delta did not have the chance to exert influence over how the technology was actually applied and what happened in the case of inappropriate handling, negative results with regard to information asymmetry were noticeable. Hence:

> *Observation 6:* Active involvement of the subsequent levels for the design of governance mechanisms during technology diffusion is negatively associated with hidden characteristics, hidden intention, and hidden information.

Observation 6 takes up various elements from the existing governance literature and transfers them to the multi-level, interorganizational context. Thus, it exceeds present knowledge and provides valuable insights for governance in interorganizational hierarchies. To begin with, the active involvement of agents gives them the possibility of signaling at a reasonable price (Grinblatt & Hwang, 1989). The costs for signaling are usually carried by the agent alone (Saam, 2007). As the principal takes an active part in creating the governing documents, he or she also has to bear some of the costs. In return, this financial commitment can be used by the principal for self-selection (Arrow, 1985). The way the agent contributes to the creation of governance documents allows the principal to draw conclusions regarding his or her abilities. This creates a desirable situation for both sides. Finally, this constellation is interesting from the perspective of authority. Especially in multiple technology–one principal constellations, the agent might have an information advantage over the principal and could take advantage of the situation. However, transferring the creation of binding documents according to the principal's instructions creates clear authority. This is comparable to the governance mechanism for vertical integration, which allows IA 2 hidden intention to be overcome (Klein, Crawford, & Alchian, 1978). Interestingly enough, this is the first study to find that such active involvement in governance design is an effective mechanism at each level of the LSC.

Contract design based on technological interaction. The interaction between the LSC user level and the technological innovation differed considerably between the cases. In Cases Alpha and Delta, high interaction with the technology was a necessary part of daily business. The employed drivers of Case Alpha, for instance, carried the handhelds with them all day and sometimes did more than 50 scans per day. In contrast, the temperature-tracking devices in Case Beta required just a few routine actions to be started and attached to the consignments. The most extreme example was Case Gamma, where the freight forwarder of the loaded containers did not have any interaction that exceeded standard physical contact. The level of interaction with the technology was considered for the design of governance mechanisms to tackle IA 4. The primary principals of Cases Alpha and Delta had installed a remuneration system with an outcome-oriented component. Only if certain key performance indicators (e.g. scanning rate) were met, was the full payment made to the secondary principal. Hidden action by the employed drivers on the LSC user level thus had a direct financial impact on the payment to the secondary principal. Cases Beta and Gamma had just installed a behavior-oriented contract between the primary and secondary principals. They did not see the necessity of financially governing technology use, as this was not a dominant part of the service provision from their perspective and it left little space for IA 4 hidden action. Consequently, it can be concluded that the choice of contract design to prevent IA 4 is dependent on the interaction between the user level of the LSC and the technological innovation. To sum up:

> *Observation 7a*: Outcome-oriented contracts are negatively associated with hidden actions at the technology-user level if there are high-interaction constellations between the technology-user level and the technological innovation.

> *Observation 7b*: Behavior-oriented contracts are negatively associated with hidden actions at the technology-user level if there are low-interaction constellations between the technology-user level and the technological innovation.

Both observation 7a and observation 7b show that it is not sufficient to infer the ideal type of contract from the mere existence of a technological innovation. However, this has been the line of argumentation in the governance literature to date (Eisenhardt, 1989a). By taking the results of this research into account, technology interaction is added to the debate as an important aspect to consider when designing contracts for governing technology diffusion. In the technology adoption literature, the important role of technology characteristics for technology integration and use is undisputed (Davis, 1989; Rogers, 2003). Boothby and colleagues (2010), for example, proved that there was increased productivity performance if the workforce training was complementary to technology characteristics. Thus, it appears as the next logical step to reconcile technology characteristics and contract design, because the degree of interaction with a technology directly impacts the way in which it is used.

Quasi-principal monitoring of the consignee. Two different consignee roles could be observed in the cases: minor technology interaction without a monitoring component (Cases Alpha and Delta) and major technology interaction with a monitoring component (Cases Beta and Gamma). Interestingly, the interviewees admitted that the degree of the consignee's technology interaction can have an impact on appropriate technology use. If the consignee intensively interacts with the technological innovation and simultaneously performs a monitoring function, he or she temporarily slips into a principal role (with the people on the LSC's user level as agents). In Case Gamma, for example, the consignee's warehouse unloaded the containers and thereby checked the intactness of the containers and the goods. The employed drivers on the LSC's third level were aware of the fact that inappropriate handling would be noticed immediately, which prevented them from IA 4 hidden action. The same could be observed in Case Beta, where the consignee's warehouse was responsible for retrieving the tracker data and sending it back to the shipper. In Cases Alpha and Delta, interaction between the consignee and the technological innovation was rather low. Although the consignee had to confirm the receipt of goods on a handheld, the practical circumstances (e.g. time pressure) did not allow for controlling every scanned packaging item that they had signed a receipt for; a situation the employed drivers frequently tried to take advantage of (e.g. through entering an incorrect packaging state and letting it be confirmed by the consignee). Therefore:

> *Observation 8:* A quasi-principal role of the consignee for mutual monitoring is negatively associated with hidden actions at the technology-user level.

Observation 8 is in line with the argumentation of multiple agency theory's foundational literature. The more complex principal–agent constellations become, the less sufficient pure hierarchical forms of monitoring are (Varian, 1990). It could therefore be a valuable complement to existing governance mechanisms if selected parties involved in the SC monitor each other (Grandori, 2001). This phenomenon is called mutual monitoring

(Child & Rodrigues, 2003). In the present study, mutual monitoring was found to be especially beneficial at the user level of the technological innovation. Although the existing literature hinted at the potentially beneficial effect of mutual monitoring, it was unclear for interorganizational principal–agent cascades regarding how and at which level this governance mechanism would be particularly effective.

Rotation-based monitoring of the principal's people. Coalitions occurred in all four cases. However, observable governance mechanisms remained rare and could only be observed in Cases Alpha and Beta, although these mechanisms were originally not intended to overcome IA 5 hidden transfers. The primary principal in Case Alpha had to fight against coalitions between dispatchers and drivers on the technology-user level of the LSC. Dispatchers regularly covered drivers if they had entered incorrect statuses into the handhelds. An effective way to break up such coalitions was found by chance. The rotation of dispatchers for a vacation replacement uncovered the prescribed practices. The secondary principal in Case Beta had a comparable rotation system in place. As warehousing services were performed for different pharma companies by this LSP, each warehouse employee was assigned to at least one pharma company. Furthermore, there were team heads for each client team with more extensive technological knowhow who could lead the teams with a minimum of two different clients. The staffing plan provided for regular changes of team heads among teams. In the course of this, the team heads were able to identify inappropriate technology handling by single individuals which might have remained undiscovered if the team heads had only monitored one team. Therefore:

> *Observation 9*: Rotation of the principal's people who are in direct contact with and control agents during technology diffusion is negatively associated with hidden transfers at the subsequent levels.

Observation 9 is, to the best of the authors' knowledge, the first empirically-grounded hint for effectively overcoming IA 5 hidden transfers in interorganizational settings. Even for intrafirm constellations, to date there are only deductively-derived governance mechanisms, for example, outside recruiting, short-term relationships, or job rotation (Tirole, 1986). The observed coalitions all occurred between parties who felt close to each other, for instance, between dispatchers and drivers (and not between business development managers and drivers). From a psychological point of view, this phenomenon is called “ingroup favoritism,” and can, in extreme manifestations, lead to IA 5 (Dasgupta, 2004; Ma-Kellams, Spencer-Rodgers, & Peng, 2011). To cut through such boundaries, job rotation has been shown to be effective in the logistics context, because task complexity does not exceed a level where job rotation becomes impractical (Wagner, Grigg, Mann, & Mohammad, 2017). What holds for intrafirm groups in firms was found to be equally effective in the interorganizational context by this research. A summary and conceptual positioning of the observations is presented in Figure C - 8.

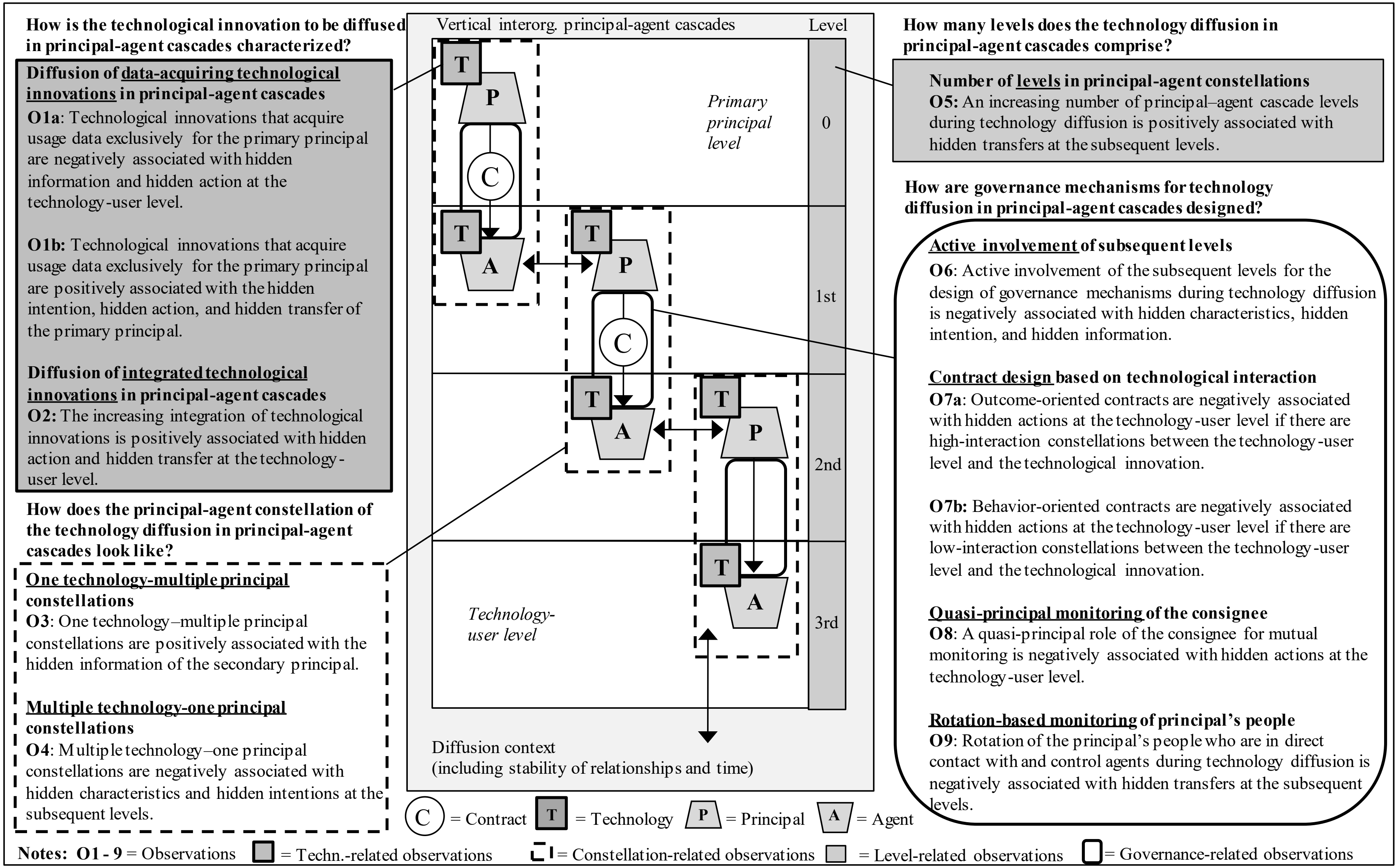

Figure C - 8. Summary of the observations on vertical interorganizational technology diffusion

C.6 Conclusion

C.6.1 Theoretical contribution

The theoretical contributions stem from the observations of this research, which are organized around four areas: (1) implications of technological innovation characteristics on information asymmetries, (2) implications of principal–agent constellations on information asymmetries, (3) implications of principal–agent cascade levels on information asymmetries, and (4) governance mechanism design to overcome information asymmetries. While the first three areas around principal-agent cascades provide answers to *RQ1*, the latter is concerned with *RQ2*.

The first area considers the diversity of the diffused technology and underlines why the application of an agency perspective for research on technology-driven phenomena in interorganizational settings is particularly promising in today's industry 4.0 environment. Existing research on agency problems suggests that the investment in information systems (e.g. data-governing technologies, as observed in this study) generally allows for information asymmetries to be overcome because the behavior of the agents becomes observable (Eisenhardt, 1989a). The present study, however, shows that this is only partially correct. While IA 3 hidden information and IA 4 hidden actions at the user level might be tackled, other information asymmetries (IA 2, IA 4, and IA 5) arise on the first level. Thus, the diffusion of data-acquiring technologies cannot be seen as a substitute for governance mechanisms; rather, these technologies might even strengthen the need for governance mechanisms at another level of the SC. Furthermore, the technological innovation's degree of integration matters for the occurrence of information asymmetries. The more integrated a solution is, the more IA 4 and IA 5 can be expected. Thus, the opportunities that arise to shirk outweigh the increased possibilities for control.

The second area around principal–agent constellations takes into account the breadth of the SC and makes an important contribution to the current developments of agency theory such as double (Child & Rodrigues, 2003; Wilhelm et al., 2016) or multiple agency relationships (Arthurs et al., 2008; Child & Rodrigues, 2003). This application field calls for an extension of Tirole's (1986) principal agency hierarchies by transferring them from the intrafirm to the interorganizational level. The paper takes up these developments and derives a principal–agent cascade for LSCs, which helps in discussing information asymmetries in a more differentiated way. For two LSC sub-constellations—namely, one technology–multiple principal and multiple technology–one principal constellations—, the occurrence of information asymmetries was thoroughly examined. One technology–multiple principal constellations grant secondary principals an information advantage over the first principal, such that the primary principal should try to avoid such a setting. Multiple technology–one principal constellations, in contrast, can help to overcome hidden IA 1 characteristics and IA 2 hidden intentions.

The third area is devoted to the depth of principal–agent cascades and extends existing knowledge from vertical intrafirm technology diffusion to vertical interorganizational technology diffusion. Zmud and Apple (1992) showed that the vertical direction of diffusion strengthens the need for effective governance mechanisms within firms. This study empirically showed that information asymmetries actually increase with the number of levels in interorganizational SCs. As a particularity of the interorganizational context, especially IA 5 is found. Actors in the principal–agent cascades take advantage of the increased complexity due to a larger number of levels and form coalitions. The first three areas of the theoretical contribution thus answer RQ1 by uncovering the principal-agent constellations under which technological innovations are diffused in interorganizational settings.

The fourth area around governance mechanism design extends the known approaches to solve information asymmetries in single-level principal–agent constellations (e.g. Saam, 2007) by reviewing their application in multi-level settings. To the best of the authors' knowledge, there are no studies that empirically examine the governance of technology diffusion in vertical interorganizational SCs, which is why valuable insights are presented. Actively involving subsequent levels in governance design (i.e. Case Beta and Case Gamma) is effective at tackling IA 1 hidden characteristics, IA 2 hidden intentions, and IA 3 hidden information. The underlying mechanisms are signaling and self-selection, which unfold their effect at every level of the chain. Further observations suggest a relationship between the technology user's interaction with the technology and contract design effectiveness. This is noteworthy, because this study is the first one linking the actual technology application context and contract design for a more nuanced discussion. In addition, monitoring could be observed to play a decisive role in multi-level

SCs. Drawing on the construct of mutual monitoring from multiple agency theory (Child & Rodrigues, 2003), the assignment of a monitoring role to the receiver was found to be helpful for preventing IA 4 hidden actions at the technology-user level. Last but not least, regular changes of people monitoring subsequent levels in nested SCs was identified as a means to break up coalitions. Although the existence of IA 5 hidden transfers (at least within firms) is well known (Tirole, 1986), there had been no empirical indication on the means to tackle them. In sum, the fourth area of the theoretical contribution answers RQ2 by providing a set of governance mechanisms to overcome information asymmetries during vertical interorganizational technology diffusion.

C.6.2 Managerial implications

The study also has important managerial implications. Decision-makers of 3PLs who are concerned with vertical technology diffusion may not be conscious of the principal–agent cascade that their company is embedded in. Due to the decisive role of principal–agent constellations for understanding potentially occurring agency problems, the present paper creates an awareness of the different SC (sub-)constellations. To make a substantial practical contribution, the implications of these sub-constellations (e.g. one technology–multiple principal constellations) for upcoming information asymmetries (e.g. IA 3 hidden information of the secondary principal) are examined. This is complemented by an investigation of the role of technology characteristics for information asymmetries. Drawing on this study, decision-makers can therefore anticipate potential information asymmetries during technology diffusion by analyzing both their SC constellation and the technology characteristics in a more structured way.

Furthermore, this study endows practitioners with an overview on effective governance mechanism designs in order to overcome information asymmetries during vertical technology diffusion. As the first paper of its kind, the effects of governance mechanisms are reflected in the different SC levels. Thus, the 3PL can either directly incorporate promising governance mechanisms or get a sense of which governance mechanisms to look at for subsequent SC levels to ensure adequate technology use. In sum, a very concrete picture on the governance of vertical interorganizational technology diffusion throughout the whole SC is provided. The summary of observations (see Figure C - 8) therefore serves not just for structuring the theoretical contributions, but also enables practitioners to grasp the information-related challenges of the vertical diffusion of a new technological innovation very quickly and make the right choices in time. Additionally, the findings can also be used by other LSC actors, for example, for joint governance mechanism design together with the 3PL.

C.6.3 Limitations and directions for future research

The study is not without limitations. First, a focus on technology diffusion in LSCs impairs the generalizability of the results. The observations should also be tested in other industries with comparable service structures, for example, tourism (Robinson et al., 2019) or construction (Brahm & Tarziján, 2014; Tanskanen et al., 2015). Second, the examined SCs were broad but not exhaustive and included both shippers and LSPs. Due to the increased amount of data through the use of hybrid technologies, completely new players emerged, for example, data intermediaries on a platform basis. Their role in overcoming information asymmetries has remained unexplained in the course of this study. Third, the clearly stated focus on vertical technology diffusion oversimplified the structures that LSPs are embedded in. Through horizontal interrelations, entire networks of service providers evolve that might lead to even more complex information asymmetry constellations (Cui & Hertz, 2011; Gadde, Håkansson, Jahre, & Persson, 2002).

Future research should go further in terms of theory testing with a large-scale study. Beyond this next natural step, there are additional promising avenues for future studies. Complementing research on information asymmetries during technology diffusion by considering power asymmetries would appear to be especially valuable (Wilhelm et al., 2016). LSCs are typically dominated by 3PLs. In other industries, the technology-user level might have more power, which in turn is expected to affect the governance throughout the whole SC. Adding to this, there is a need for the examination of speed in interorganizational technology diffusions. The findings of the within-case analysis exhibit interesting differences in the time required for diffusion, which is why time was included as a diffusion context in this study. It is thus expected that future research on information asymmetries in interorganizational technology diffusion can make a substantial explanatory contribution in this regard. Finally, future research efforts should try to grasp the technology diffusion success in vertical SCs. There are various possibilities for operationalizing the success in technology adoption such as acceptance, process quality, speed, or costs (Mathauer & Hofmann, 2019). Scholars should try to grasp them at the different levels of the SC, because players in the highly competitive logistics industry are always forced to lead technology projects to success at the end of the day.

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C.8 Appendix

C.8.1 Extract of the interview guideline from a 3PL perspective

1. **Logistics service chain**
   a. How do the logistics service chains look like in which your company is embedded in?
   b. Do you make use of subcontractors?
   c. Are your subcontractors allowed to enter into subcontracting relationships as well (tiering)?
2. **Technological innovation**
   a. Please describe the technological innovation in detail.
   b. Please describe the concrete logistics service chain which is concerned by the diffusion of the technological innovation.
   c. What kind of data is acquired by the technological innovation and who is authorized to access it?
   d. Are there any technology-related contracts you enter in with your subcontractors?
   e. How long did it take from the technology adoption decision until the appropriate technology handling on user level?
   f. How does the interaction between the technological innovation and the driver look like?
   g. How does the interaction between the technological innovation and the consignee look like?
3. **Information asymmetries**
   a. What kind of problems emerged during technology diffusion?
   b. Which of these problems can possibly be attributed to information asymmetries?
   c. How do you select users for pilot projects?
   d. In how far do you evaluate certain characteristics of subcontractors before they are integrated in technology projects?

e. Are you able to judge whether the technological innovation is applied correctly at each level of the logistics service chain?
f. At which level(s) of the logistics service chain is the technological innovation deliberately used wrong?
g. Are there any examples of coalitions to your disadvantage in the logistics service chain the technological innovation is used?

4. Governance mechanisms

a. Do you have governance mechanisms in place that ensure appropriate handling of the technological innovation throughout the logistics service chain?
b. How do these governance mechanisms look like?
c. Does the recipient have a controlling function with regard to the technology used for service provision?
d. Are governance mechanisms/documents for correct technology use designed jointly with your partners in the logistics service chain?
e. In your opinion, what should governance ideally look like in order to overcome the described problems of technology diffusion?
f. Please describe a less successful technology diffusion from the past. From a governance perspective, what should have gone differently?

C.8.2 Overview on selected quotes and the coding

Quotations from the interviews (selection)	Selective Codes	Theoretical codes
"[Alpha L1] has the exclusive access to all data, although it is generated by our drivers, so to speak. Isn't that crazy? If we want to see how many shipments our driver has delivered and scanned, we have to ask [Alpha L1] for an extract from the system." (CEO of Alpha L2a)	Data acquisition	Characteristics of technological innovation
"In my opinion, data protection is being trampled underfoot here […]. Personal data is transmitted to the 3PL unfiltered. In our dependency relationship we can do nothing else than watch. The data sovereignty lies solely with [Alpha L1]." (Co-CEO of Alpha L2b)	Data protection	
"The new solution has a lot of functions, for example text messaging. These devices have more in common with a smartphone than with an actual scanner. The downside is that all these functions also have the potential to distract from the correct application." (Chief dispatcher of Delta L1)	Technological integration	
"[…] yes, this is nothing special in this industry. We attach trackers to the shipments of all our pharma customers. Our employees therefore know very well how to handle them and we exchange the knowledge among the customer teams on a regular basis. You would call it horizontal knowledge transfer probably." (Member of divisional management health care of Beta L1)	One technology-multiple principal constellation	Principal agent constellations
"It used to be that we only had one technological solution for one customer. Today, things look completely different. Something new is constantly being added, which we also include in our services. From a single technology perspective, the handling is usually not that difficult. The challenge, however, is to master the whole set of technologies." (Group leader warehousing of Beta L1/2)	Multiple technology-one principal constellation	
"There are those cases where people do not even think about using the technology correctly. They want to continue to do their own thing and obstruct new technology projects. It's […] difficult because you can't get inside people's heads." (Dispatcher of Delta L1)	Hidden intention	Information asymmetry types
"Of course there is something you call hidden action. Drivers can be lazy guys. When they see 25 individual consignments that they would have to scan individually under time pressure, they get creative. We are responsible to design a solution that makes it very difficult to cheat. […] and expensive to cheat." (Dispatcher of Alpha L1)	Hidden action	
"The more levels there are in the service chain, the more difficult it is to keep the exact overview. I can tell you stories you won't believe […]. Our products also have to be shipped to nations which are less well developed. At some pallets there, the trackers suddenly disappeared. People hade made common cause and sold the stuff." (Supply & demand specialist of Beta L0).	Hidden transfer	
"If you work together with a new partner, you don't know his technology skills before. SOPs are therefore a good thing […] We work together for months on binding documents and talk almost daily on operative processes. At some point, you really know whether they fooled you in the tender or know their business well." (Senior manager cold chain distribution of Gamma L0)	Collaborative mechanisms	Governance mechanisms
"It must hurt financially. All other governance mechanisms are nice to have, but less effective." (Business development manager of Alpha L1)	Financial penalties	

D. Additional managerial implications

D.1 Dimensions and questions from the technology adoption pilot

Table D - 1. Overview of dimensions and questions from the technology adoption pilot

Sphere	Guiding question	Dimension	Suggested specific questions
Activity-legitimizing	*Why* should the technological innovation be adopted?	Value proposition	What value is delivered (in terms of the customer, the firm, and the value chain partners)? Which needs are satisfied (in terms of the customer, the firm, and the value chain partners)? Etc.
		Profit mechanism	How can the technological innovation contribute to save costs? How can the technological innovation contribute to generate additional revenue? Etc.
Activity-influencing	*Where* is the technology adoption activity embedded in?	External	How do external factors influence technology adoption (in terms of politics, economy, social culture, technology, ecology, and law)? Etc.
		Internal	How do internal factors influence the technology adoption (value system, the organization structure, the corporate culture, and the mission and objectives)? Etc.
Activity-guiding	*What* is the technology adoption activity geared at?	Technological innovation	How can the potential technological innovation be characterized (in terms of newness to the firm, tangibility, and personalization)? How does interaction with the technological innovation look like? Etc.
	How is the technology adoption activity conducted?	Resources	What resources are required to conduct the technology adoption activity? How should these resources be used for contributing to the value proposition? Etc.
	Who is affected by the technology adoption activity?	Value chain configuration	How does the value chain configuration look like? What does the value chain configuration imply for the technology adoption activity? Etc.
		Technology suppliers	Who are technology suppliers? How can technology suppliers contribute to the course of the technology adoption activity? Etc.

D.2 Application of the technology adoption pilot to technology searching by logistics service providers

To make the application of the technology adoption pilot presented in Section 6.2 more concrete, it is applied to a further real-life case setting hereafter.[55] The example is about searching for technological innovation in a very specialized field of logistics services. More concretely, a large LSP aims to adopt smartphones equipped with an app for streamlining processes in car logistics. All employees working in the car preparation shall receive the services booked by the customer on their app, so that they just have to perform the activities in the presented order and in the given time. This is challenging, because paper-based processes become digital from one day to another, requiring investments both in hardware and in software development. For setting the stage, Table D - 2 depicts the most important aspects of the activity-legitimizing, the activity-influencing, and the activity-guiding dimensions of the technology adoption pilot.

Table D - 2. Exemplification of the three spheres of the technology adoption pilot for technology searching

Sphere	Dimension	Exemplified for technology searching
Activity-legitimizing	Value proposition	The LSP wishes to facilitate the process of car preparation in car logistics, thereby saving time and administrative work. The shippers are keen about innovations in car logistics and expect future-oriented solutions from time to time.
	Profit mechanism	The present process is largely paper-based, which results in millions of printed pages that could be saved per year by the 3PL. The time which may be required is specified, so that both the speed of service provision and its plannability increase.
Activity-influencing	External	The market for car logistics has been relatively stable over time, which has tempted LSPs not to invest in technological innovations for a long time. As technological progress is fast, existing players are now threatened by new entrants with very efficient processes. Changes concerning driving technology affect the service portfolio of LSPs that are active in car logistics. For example, electric vehicles have to be charged after preparation.

[55] The setting draws on Case L4 of Appendix A.4.1. Thus, the descriptions are amended and extended extracts from Study A.

Table D – 2. (continued)

Sphere	Dimension	Exemplified for technology searching
	Internal	The 3PL has six main business segments, which are largely operating independently. This leads to inefficiencies during the technology searches. The people working with the technological interface functions have much personal responsibility in terms of how they deal with new technologies.
Activity-guiding	Technological innovation	The technological innovation is an app solution that presents all work to be done in car logistics step by step together with information on the required service level. There is a timer that counts down the time that may be required for preparation work. The technological solution does not yet exist on the market and has to be developed first.
	Resources	A high level of process know-how is required by the people who manage the project. All people involved in car preparation have to be endowed with a smartphone, which is why substantial financial investments are needed.
	Value chain configuration	As the technological innovation is inward-oriented, employees who are preparing the cars are most affected. However, close interaction between employees and the technology supplier is needed due to the newness of the technology that first needs to be developed.
	Technology suppliers	The most important partners are technology suppliers who have the technology-related know-how that the LSP is lacking.

Departing from the status quo presented in Table D - 2 managerial implications are derived for each dimension of the technology adoption pilot. These implications leave the actual case setting and represent a transfer, reflection and extension of selected findings across cases from Study A. The managerial implications are located in Figure D - 1, while Table D - 3 comprises more detailed explanations of the individual implications.

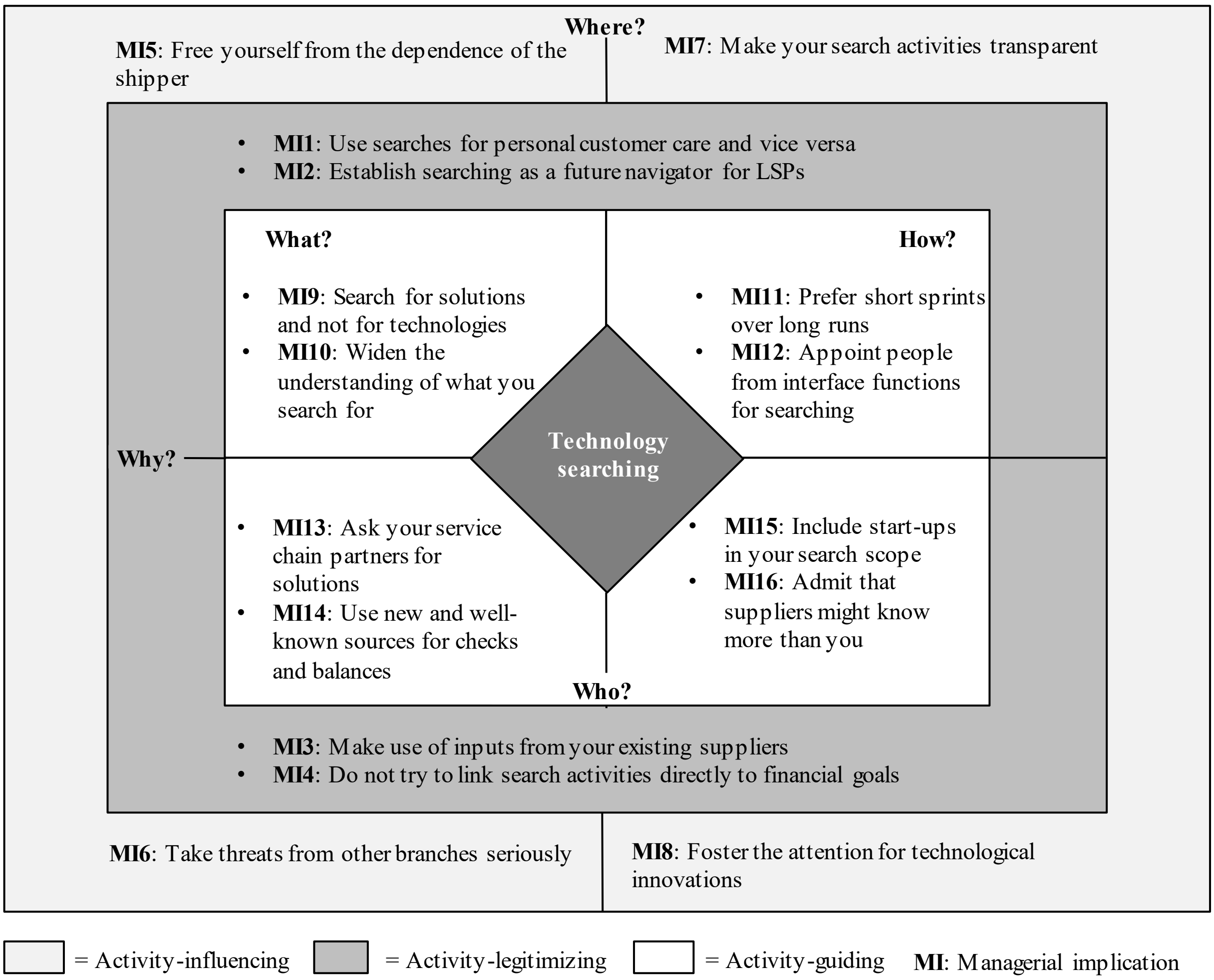

Figure D - 1. Selected managerial implications for technology searching

Table D - 3. Explanation of the managerial implications for technology searching

Dimension	Managerial implications	Explanation
Value proposition	MI1	The shipper is a valuable source of technological innovations at LSPs. If shippers do not even propose technologies on their own initiative, they are often open to discussing conceivable solutions. Being perceived as innovative is important in today's business environment and helps to strengthen personal relationships with the customer.
	MI2	LSPs who are regularly searching their business environment for technological innovations are more likely not to miss out on current developments. Technology adoption projects are a chance to professionalize search efforts and perpetuate search activities afterward.
Profit mechanism	MI3	It might be reasonable to systematically exchange views with existing technology suppliers to remain informed of their latest solutions. LSPs tend to forget about their current suppliers when searching for technological innovations they do not initially associate with them. However, the portfolio of most suppliers is broader than their customers know.
	MI4	The operationalization of search efforts is difficult and should not be directly linked to financial goals. Sometimes, positive effects show up with such a time lag that they can no longer be traced back to a search alone. Instead, LSPs should instead limit their budget and the time allocated to providing guidance.
External	MI5	Shippers want to tie in LSPs as much as possible. Frequently, shippers even dominate technology adoption and guide the attention during technology searches. With customers being in their focus of service provision, LSPs should still try to free themselves from single customers to find new technological innovations with the potential for multi-client capability.
	MI6	LSPs like to define their market environment narrowly and rely on the fact that physical goods will always need to be shipped from A to B. The market entrance of new competitors, for example, e-commerce providers, is slowly changing their view. Regarding the very fast technological progress, it is in any case advisable to pay close attention to what companies in other industries with relevance to logistics are doing and which technologies they are using.
Internal	MI7	Geographic dispersion complicates technology adoption in general and searching for technologies specifically. Due to their decentral structures, LSPs should try to make search activities transparent to avoid inefficiencies.
	MI8	Searching at LSPs is about structuring and channeling the attention of the people affected. Also, small LSPs should therefore try to create an awareness of technological innovations to ensure that people coming across technological innovations also recognize the potential value of their application in the firm-specific context.

Table D – 3. (continued)

Dimension	Managerial implications	Explanation
Technological innovation	MI9	New problems can regularly be solved with existing technologies. Due to low profit margins in logistics, technologies should not be adopted for the sake of the technology. Therefore, decision-makers should suppress personal affinity and ensure that selected technologies contribute to the value proposition.
	MI10	There is a tendency of LSPs to commit to a specific technology too early. However, widening the scope of what is searched allows for unexpected solutions.
Resources	MI11	Searching can become expensive, especially if an LSP does not know exactly what the search is directed at. Therefore, it is recommended that the search intensity is limited and that there should be an exchange with customers and the other stakeholders from time to time. On that basis, it can be decided whether to continue or stop search activities.
	MI12	Search results are dependent on the people who conduct search activities. LSPs should try to appoint people for searching who have both technological and process knowledge. The latter is indispensable in a logistics context and prevents nasty surprises during implementation.
Value chain configuration	MI13	LSPs who are embedded in complex service networks should approach their service chain partners during the search. This might have two positive effects: (1) the service chain partner might know about a technological solution that meets the requirements of what the LSP is initially searching for, and (2) questions of technological interoperability can be addressed even in this very early stage of technology adoption.
	MI14	As outlined above, established sources can be very helpful and make searches particularly effective. Nevertheless, the solutions suggested by existing suppliers should be checked with what other suppliers offer to compare functionality and price.
Technology suppliers	MI15	Although LSPs typically seek established solutions and try to avoid the unknown, startups are a valuable source for technology searching. Even LSPs who exclude partnerships with startups should get inspired by the ideas of these new firms.
	MI16	Working with technology suppliers is typically a field of tension for LSPs. They feel that the suppliers do not understand their business, while the suppliers feel that the LSP does not understand the technology. In case of doubt, however, the supplier knows more about a technological innovation than the LSP does. So LSPs should stay open and try to distill what is important for them when talking to suppliers.

D.3 Application of the technology adoption pilot to accessing technology by logistics service providers

Another example of the application of the technology adoption pilot presented in Section 6.2 is provided by a real-life setting from contract logistics.[56] The example is about accessing a robotic solution to improve commissioning processes. More concretely, a large LSP aims to adopt collaborative robots that allow for the picking and stowing of goods from e-commerce firms. There are no comparable robots on the market to date, so that the solution has to be co-developed. The robots are expected to work hand in hand with employees on the shop floor and do not require any physical preparations to be made to the warehouse. As they are all interconnected via the cloud, the project includes hardware- and software-related issues. To set the stage, Table D - 4 depicts the most important aspects of the activity-legitimizing, activity-influencing, and the activity-guiding dimensions of the technology adoption pilot.

Table D - 4. Exemplification of the three spheres of the technology adoption pilot for accessing technology

Sphere	Dimension	Exemplified for accessing technology
Activity-legitimizing	Value proposition	Shippers (firms from the fashion industry engaged in e-commerce) wish the commissioning to be provided 24/7 to ensure the fastest possible delivery to the customer after his or her order, even on weekends. The 3PL is confronted with a severe manpower shortage, increasing costs for employees, and a dusty image.
	Profit mechanism	The technological innovation is to be operated around the clock and thus will contribute to revenue increases. As commissioning processes are highly error-prone, robots will help to reduce the costs of process faults.
Activity-influencing	External	The 3PL operates in a highly competitive market surrounding. On the one hand, direct competitors are moving their warehouses to countries with lower wage structures. On the other hand, e-commerce firms have started to operate warehouses themselves and have aggravated competitive pressure. A lot of media attention is focused on the remuneration of employees in this area, which is why social pressure is also noticeable.

[56] The setting draws on Case L1 of Appendix B.3.2. Thus, the descriptions are amended and extended extracts from Study B.

Table D – 4. (continued)

Sphere	Dimension	Exemplified for accessing technology
	Internal	Top management support technological innovations, as the owner-manager is trying to reposition the firm. There are low hierarchies in relation to the number of employees, which allows for ad-hoc project teams in case of technology adoptions.
Activity-guiding	Technological innovation	The technological innovation is a collaborative robot specifically manufactured for the 3PL and designed for commissioning processes (both picking and stowing) when order sizes are small. All collaborative robots are connected via the cloud. This allows for unlimited scalability. Warehouse employees interact with the technology.
	Value chain configuration	The technology supplier and the 3PL co-develop the technological innovation and therefore closely interact during technology access. Warehouse employees of the 3PL play a significant role in sharpening the requirement profile of the technological innovation.
	Resources	The financially-required resources are difficult to plan, since the technological innovation must first be adapted to the firm's own application context. Implicit knowledge of warehouse employees must be made explicit to improve supporting them with the technological innovation.
	Technology suppliers	Main partner is the technology supplier, who even receives workplaces at site to facilitate working together. The exchange with start-ups from the circle of suppliers is deliberately sought for the generation of new ideas.

Departing from the initial technology adoption setting presented in Table D - 4, managerial implications are derived for each dimension of the technology adoption pilot. These implications leave the actual case setting and represent a transfer of, reflection on, and extension of selected findings across cases from Study B. The managerial implications are located in Figure D - 2, while Table D - 5 comprises more detailed explanations of the individual implications.

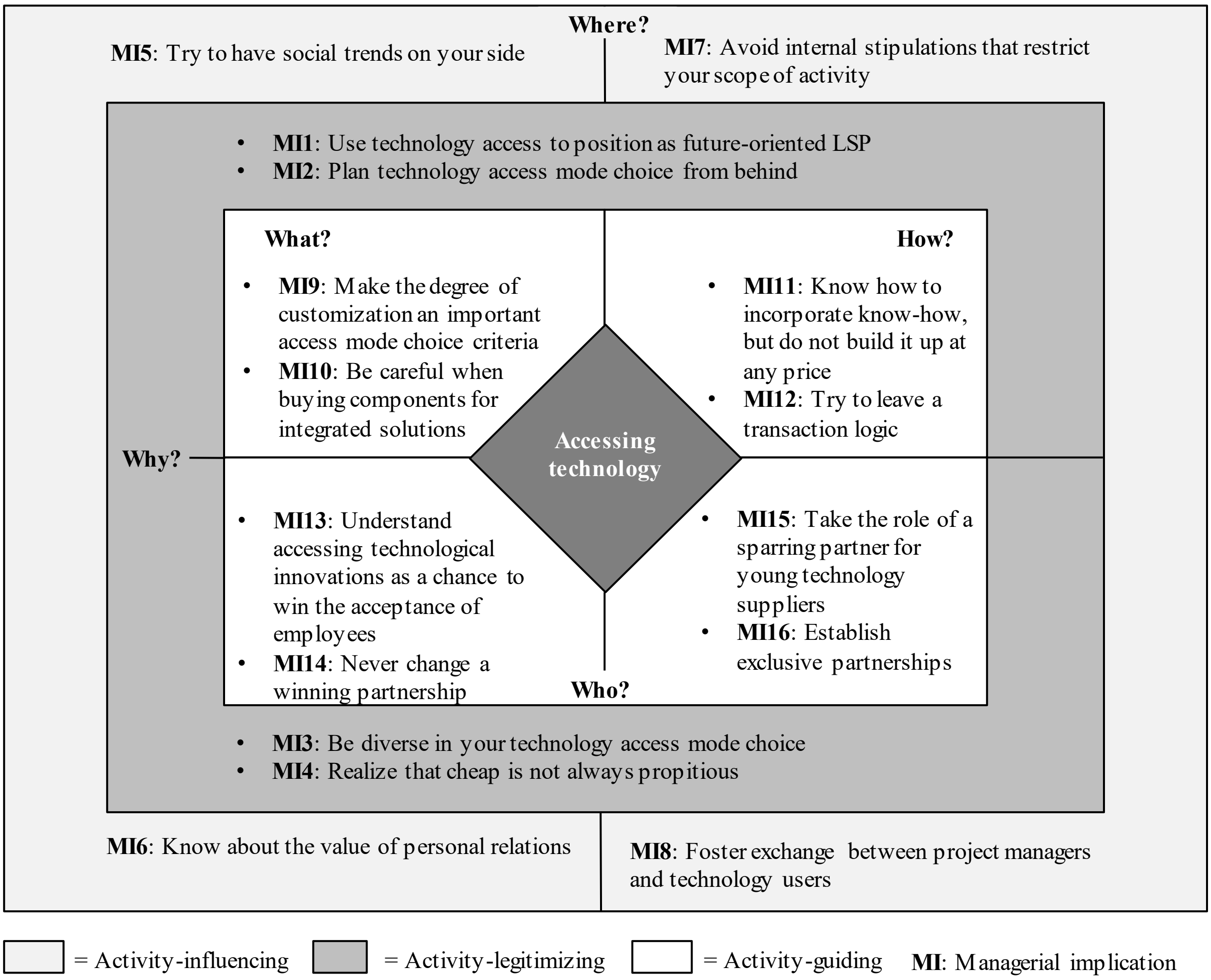

Figure D - 2. Selected managerial implications for accessing technology

Table D - 5. Explanation of the managerial implications for accessing technology

Dimension	Managerial implications	Explanation
Value proposition	MI1	The technology access-mode choice reveals much about 3PLs. It is nothing new that their image is slightly dusty. Projects like the co-development of intelligent robots for commissioning have a signaling effect and help to both recruit people and improve customer perceptions.
	MI2	The choice of technology access modes should not only be based on whether the technology can be procured at all and whether it corresponds to the technological expectations. Instead, it is important to consider how the integration should proceed to maximize the value of the technological solution for the stakeholders. If the shipper, for example, has a zero-error culture, it is not reasonable to focus on the fastest technology access modes that are prone to process errors.

Table D – 5. (continued)

Dimension	Managerial implications	Explanation
Profit mechanism	MI3	Choosing an access mode for the first time is expensive, as the necessary knowledge must be built up first. However, this can save money in the long run. 3PLs, for instance, who have already entered into a strategic alliance and have co-developed a technological solution, might improve their evaluation of purchases, because they better know what criteria to concentrate on.
	MI4	LSPs tend to prefer the cheapest technology access mode, which is often the purchase of a standardized solution. However, customization and integration can make the technology access expensive afterward—even more expensive than accessing a customized solution would have been from the beginning.
External	MI5	Capturing the zeitgeist makes accessing technological innovations much easier. This is especially true for social trends. As low wages and tough working conditions are attracting bad press in logistics, technological innovations that contribute to improvements in the situation (e.g., less tough work due to robots) will be pushed by technology suppliers and received with open arms by employees.
	MI6	Logistics is a people's business where professionals are well connected. These connections, either to competitors, customers, or other partners in the service chain, are very valuable for accessing technological innovations. Small firms and family firms structurally draw on hints from their peers, but large LSPs still underestimate this aspect.
Internal	MI7	Most large firms are prone to a wide range of internal guidelines that also restrict the scope of activities concerning technology access-mode choice. 3PLs should not rule out *a priori* developing a solution on their own or investing in a small firm, as highly dynamic technology surroundings require flexibility with regard to technology access mode choice.
	MI8	At LSPs, the workforce is usually geographically dispersed, with people working in the offices at different sites and many other people working in warehouses or driving vehicles. Consciously fostering the exchange between the project managers of technology adoptions and the technology users can even enrich the access mode choice, because there might be very practical arguments as to why one alternative should be preferred over another.
Technological innovation	MI9	Although it might seem clear, LSPs account far too little for this in practice. Defining the necessary degree of customization in advance helps to exclude certain technology access modes from the outset and facilitate decision-making.

Table D – 5. (continued)

Dimension	Managerial implications	Explanation
Technological innovation	MI10	Integrated solutions typically consist of various components (e.g., hardware and software components). Not being specialized in technologies, LSPs might face severe problems with combining components that were accessed from different suppliers. Whenever the possibility exists, integrated solutions should be accessed from only one supplier.
Resources	MI11	If a technological solution is completely new to the firm, like robots are for a 3PL, there is a tendency for the project managers to build up as much knowledge on the technology as possible. Although this might be exciting for the persons involved, it can be costly for the company. Instead, it is much more important to know how the knowledge of the supplier can be effectively absorbed and incorporated. Thus, knowledge on building up absorptive capacity is more important than knowledge of individual technologies.
	MI12	Especially for complex technological innovations, 3PLs should ensure the fit of technology and the requirements. If there is no appropriate technology on the market, the transaction logic should be abandoned to try out new forms of technology access.
Value chain configuration	MI13	Being the ones who will finally work with the technological innovations, people from operations will later decide on the integration success. The choice of technology access mode is a good chance to foster internal acceptance of the technological innovation, because people can already be involved during the customization or development processes.
	MI14	Accessing technological innovations from long-term partners is always more efficient than evaluating new partners. This is not to say that the same access mode should always be pursued with these partners. For example, participation might evolve with a supplier from which standardized solutions were accessed at the beginning.
Technology suppliers	MI15	Young technology startups are very much driven by the possibilities of their technological solutions but lack both practical problems and process know-how. Due to their problem-orientation and their process competencies, LSPs are ideal sparring partners for these firms. Once cooperation has been successful, the LSP will be approached by further startups, so that the range of potential partners can be increased.
	MI16	Technology suppliers are of outstanding importance for accessing technological innovations. The better their reputation, the better the outcome will be for the technology project. Exclusive partnerships can be a promising route. Partnership agreements or buying equity are a means to ensure direct information flow and long-standing partnerships.

Curriculum Vitae

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Education

03/2017-04/2020	**UNIVERSITY OF ST. GALLEN**, St. Gallen, Switzerland PhD Candidate in Management
08/2015-02/2017	**UNIVERSITY OF ST. GALLEN**, St. Gallen, Switzerland Master of Arts in General Management
08/2012-07/2015	**UNIVERSITY OF LIECHTENSTEIN**, Vaduz, Liechtenstein Bachelor of Science in Business Administration
09/2003-07/2012	**GYNMASIUM AT DEUTENBERG**, VS-Schwenningen, Germany Abitur with Focal Areas in Economics and Physics

Professional Experience

05/2020-today	**FUNK-EXPRESS-TRANSPORTE**, Dauchingen, Germany Deputy CEO and Member of the Executive Board
03/2017-04/2020	**UNIVERSITY OF ST. GALLEN**, St. Gallen, Switzerland Research Associate and Project Manager at the Institute of Supply Chain Management
03/2018-11/2018	**LOGISTICS ADVISORY EXPERTS**, Arbon, Switzerland External Consultant for SCM- and Logistics-related Projects
03/2015-02/2017	**KAISER PARTNER**, Vaduz, Liechtenstein Trainee Special Task Team Trust Management
02/2013-02/2015	**UNIVERSITY OF LIECHTENSTEIN**, Vaduz, Liechtenstein Student Assistant at the Chair of Company, Foundation and Trust Law

Awards

09/2015	**BANKING AWARD LIECHTENSTEIN**
	Impact of Bachelor's Thesis on Liechtenstein Financial Center
	AWARD OF THE LIECHTENSTEIN BANKING ASSOC.
	Best Bachelor's Graduate of the University with Financial Focus
07/2012	**AWARD OF THE LORD MAYOR**
	Best School Graduate
	FERRY PORSCHE AWARD
	Best School Graduate in Physics and Mathematics
	SCHEFFEL AWARD
	Best School Graduate in German Language
	SUEDWESTMETALL AWARD
	Best School Graduate in Economics
	WALDMANN AWARD
	Best School Graduate in English and Mathematics

Scholarships

07/2012-02/2017	German Academic Scholarship Foundation
07/2012-04/2020	e-fellows.net

Extracurricular Activities

12/2015-today	Family Business Club of the University of St. Gallen (Former President, Member of the Board)
06/2017-today	Rotaract Club Liechtenstein (Founding Member)
09/2013-07/2015	High Potential Program of the University of Liechtenstein (Founding Member)
07/2010-today	Rotaract Club Schwarzwald-Baar (Member of the Board)

VS-Villingen, 11 June 2020