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Green innovations in third-party logistics: managerial reasons, external stakeholder influences and contingencies in the natural-business environment

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ABSTRACT

Increasing ecological consciousness makes adopting green innovations a strategic concern for third-party logistics providers (3PLs). This article addresses gaps in understanding how 3PLs can strategically leverage green innovations and the business environment characteristics influencing their adoption through a multiple-case study of six environmentally proactive German 3PLs using semi-structured interviews and triangulated with secondary data. Results show varied adoption levels with process innovations linked to cost savings, enhanced reputation and long-term energy independence. Large 3PLs differentiate through green services in eco-aware segments. Moreover, findings highlight the importance of managing external stakeholder relationships and reveal market-related contingencies that create uncertainty and complexity for 3PLs, such as unpredictable technological developments or shifting governmental regulations. Market munificence plays a crucial role in enabling green innovation adoption, with small-/mid-sized 3PLs facing challenges in accessing external green knowledge and personnel. This study is informed by the Natural Resource-based View (NRBV), Stakeholder Theory (ST) and Contingency Theory (CT) perspectives, developing a comprehensive framework that coherently structures the problem-situation and derives propositions for subsequent explanatory investigations. It recommends a step-by-step approach to green innovations, forming diverse partnerships and maintaining communication with shippers to overcome perceived market-related contingencies. Small-/mid-sized 3PLs should consider horizontal cooperation for unified advocacy and shared best practices.

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1. Introduction

It is common practice for industrial corporations and retailers to outsource multiple logistics activities to third-party logistics providers (3PLs), thereby leveraging their expertise in coordinating and integrating logistics resources more effectively (Marchet et al., 2018). However, the services conducted by 3PLs also have significant adverse ecological impacts. 3PLs are not only claimed to be significant energy users but global transportation and warehouses are also recognized contributors to the rise of greenhouse gas (GHG) emissions (IEA, 2023; Mangina et al., 2020). Additionally, value-added services offered by 3PLs encompass substantial consumption of packaging materials, water, and, in some instances, chemicals, increasingly raising sustainability concerns (García-Arca et al., 2017; Piecyk & Björklund, 2015). The limited availability of critical energy resources and the significant costs associated with environmental damage have led to ongoing debates about the negative impacts of logistics services in societal and business contexts. While regulations tighten and stakeholders increasingly demand proactive corporate social

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responsibility, adopting green innovations becomes a strategic priority for 3PLs (Evangelista et al., 2019; Premkumar et al., 2021).

Academic interest in green logistics has also increased significantly in recent years (Islam et al., 2021; Ren et al., 2019). Considerable research has focused on the initial development and classification of ecological practices from the perspective of 3PLs (Centobelli et al., 2017; Evangelista et al., 2018; Ren et al., 2019). Certain studies also highlight the multifaceted benefits of green innovations in the 3PL sector, such as operational cost savings and enhanced reputation (Evangelista et al., 2018; Noorliza, 2023). However, investigations usually do not distinguish between internal process changes and marketed new service offerings, limiting a comprehensive understanding of how 3PLs may strategically leverage green innovations to enhance their competitiveness. In response to the increased ecological consciousness of society and businesses, scholars call for an expanded research perspective that addresses the environmental strategy of 3PLs more interventively (Evangelista et al., 2019; Noorliza, 2023; Premkumar et al., 2021). This may involve a research approach focusing on practical interventions, such as case studies, to understand better the strategic implementation and impact of green innovations.

An expanded research perspective addressing the environmental strategy of 3PLs in an interventive way may also require the integrated and systematic examination of external determinants of the business environment influencing their green innovation behavior. Studies examining external drivers of green innovation adoption at 3PLs usually refer to the pressure exerted by different external stakeholder groups (e.g., Evangelista et al., 2018). However, the influence and role of specific external stakeholders, such as governmental bodies or associations, may depend on the specific country's context, while competitive pressure may be subject to the circumstances prevalent in the particular region and specific shipper segments (Abbasi & Nilsson, 2016; Bálint et al., 2021; Evangelista et al., 2018). The findings of empirical research, thus, are often contradictory. Moreover, less is known about the role of societal stakeholders, such as environmental groups or educational and research institutes, and the proactive strategic approach of 3PLs to anticipate and address such stakeholders' pressure (Creazza et al., 2024; Evangelista et al., 2019; Prataviera et al., 2024).

Similarly, characteristics of the business environment that inhibit challenges or facilitate the successful adoption of green innovations at 3PLs remain mostly unexplored. The few available empirical indications are highly fragmented in literature (e.g., Evangelista et al., 2018; Huge-Brodin et al., 2020; Yuen et al., 2019), meaning they are scattered across different studies. This fragmentation may arise because existing insights often emerge from descriptive analyses focusing on general drivers and barriers rather than systematically analyzing external contingency factors. However, understanding the dynamic market conditions that impact the adoption of green innovations is crucial for 3PLs to develop a comprehensive strategy that not only responds to immediate external pressures but also fosters long-term sustainability and competitiveness.

This study adopts an exploratory, multiple-case-based investigation approach to contribute to the body of knowledge by addressing the identified gaps in the literature. The research focuses on six 3PLs in Germany, chosen for their strategically proactive engagement in environmental sustainability. Data were collected through semi-structured interviews with key decision-makers and triangulated with additional company information. Germany was chosen for this study as the empirical context, a country widely neglected in 3PL-related research. Only a few studies have investigated German 3PLs' green innovation behavior and the prevailing business environment in-depth, while most results might be considered outdated (Evangelista et al., 2018; Islam et al., 2021; Ren et al., 2019). However, the German 3PL industry is considered one of the most technologically advanced in the world, with the highest yearly turnover in Europe and even further increases expected in the next few years (Schwemmer & Klaus, 2021). Moreover, in Germany, a high level of eco-consciousness is evident in widespread public awareness and commitment to comprehensive governmental policies (Bogner & Dahlke, 2022; Lo Storto & Evangelista, 2023), providing a rich ground for investigating 3PLs green innovation adoption.

This study initially employs the Natural Resource-based View (NRBV) (Hart, 1995; Hart & Dowell, 2011) to frame the analysis, thereby extending empirical research on the relationships between environmental management and 3PLs' competitiveness. Accordingly, the green innovations adopted by six German proactive 3PLs of various sizes are analyzed, and the reasons for their adoption are explored. Thereby, 'reasons' refer to the underlying rationales and motivations guiding the company's strategy and consequent actions to

attain its business objectives, anticipating the advantages of green innovations in enhancing competitiveness (Pålsson & Johansson, 2016). By further adopting the perspective of Stakeholder Theory (ST) (Freeman, 1984), which posits that organizations must consider the interests and influences of all their stakeholders to achieve long-term success, this study also explores how external stakeholders influence the selected 3PLs' green innovation behavior. Finally, the research acknowledges the relevance of specific characteristics of the general business environment, such as uncertainty, complexity and munificence. These dimensions are based on the Contingency Theory (CT), as outlined by Aragón-Correa and Sharma (2003). By aiming for a better understanding of the German 3PL industry's evolving landscape, this study identifies indications of such market-related contingencies affecting the adoption of green innovations at 3PLs.

Figure 1 illustrates the study's conceptual model, addressing the identified gaps within a scope carefully selected and underpinned by relevant management theories that guide systematic research. The findings indicate varied adoption levels of green innovations, with process innovations linked to cost savings, enhanced reputation and long-term energy independence, while large 3PLs increasingly pursue service innovations to differentiate their services in eco-aware market segments. The findings also highlight the importance of managing specific external stakeholder relationships and reveal critical challenges faced by German 3PLs, such as unpredictable technological developments and shifting governmental regulations. By cross-checking the findings with existing literature, this exploratory research develops a comprehensive framework that coherently structures the problem-situation and derives propositions for subsequent explanatory investigations. Overall, the research contributes to understanding how 3PLs may enhance their competitiveness by adopting various green innovations and how external stakeholders influence their innovation behavior while exploring factors related to contingencies in the 3PLs' business environment. It provides valuable insights for logistics practitioners, offering managerial recommendations to enhance environmental sustainability in 3PL firms.

The remainder of this article develops as follows. Section 2 conducts a comprehensive literature review and presents the emerging research questions. Section 3 introduces and justifies the adopted methodology. Section 4 presents the study's findings. In Section 5, the article discusses the empirical results and concludes in Section 6 with theoretical, managerial and research implications.

2. Literature review and research questions

2.1. Green logistics and green innovations at 3PL

Logistical activities harm the environment through resource consumption, emissions of harmful pollutants, effluents and waste. However, such environmental externalities cannot be entirely avoided, as

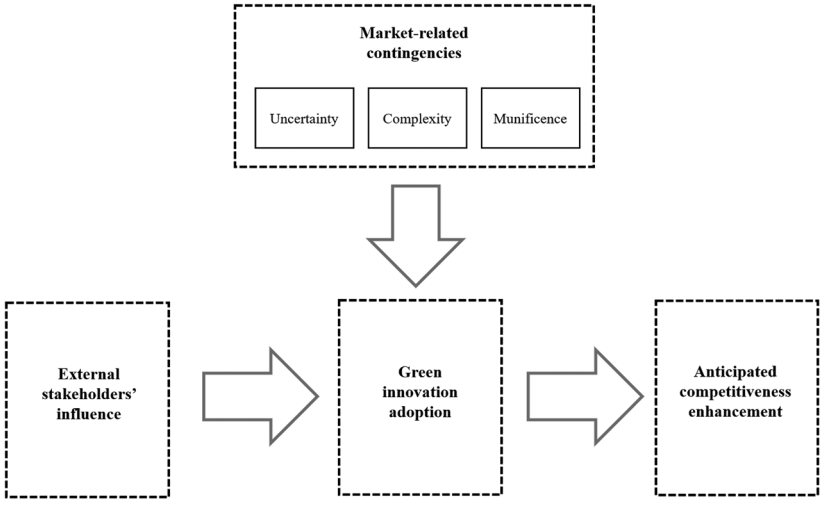

Figure 1. Conceptual model.
Source: Authors' elaboration based on Freeman (1984), Hart (1995), and Aragón-Correa and Sharma (2003).

resource consumption is necessary to perform logistics functions. This ecological impact necessitates *Green Logistics*, a systematic, continuous process reducing resource consumption and emissions within and across companies, prioritizing pollution prevention and resource stewardship over implementing end-of-pipe technologies (Deckert, 2018). Accordingly, in this study, green innovations of 3PLs are considered those surpassing legal regulations, actively reducing resource consumption, emissions, effluents and waste.

Green innovations of 3PLs are usually distinguished by whether they have a predominant effect within the company's boundaries or extend their impact to different supply chain stages (Evangelista, 2014; Evangelista et al., 2017). Green innovations internal to 3PLs are usually further categorized by their phase of service, namely, transportation, packaging and warehousing/buildings (El Baz & Laguir, 2017; Evangelista et al., 2017). However, this approach of categorizing is associated with disadvantages as it does not consider the possible relevance of the distinction between green innovations involving internal process changes and those marketed as new service offerings (Isaksson et al., 2017; Isaksson & Huge-Brodin, 2013). The literature also barely distinguishes green process innovations explicitly through the mechanisms that reduce and prevent the environmental externalities of logistics operations. Thus, this study employs the term '*green innovation*' to denote eco-innovation, embodying the development and commercialization of logistics innovations that deliver economic value while minimizing environmental externalities (Rossi et al., 2013). As such, this study applies a categorization scheme for green innovation that differentiates between green innovations into processes and services, which is underrepresented in existing studies.

Green process innovations, typically internal to the 3PLs, may relate to service phases like transportation, warehousing/buildings and packaging. However, the beneficial introduction of green process innovations may sometimes require cooperation with immediate value-creation partners, e.g. when process integration becomes necessary at enterprise interfaces (Rogerson & Sallnäs, 2017). The value added by green process innovations can be evaluated based on their contribution to reducing environmental impact and enhancing *resource efficiency* (Deckert, 2018). Resource efficiency, in this context, includes: (1) material efficiency that aims to reduce the use of raw materials while maintaining a current output, also comprising measures for the reuse and recovery of materials and the usage of secondary raw materials; (2) energy efficiency that aims to reduce energy usage while maintaining the existing performance; and (3) the sustainable use of natural resources, such as water, air, space and the increased use of renewable materials and energies (Deckert, 2018).

Meanwhile, *green service innovations* are new service provisions for shippers. They may combine different resources in a new way, leading to differentiated service offerings (Isaksson & Huge-Brodin, 2013). Green service offerings may incorporate various process innovations constituting an extended or completely new service bundle, the value-added provided of which may depend on how much it helps shippers achieve their sustainability goals (Isaksson et al., 2017; Sallnäs & Huge-Brodin, 2018). Green service innovations can either be standardized and thus easily scalable after their initial market introduction or shipper-tailored, requiring deep involvement in conceptualizing and innovation-specific investments from both sides (Isaksson et al., 2017; Jazairy et al., 2021).

Based on this background, the present research aims to answer the following first research question:

RQ1: What are the green innovations in processes and services adopted by 3PLs?

2.2. Reasons motivating 3PLs to adopt green innovations

Improving operational processes through environmental practices can decrease costs and boost a company's short-term profitability, creating cost advantages (Hart, 1995; Hart & Dowell, 2011). For logistics firms, cost reductions may result from various sources, such as decreased operational costs associated with fuel, electricity and packing materials, reduced fees and fines, lower compliance costs and fewer investments in end-of-pipe technologies (McKinnon et al., 2015). Accordingly, many empirical studies focusing on the motives of logistics firms to adopt green innovations often highlight the relevance of expected efficiency improvements and operational cost savings primarily, with little regard for the environmental perspective (Facanha & Horvath, 2005; Lun et al., 2015; Oberhofer & Dieplinger, 2014; Perotti

et al., 2012; Rossi et al., 2013; Tacken et al., 2014). This is reasonable, considering the logistics sector is typically characterized by intense competition and price sensitivity (Abbasi & Nilsson, 2016; Oberhofer & Dieplinger, 2014).

Even though cost savings and profitability are critical in investment decisions, some studies also highlight the increasing need for the 3PL's self-legitimation within its social environment (Baah et al., 2020; Karaman et al., 2020; Sureeyatanapas et al., 2018). Self-legitimation may be achieved by creating a positive environmental reputation, understood as the perception held by stakeholders regarding the 3PL's commitment to and performance in environmental sustainability (Pålsson & Johansson, 2016; Pålsson & Kovács, 2014). A credible reputation may attract environmentally conscious stakeholders. Given the high personnel intensity of the 3PL industry and the challenges related to an aging workforce and high personnel turnover (Kollmann et al., 2020; McKinnon et al., 2017; Miller et al., 2021), being perceived as a responsible employer may be crucial in the intensive competitive business environment of 3PLs. However, only a few studies provide a first indication that a credible green reputation enhances satisfaction and strengthens the commitment of current employees (Baah et al., 2020; Evangelista et al., 2017; Longoni et al., 2018). Moreover, rapid technological changes and the need for advanced consulting services increase the knowledge requirements for logistics companies' personnel (Klumpp, 2016). Given these circumstances, 3PLs may pursue a proactive environmental strategy to attract scarce and highly qualified personnel. In their laboratory experiments, Sohn et al. (2015) demonstrate that logistics firms can attract talented university graduates through corporate sustainability initiatives.

Case-based investigations highlight that shippers appreciate when 3PLs engage in environmental sustainability; however, they also confirm that shippers often are barely willing to pay higher prices or share investment costs (Abbasi & Nilsson, 2016; Evangelista et al., 2019). One reason for the contradictory attitude of shippers may be that logistics processes have a comparatively low environmental impact on the life cycle assessment of a product. In addition, when 3PLs serve shippers in the value chain at a greater distance from the end consumer, their environmental footprint usually remains unnoticed (Evangelista et al., 2017). However, this perspective falls short as outsourcing increasingly involves 3PLs in core value-creation processes, e.g. packaging design and subcontracting (Marchet et al., 2018). This involvement makes 3PLs significant in making shippers' supply chains more environmentally friendly. Engaging shippers in joint service development may result in the path-dependent development of individual relationships potentially representing precious and hard-to-copy resources (Bálint et al., 2021; Evangelista et al., 2019; Huge-Brodin et al., 2020; Sallnäs & Huge-Brodin, 2018). Thus, from the 3PL's point of view, pursuing a proactive environmental strategy may offer new business opportunities to increase market share and set up entry barriers.

Overall, research conducted from a 3PL's point of view predominately highlights the prospects of cost reduction and enhanced profitability as the primary motivations to adopt green innovations. A few studies also indicate that proactiveness may offer 3PLs opportunities to position themselves strategically as green, thus striving for a value advantage. However, the lack of studies offering in-depth examinations of the motives for introducing different types of green innovations is apparent. Given the evolving regulatory landscape and society's increasing emphasis on corporate social responsibility, it is crucial to understand how 3PLs can strategically leverage green innovations to enhance their competitiveness. However, since there might be differing rationales behind adopting different types of green innovations (Massaroni et al., 2016), the following research question arises:

RQ2: What are the reasons for 3PLs to adopt green innovations in processes and services?

2.3. External determinants of 3PLs business environment

Scholars recognize the relevance of the external environment in which firms operate. This study refers to the widely acknowledged external determinants of 3PLs' business environment influencing their green innovation behavior, namely the influence of external stakeholders and the less examined contingency role of market-related uncertainty, complexity, and munificence. The authors acknowledge that further critical external factors may exist; however, they fall outside this investigation's purview.

2.3.1. External stakeholders

According to the *Stakeholder Theory*, organizations are influenced by multiple stakeholder groups who can affect or are affected by the firm's objectives and actions (Freeman, 1984). Customers are usually regarded as influential external stakeholders exerting unique pressures on organizations steering their strategic decision-making processes. However, in 3PL-related research, the shipper's role (3PL's customer) is considered contradictory. Case-based research emphasizes the need for shippers' commitment to introducing green innovations. At the same time, 3PL informants often refer to a lack of interest and concrete requirements from shippers, thus barely experiencing pressure (e.g., Abbasi & Nilsson, 2016; Evangelista et al., 2017; Jazairy, 2020; Perotti et al., 2015). Large-scale studies yield mixed results. Some find that shippers' pressure exhibits no relevance for green innovation adoption among logistics firms (e.g., Ho et al., 2014; Ho & Lin, 2012), while more recent studies highlight shippers' environmental requirements driving logistics service providers' low-carbon innovations (e.g., Chu et al., 2018; Qian et al., 2019; Zailani et al., 2014). Other researchers point to the importance of the proactiveness of a 3PL and suggest that adopting a network approach by anticipating future pressure from the shipper's clients could provide a time advantage (Huge-Brodin et al., 2020; Sallnäs & Huge-Brodin, 2018). Finally, Qureshi et al. (2024) emphasize how 3PLs may proactively leverage industry 4.0 technologies for more sustainable practices, enhancing shippers' procurement intention.

Regarding the role of regulatory pressure, large-scale studies also provide mixed results. Certain emphasize the strong influence of regulatory entities (e.g., Baah et al., 2020; Ho et al., 2014; Ho & Lin, 2012; Maas et al., 2018), while others find that regulatory pressure has no significant driving effects on 3PLs' innovation adoption (e.g., Chu et al., 2018; Zhang et al., 2020). Similarly, some case-based investigations highlight that regulatory bodies are the only group truly impacting 3PL's green innovation behavior (e.g. Tacken et al., 2014), while others emphasize that regulatory pressure does not seem prevalent in steering 3PLs' greening decisions (Jazairy & von Haartman, 2020, 2021). Moreover, Chu et al. (2018) highlight that competitive pressure, mainly arising from a 3PL's perceived success of its competitors' strategies and actions, is also positively related to green innovation adoption. Maas et al. (2018) additionally point to social pressure from the general public, industry associations, and environmental groups significantly affecting the adoption of green innovations among 3PLs.

In summary, existing literature highlights external stakeholders as influential exogenous determinants of 3PLs' green innovation behavior. Nevertheless, contradicting views indicate an ongoing debate, suggesting that more comprehensive research is needed. This need also arises from the limited understanding of the influence of various external stakeholder groups on 3PLs' green innovation behavior (e.g., Creazza et al., 2024; Maas et al., 2018; Prataviera et al., 2024). To address this gap in the literature, the following third research question is posed:

RQ3: How do external stakeholders influence 3PLs' green innovation behavior?

2.3.2. The contingency role of uncertainty, complexity, and munificence

Uncertainty refers to the degree of unpredictability in the business environment, representing a significant external factor shaping a firm's strategic planning and decision-making. In the context of 3PLs, uncertainty may arise, for instance, from volatile shifts in shippers' preferences, new logistics modes, erratic competitor behaviors, regulatory changes or technology advancements (Huo et al., 2018). Theory suggests that firms gather and process information proactively when facing uncertain market conditions to secure a strategic advantage via technological innovation (Damanpour & Gopalakrishnan, 2001). Certain studies confirm this view, highlighting that perceived uncertainty can prompt green innovation in 3PLs (Lin & Ho, 2008; Zailani et al., 2014). In contrast, others find a negative link between perceived uncertainty and adopting green practices, emphasizing 3PLs' hesitance to invest in green innovations (Lin & Ho, 2011) or find no effect on 3PLs' approach to environmental innovations (Ho et al., 2014; Ho & Lin, 2012). Adding complexity, Abbasi and Nilsson (2016) underline the adverse effects of technological and legislative uncertainties, positing that they push 3PLs to a more reactive stance given the unpredictability of investment returns. Meanwhile, Chu et al. (2018) observe that market uncertainty weakens shippers' influence on green innovation in 3PLs but strengthens green innovations' positive impact on 3PLs' financial performance.

Complexity in a market context refers to the number and diversity of factors a company must consider in its external environment. It may stem from the proliferation of stakeholders and their concerns and needs to navigate and address multiple, often conflicting, interests in the business environment. It may also stem from multifaceted regulatory frameworks and intricate supply chains (Aragón-Correa & Sharma, 2003). Managers who perceive a complex business environment have difficulty making far-reaching decisions and implementing significant organizational changes (Vasconcelos & Ramirez, 2011). A complex market environment requires extensive effort and resources to integrate green innovations effectively, potentially deterring a firm from extensive adoption (Aragón-Correa & Sharma, 2003). Implementing green innovations at a 3PL requires the integration of different stakeholder perspectives and significant organizational changes through restructuring processes and responsibilities and often involves high investments in clean technology (Abbasi & Nilsson, 2016; Evangelista et al., 2017). However, only a few studies spotlight the various external stakeholder perspectives that 3PLs must manage. They resonate in the ongoing scientific and political debates on environmental concerns, differing methods used for GHG emissions accounting depending on the mode of transport, rapid technological development and ever-evolving regulatory frameworks (Abbasi & Nilsson, 2016; Björklund & Forslund, 2019; Evangelista et al., 2017, 2019). Moreover, demands from different industries and fragmented logistics markets may also increase complexity in 3PLs' business environment (Abbasi & Nilsson, 2016).

Munificence generally refers to the degree of available resources and opportunities in a company's business environment that can support continuous growth, provide slack resources and help firms invest and innovate. In a resource-rich business environment with ample opportunities, firms might find it easier to invest in and benefit from green innovations (Aragón-Correa & Sharma, 2003; Shepherd et al., 2013). Conversely, in a hostile environment where resources and opportunities are scarce, firms may prioritize immediate operational needs over adopting new and potentially risky green innovations. In the natural-business context, indications of munificence may include the availability of specialized suppliers and workforce, bank financing with lower rates for environmentally friendly technology, lower insurance premiums for lower environmental risks, access to new clean technologies and solvent customers willing to pay for green products and services (Aragón-Correa & Sharma, 2003; Martinez-del-Rio et al., 2015). Furthermore, the government can increase munificence, e.g. through tax incentives, subsidies and technical assistance (Singh et al., 2016).

Although research has explored indications of munificence in various business sectors, studies related to 3PLs have not sufficiently focused on the specific factors contributing to the munificence level. Large-scale studies are limited to examining the relevance and level of governmental support, delivering contradictory results (Ho et al., 2014; Ho & Lin, 2012; Lin & Ho, 2011; Zailani et al., 2014). More recent case-based investigations indicate a rather hostile environment for 3PLs, with an apparent lack of financial resources and funding possibilities. These studies also identify limited access to green technologies and shippers' disinterest in paying higher rates or share investment costs (Abbasi & Nilsson, 2016; Creazza et al., 2024; Evangelista et al., 2017, 2019; Zailani et al., 2014).

Overall, the existing literature does not sufficiently address market-related contingencies in the natural-business environment of 3PLs. However, a thorough understanding of these contingencies is crucial to grasp their impact on adopting green innovations. Current discussions are limited and sometimes present contradictory findings, possibly because most studies focus primarily on larger 3PLs (Creazza et al., 2024). Against this backdrop, the following fourth research question emerges:

> RQ4: What are the factors of uncertainty, complexity, and munificence in the 3PLs' business environment influencing the adoption of green innovations?

3. Methodology

3.1. General research approach

Literature indicates the need to investigate 3PLs' multifaceted reasons for adopting green innovations in processes and services. It also highlights the contradictory role of different external stakeholder groups and provides fragmented information concerning market-related contingency factors. Accordingly, this

study aims to structure the incoherent problem-situation within the domain of green innovations at 3PLs. Empirical support is provided through an exploratory multiple-case study research approach, which facilitates understanding such complex phenomena within real-life contexts (Aastrup & Halldórsson, 2008). Such an approach allows for exploring green innovation adoption in 3PL companies of different sizes in different segments of specialization and capturing a broad range of experiences transmitted by carefully chosen representative decision-makers.

How managers and employees perceive environmental issues mainly determines whether a firm characterizes its interaction with the natural environment as an opportunity or a threat (Hart & Dowell, 2011; Tenbrunsel et al., 2000). Accordingly, this study is primarily informed by the views and experiences of key decision-makers in introducing green innovations, thereby using qualitative data and maintaining an interpretative philosophical stance. A comprehensive understanding is achieved by triangulating interviewees' views with information from other sources, such as internal documentation, CSR reports, press releases or conference presentations and podcasts, enhancing the depth and credibility of the findings (Saunders et al., 2015).

The literature review conducted for this study identified key knowledge areas relevant to green innovations in 3PLs, guided by the NRBV, ST and CT. These theories inform the development of the interview questions and the subsequent qualitative data analysis. Using Template Analysis (King & Brooks, 2017), the interview data were coded, recurring themes were identified, and propositions were developed. This iterative process involved refining the conceptual model based on the empirical findings, ensuring the approach was theoretically grounded and empirically supported.

The qualitative data collected in this empirical study are crucial in cross-checking the factors identified in the literature while uncovering new, context-specific aspects. Such an adjusted form of eventual literal replication is suitable for improving the robustness of exploratory research as it concerns internal validity (Yin, 2018). Thus, both the research's relevance and the model's strength are improved by incorporating further practical insights into the development of its elements and relationships. Further empirical validation and testing of the model will require collecting data from another set of cases or conducting surveys in future explanatory research.

3.2. Research setting and case selection

This research was conducted in the German 3PL industry, acknowledged as the largest in the European Union (Schwemmer & Klaus, 2021), offering a vast spectrum for examining diverse business practices. 3PLs business environment in Germany inhibits challenges, such as intense price competition, rapid technological developments and acute personnel shortage and fluctuation (Schwemmer et al., 2020; Sucky & Asdecker, 2019). However, Germany's societal emphasis on environmental protection provides a rich ground for investigating the reasons motivating 3PLs to adopt green innovation (Deckert et al., 2021). The diverse and often highly specialized nature of German 3PLs (Schwemmer et al., 2020) also presents an ideal opportunity for scrutinizing various market-related factors, some of which may be sector-specific. Moreover, the predominance of small- to mid-sized 3PLs in Germany (Schwemmer et al., 2020) accentuates the need to understand their motivations for and perceived market-related barriers in green innovation adoption, contributing to a less-explored literature area (Creazza et al., 2024).

This exploratory study aims to provide a richer understanding of the context in which German 3PLs adopt green innovations. Hence, six environmentally proactive 3PLs were approached, representing a recommended number of cases in multiple-case study analysis in logistics research (Aastrup & Halldórsson, 2008). All purposefully selected case companies strategically engage in environmental sustainability mirrored in their public company statements, such as actively communicating green innovations and engaging external stakeholders (Delmas et al., 2011). A range of experiences is ensured by considering companies of diverse sizes, offering different geographical coverages, providing various services and operating in multiple market segments. Detailed profiles of the selected case companies are presented in Table 1.

Table 1. Profile of the case companies.

Case company	Size (no. employees, annual turnover in MEUR)	Ownership	Assets specificity	Geographical area served	Specialized shipper segments	Environmental strategy	Responsibility for sustainability	Applied standards/ ratings
Alpha	Large >10.000, >1.000	Listed	Mainly outsourced	Worldwide	Aerospace, automotive, consumer goods, healthcare, high-tech, chemicals	Explicit: aiming at CO_2 neutrality	Site, business unit, and corporate level	ISO9001, 14001, 50001 EN16258 GLEC LEED SQAS CDP EcoVadis
Beta	Large >10.000, >1.000	Privately owned	Mainly company owned	Worldwide	Automotive, chemical, cosmetics, DIY, fashion, life science, healthcare	Explicit: aiming at CO_2 neutrality	Site and corporate level	ISO9001, 14001, 14083, 50001 EN16258 SQAS CDP EcoVadis
Gamma	Large >10.000, >1.000	Privately owned	Mainly company owned	Worldwide	Automotive, retail, home delivery, life science, healthcare, large-scale industrial equipment, commodities	Explicit: aiming to minimize operations' externalities	Site, business unit, and corporate level	ISO9001, 14001, 50001, 14064 (ongoing implementation), 14083 EN16258 SQAS EcoVadis
Delta	Mid-sized 700–800, 100–150	Foundation	Entirely in company's possession	Central and Western Europe	Automotive, food, pharmaceuticals, paper products, small and spare parts	Explicit: aiming to minimize operations' externalities	Corporate level	ISO9001, 14001 SQAS GDP
Epsilon	Mid-sized 200–300, 50–100	Privately owned	Entirely in company's possession	Western Europe	Buildings, construction, furniture, food, commodities, private goods, relocation	Implicit: aiming to minimize operations' externalities	Corporate level	ISO9001, 14001 EN16258
Zeta	Small <50, <10	Privately owned	Entirely in company's possession	Western Europe	Heavy and large-scale devices and equipment in health care, biotechnology laboratories, and banking	Implicit: aiming to minimize operations' externalities	Not explicitly defined	ISO9001

3.3. Data collection and analysis

The primary dataset comprises semi-structured interviews (Saunders et al., 2015) conducted via video telephony. The selection of the interviewees was based on their formal qualifications, such as an academic degree and training in sustainability, extensive experience as logistics experts and their ability to position the problem-situation in the organizational context, both internal and external. Thus, the selected interviewees have worked at case companies for more than 5 years, thereby being directly involved in initiating and implementing green innovations. All these criteria ensure that the insights gathered are grounded in practical experience and in-depth knowledge of the subject matter. The profiles of the interviewees and an overview of the secondary data sources are presented in Table 2.

Interviewees were provided details about the research project 2 weeks before the interviews to familiarize themselves with the subject and leading questions. Written informed consent was obtained from all interviewees, ensuring that all participants were fully informed about the nature of the research, their rights as participants and the use of their data. The interviews typically lasted 50–60 min, were transcribed verbatim, and provided to the interviewees for final confirmation. The interview protocol (Supplementary Appendix 1) included open-ended questions with probes and prompts used as necessary (Saunders et al., 2015).

Template Analysis processed the qualitative data obtained for this study. Template Analysis is a generic, flexible approach that evolved from the thematic analysis tradition, aiming to classify data into a hierarchical *template* with broad, higher-level themes (King & Brooks, 2017). Its analytical strategy's strong emphasis on research in real-world settings corresponds to this study's exploratory multiple case-study research approach using qualitative data and adopting an interpretative philosophical stance (Saunders et al., 2015). King and Brooks (2017, pp. 25–39) propose an analysis procedure to conduct Template Analysis, which was followed in this study. The procedure involves first familiarizing oneself with the data and then processing it through an iterative process by which data is initially coded, then clustered and organized into analytical themes. The final template then enables systematic comparison across cases, examining patterns of themes in the data.

Using Template Analysis in this study provides several advantages compared to Thematic Analysis (e.g. Braun & Clarke, 2006). Given the theoretical foundations of this study, it allows for incorporating *a priori* themes derived from the literature in coding to develop an initial template, thereby ensuring that data analysis remains anchored in the considered theoretical constructs. The subsequent iterative refinement process allows for continuous adjustment of the coding template as new data insights emerge, ensuring the analysis is both data-driven and theoretically informed (Kings and Brooks, 2017). Moreover, the template's hierarchical nature facilitates the organization of complex data obtained into broad themes and

Table 2. Profile of the interviewees and secondary data sources.

Case company	Interviewees		Secondary data used
Alpha	*Interviewee 1 (male, 57 years)* Manager multi-user warehousing 30 years of work experience; over 18 years in the current position	*Interviewee 2 (male, 64 years)* Corporate R&D Manager 40 years of work experience, over 6 years in the current position	CSR report, code of conduct, company website, and press releases
Beta	*Interviewee 3 (male, 48 years)* Corporate R&D Manager 24 years of work experience, over six years in the current position	*Interviewee 4 (male, 54 years)* Site and project manager 28 years of work experience, over 14 years in the current position	Internal documentation of green innovations, company website, and press releases
Gamma	*Interviewee 5 (female, 36 years)* Corporate Project Manager 10 years of work experience, over six years in the current position	*Interviewee 6 (male, 58 years)* Managing Director 34 years of work experience, over 18 years in the current position	Internal documentation of green innovations, conference presentations, podcasts, company website, and press releases
Delta	*Interviewee 7 (male, 42 years)* Chief Operating Officer 18 years of work experience, over 5 years in the current position	*Interviewee 8 (male, 46 years)* Chief Technology Officer 20 years of work experience, over 10 years in the current position	Internal sustainability report and documentation, company website, press releases
Epsilon	*Interviewee 9 (male, 38 years)* Managing Director and R&D Manager 16 years of work experience, over 6 years in the current position		Internal documentation of projects, company website, and press releases
Zeta	*Interviewee 10 (male, 56 years)* Chief Executive Officer and R&D Manager 32 years of work experience, over 6 years in the current position		Internal presentation of the company, conference presentation, company website, press releases

Table 3. Summary of quality measures taken to ensure research rigor through *trustworthiness*.

Category	Purpose	Measures taken
Confirmability	Ensuring the integrity of the results based on the data collected and analyzed	Data was collected from expert respondents who, as decision-makers, have direct project responsibility and influence in the planning and implementation of green innovation. Two researchers were employed to confirm the accuracy and reliability of the interpretations that underpinned the propositions. Discussing the research findings with other researchers who are not involved in the study, providing external perspectives, and helping identify any biases or assumptions that may have influenced the results.
Credibility	Ensuring a *match* between the constructed realities of respondents with researchers' representation	Free discussion with interviewees at the end to clarify vague and indistinct answers noticed by the researcher during the interview. Transcriptions were provided to the interviewees for confirmation. Multiple data sources were used to confirm emergent findings.
Dependability	Trackable variance and transparency	Systematic, iterative coding procedure. MAXQDA20 software was used for coding. Interview quotations are provided.
Transferability	Context of scope in which findings might be generalizable	Multiple case study approach. Adequate contextualization of the study. Purposeful selection of six environmentally proactive 3PL companies.

specific sub-themes, providing a nuanced understanding of the motivations and external influences on green innovation adoption at German 3PLs. The final data structure is presented in Supplementary Appendix 2. Data interpretation comprised two phases. First, an in-case analysis depicts each company's green innovations, perceived external stakeholders' influences on adopting green innovations, and market-related contingency factors. Second, a cross-case analysis synthesized inter-case similarities and differences.

Lincoln and Guba (1985) proposed four criteria to assess the *trustworthiness* of qualitative research, which were addressed following the guidelines of Halldórsson and Aastrup (2003), as summarized in Table 3. Regarding confirmability, data was collected from relevant respondents, and two independent researchers confirmed the accuracy and reliability of the interpretations underpinning the propositions and findings, which were further discussed with other researchers to minimize potential bias. Credibility was ensured by eliminating vague answers and ensuring a match between the constructed reality and its representation through feedback from interviewees and using multiple data sources. Dependability was addressed by tracking variance and maintaining transparency through the tools used. Transferability was ensured by purposefully choosing cases of environmentally proactive 3PL companies to contextualize the study, enabling a scope for future analytical generalization.

Finally, this study was approved (No. 49/2021) by the Ethics Council of Instituto Universitário de Lisboa (ISCTE-IUL) and conducted according to the Codes of Ethical Conduct in Research at ISCTE-IUL and Technische Hochschule Mittelhessen (THM).

4. Empirical findings

4.1. Green process innovations and reasons for adoption

A comprehensive review of the case companies' actions and responses was conducted, targeting the identification of green process innovations and the motivations behind German 3PLs adopting a specific set of innovations. Table 4 outlines the ongoing, planned and completed green process innovation projects among the case companies; the majority adopted to increase energy and material efficiency.

Case companies prioritize innovations that allow for efficient vehicle utilization, significant energy savings in facilities, reduced packaging material usage and handling waste. Despite the resulting reduction in externalities, the motivation for these process innovations is predominantly their potential for immediate cost savings rather than environmental concerns. Interviewees underscore the importance of transparent and realistic investment calculations with a comparatively short payback as a prerequisite for gaining critical internal stakeholders' commitment. Interviewee 5 illustrates this with an example of the firm's conversion of warehouse lighting to sensor-controlled LED technology:

Table 4. Overview of the introduced and planned green process innovations for resource efficiency.

Category	Subcategory	Innovation	Alpha	Beta	Gamma	Delta	Epsilon	Zeta
Energy Efficiency	*Vehicle utilization*	Eco-driving training programs for truck drivers	●	●	●	●	●	●
		Routing system to minimize travel distance	●	●	●	●	●	●
		Aerodynamic measures for vehicles	●	●	●	●	●	●
		Introduction of the newest low-emission diesel vehicles	●	●	●	●	◑	◑
		GPS-supported, advanced transportation planning/fleet management system for effective shipment consolidation	●	●	●	◑	◑	/.
		Shifting freight from road to rail or water	●	●	●	●	/.	/.
		Monitoring driving behavior and analyzing driver fuel efficiency performance, enabling individual coaching	●	◑	◑	/.	/.	●
		Roll-optimized tires	/.	●	/.	●	/.	/.
		Mega trailer and jumbo swap bodies	/.	●	/.	/.	●	/.
		Double-deck loading	/.	◑	◑	/.	●	/.
		Long trucks (Gigaliner) in cross-border shuttle traffic	◑	●	/.	/.	/.	/.
		Containers for office documents reporting filling level via special sensors so that the number of tours can be reduced	/.	/.	●	/.	/.	/.
	Building structure	Insulation of facades/roofs of warehouses	/.	●	●	●	/.	/.
		Greening the roofs of warehouses	/.	/.	●	●	/.	/.
		High-speed automated doors at the ramps	/.	●	●	/.	/.	/.
		Polycarbonate windows with thermal insulation	/.	/.	◑	/.	/.	/.
	Illumination	Interior lighting systems with sensor-controlled LED lighting	◑	●	●	●	◑	◑
		Sensor-controlled LED lighting system for the exterior areas	◑	◑	●	●	/.	/.
	Heating, ventilation, and air conditioning	Heat recovery of ventilation/refrigeration	/.	●	/.	/.	/.	/.
		Optimized switch-on/-off schedules, adapting room temperature to the climate conditions	/.	/.	●	/.	/.	/.
		Energy-efficient gas heating system	/.	/.	/.	/.	/.	●
	Material handling	Forklift trucks equipped with lithium-ion batteries	●	●	/.	/.	/.	/.
		Optimized charging cycles for electric forklifts	/.	/.	●	/.	/.	/.
Material Efficiency	*Reusing packaging material*	Packaging systems to reduce packaging material	●	●	●	/.	/.	/.
		Company-wide pooling of reusable material	●	●	/.	/.	/.	/.
		Open exchange pool for reusable packaging material	/.	●	/.	/.	/.	/.
		Eco-friendly small load carriers and pallets pooling	●	/.	/.	/.	●	/.
	Waste handling/ recycling	Company-specific waste collecting and sorting system	●	●	●	●	●	◑
		Packaging remnants are pressed to stowage cushions and reused in load securing.	/.	●	/.	/.	/.	/.
		Cardboard runners are made from recycled material for handling ULDs in air cargo.	/.	/.	●	/.	/.	/.
		Reverse logistics (waste transport and disposal)	●	/.	●	/.	●	●
Sustainable use of natural resources	*Renewable energy sources' integration*	Photovoltaic systems integrated into the site-based charging infrastructure for electric trucks.	◑	◑	◑	○	○	○
		Photovoltaic systems providing energy supply at high-bay and temperature-controlled warehouses	/.	/.	◑	●	/.	/.
		Photovoltaic systems for site-based water heating	●	●	●	○	○	○
		Replacement of gas heating systems with solar-powered heat pumps at selected sites	/.	/.	●	/.	/.	/.
		Integrating warehouses into regional geothermal power plants for heat supply and feedback of surplus energy	/.	●	/.	/.	/.	/.
	Deployment of alternative fuel and propulsion systems	Regular use of biodiesel in road transportation	●	●	●	●	●	●
		HVO renewable diesel in cross-border shuttle operations	/.	●	/.	/.	/.	/.
		Pilot deployment of Bio LNG/CNG-powered trucks	●	●	●	○	/.	/.
		Pilot deployment of hydrogen fuel cell trucks powered by green (Co2 neutral) hydrogen	/.	◑	◑	○	/.	○
	Rainwater recovery/ management	Rooftop rainwater collection system – water used for landscape irrigation, green roofs or cleaning purposes or toilet flush system	●	●	●	●	●	●
	Reducing the harmfulness of packaging material	Environmentally friendly filling material (e.g. foil padding made of recycled plastic)	●	/.	●	/.	/.	/.
		Cartonnage made of grass fibers and fibers from waste.	●	/.	●	/.	/.	/.
		Replacement of plastic packaging material with paper-based or compostable/biodegradable materials	●	●	/.	/.	/.	/.
	Preservation of local biodiversity	Demarcation of green areas for wild meadows and colonization of bees	●	●	●	●	/.	/.
		Tree planting on the ground of the company.	●	●	●	●	○	○
		Landscaping of green areas at new sites under the supervision of ecologists	/.	/.	●	/.	/.	/.

Current state: ● = implemented; ◑ = ongoing implementation; ○ = implementation planned; /. = Not planned or perceived as irrelevant.

> …e.g., at the switching to LED, we also have a warehouse example that pays for itself after just half a year… the decision is usually not just that it is supposed to be more sustainable, but it also saves us costs. That is one main critical factor for all parties involved.

Nevertheless, the data also reveal the case companies' dedication to the sustainable use of natural resources through measures offering ecological and long-term economic advantages. For instance, rainwater collection systems are adopted across the studied companies, with the harvested water used for diverse applications such as landscape irrigation, watering warehouse green roofs and cleaning. While this measure promotes the careful use of water as a natural resource, it also offers financial benefits due to reduced urban water consumption charges. Beta, Gamma and Delta have also enhanced the insulation of older warehouses using non-combustible mineral-based materials. Despite the higher initial costs of such materials, these companies foresee substantial savings due to ever-increasing electricity supply costs and the significantly lower disposal costs upon the end of the insulation material's life cycle. Similar logic applies to the installation of green roofs, as Interviewee 8 indicates:

> …it is not only for the bees. If I choose the right green roof, I need much less energy, especially for a cold warehouse… If I had calculated this ten years ago, I would have had to operate it for almost 40 years…however, it will be much shorter due to constantly rising electricity supply costs…

A dominant reason for considering deploying renewable energy sources appears to lie in companies' ambition to become as independent as possible from external energy suppliers, circumventing escalating long-term energy costs. Accordingly, all are exploring photovoltaic systems, with plans to incorporate the generated power into their local operations, such as cooling warehouses, heating water, powering electric forklift charging stations or illuminating facilities. However, the strategic selection of warehouse locations allows for the efficient integration of supplementary renewable energy sources, such as geothermal and wind energy (Beta and Gamma), accelerating the transition toward external supply independence, as Interviewee 5 emphasizes:

> …we must be as self-sufficient as possible; as far as possible, no longer dependent on external cost drivers… for this, we must use all the options available, which often depend on the particular geographical location.

Data also reveal that large case companies' desire for self-legitimation, achieved through aligning with broader societal expectations, motivates them to consider specific green process innovations that are not inherently tied to efficiency gains. Consequently, Alpha, Beta and Gamma implement test-wise vehicles with alternative propulsion technology, adopt eco-friendly filling and packaging material, and maintain local biodiversity on the company premises and the immediate surroundings. By systematically communicating undertaken measures in media, these companies strive to be perceived as environmentally conscious, pursuing multiple strategic objectives. First, companies appear to be well aware of the media ramifications of their innovations, experiencing increased shipper interest and collaborative inquiries, as Interviewee 6 describes accurately:

> The more our projects have been spread in the media, the more frequent customer inquiries occur. They do not ask how much it will cost, but seriously, can we make the logistics and supply chains CO_2-neutral? And then I say: no, at least not yet, but let us discuss possibilities for reducing together. That is how we get into conversations with customers.

Second, all Alpha, Beta and Gamma interviewees emphasize the binding effect on current employees' commitment and motivation. However, Interviewee 5 (Gamma) additionally emphasizes a positive impact on their appeal to prospective young talents, crucial in times of acute shortage of highly skilled workforce in logistics:

> Young people are increasingly paying attention to the fact that their employer has a particular image and is active in this area. We, as a logistics company, must commit ourselves to the issue of sustainability. Otherwise, we will have problems attracting young, highly skilled people.

4.2. Green service innovations and 3PLs' motivation for adoption

Analysis reveals that case companies' development and provision of green services vary based on size. Delta, Epsilon and Zeta exhibit minimal uptake of green services. In contrast, Alpha, Beta and Gamma appear keen to develop scalable, standard green service offerings. Table 5 presents the supplementary services these large companies have integrated, addressing predominantly transportation-linked processes. These services enable shippers to prioritize emission mitigation over speed, flexibility and reliability by shifting transport from road to rail and employing eco-friendly fuels in maritime and air transport. However, Alpha, Beta and Gamma also incorporate externally certified systems for emission calculation and reporting, illuminating potential carbon savings for shippers and offering possibilities to offset their shipments' remaining direct CO_2 emissions.

Implementing these transportation-linked service innovations necessitates cooperation with specialized technology suppliers, freight operators and research institutions, representing substantive financial commitments without immediate tangible returns. Therefore, the motivation of these three companies appears twofold. First, they actively advertise their additional services to reinforce the companies' green image in society, making the emphasis on emission mitigation and offsetting palpable, which is very much in line with current social debates in Germany. Second, companies aim to differentiate their standard offerings to cater to the potential evolving needs of shippers, expecting increased sales volume in standardized transport services. Accordingly, most interviewees confirm that the ability of a 3PL to measure and report CO_2 emissions currently represents an advantage in the context of tenders. In the long term, however, all also assume these capabilities will no longer represent a differentiating feature, as they can be easily imitated due to the standardized procedures in freight transport.

The Beta case additionally demonstrates how a 3PL's new ability to calculate and report CO_2 emissions in road transportation can also be leveraged to facilitate enhanced collaborations with some of its eco-conscious shippers and spawn operational efficiencies. Two of the company's shippers recently introduced double-deck loading for their less-than-truckload shipments. Switching to double-deck loading increases the loading factor of Beta's semi-trailers, emphasizing volume utilization over weight, a recurrent challenge in the general cargo segment. However, loading double-deck requires additional effort from these shippers, which Beta rewards through free emission data reports. Interviewee 4 emphasizes the benefits of such cooperation for both sides:

> …two customers have been willing to load our units, which we collect in the double deck. So they use double-deck technology, meaning we only have to put about two-thirds of the vehicles on the road…this is positive for both sides. We save costs, and the customers improve their ecological footprint and advertise that with our data.

Table 5. Overview of the introduced and planned green services.

Innovation	Alpha	Beta	Gamma	Delta	Epsilon	Zeta
Shifting transport from road to rail and employing eco-friendly fuel in maritime and air transport	●	●	●	/.	/.	/.
Consultancy services for developing multi-modal, environmentally friendly transport chains tailored to individual shippers' needs and incorporating low-emission technologies.	●	◑	●	/.	/.	/.
Certified web-based carbon calculation services for road haulage on a shipment and shipper basis, including optional reporting	●	●	●	○	○	○
Certified web-based carbon calculation services for alternative sea container transport routes, including all pre- and onward carriage, allowing shippers to reduce their environmental impact on a shipment basis.	●	●	●	/.	/.	/.
Certified web-based carbon calculation services for airfreight shipments enable shippers to choose the most efficient aircraft type for selected routes to reduce CO_2 emissions of particularly time-critical goods.	/.	/.	●	/.	/.	/.
CO_2-neutral inner-city last-mile delivery services in selected cities.	◑	●	◑	/.	/.	/.
Contract logistics services are offered at selected warehouses with a CO_2-neutral footprint.	◑	◑	◑	/.	/.	/.
Certified carbon offsetting services for individual shipments	●	●	●	/.	/.	/.
Consultancy services for designing individual but sustainable product packaging, including conception and physical implementation.	●	◑	●	○	/.	/.

Current state: ● = implemented; v = ongoing implementation; ○ = implementation planned; /. = Not planned or perceived as irrelevant.

Beta also introduces CO_2-neutral last-mile distribution services in large cities in a standardized form. It conducts individual deliveries through small electric trucks from its local distribution centers and partners with local micro-depot operators employing emission-free vehicles, such as electric cargo bikes. Beta's aim in this initiative is not immediate profitability but strategically positioning itself in a nascent logistics niche shaped by evolving legal regulations and societal needs, as highlighted by Interviewee 4:

> …from a purely economic point of view, there are much better solutions, but it is simply necessary for city development to break fresh ground and set impulses. This area of service will continue to develop significantly. The structures and expectations within the big cities are changing, and we must consider this.

Anticipating a future where various propulsion systems cater to distinct operational requirements, Beta and Gamma discern an emergent demand for consultancy services, advocating that 3PLs, with their direct experience, are best prepared to offer the best guidance to prospective shippers. The companies' pioneering work allows them to pre-empt potential pitfalls and prepare for specialized shipper queries. The accumulated technical know-how and practical experience become invaluable assets and may offer a time advantage, as Interviewee 6 indicates:

> We are not doing this entirely altruistically…We want to know which mistakes we should not make next time; we want to have already made them. We also want to have tried out what works where… we want the experience needed and technical knowledge available when the customer has specific requests and needs good advice.

Alpha and Gamma are also concerned with systematically deepening individual shippers' relationships by advising them to develop customized packaging services. Such cooperation includes shipper-specific on-demand packaging systems that customize the packaging size to the content, saving packaging and filling materials and ensuring enhanced loading efficiencies. Gamma's collaboration with a particular shipper over several years has developed a sustainable packaging strategy, systematically integrating recycled and bio-degradable material to establish long-term contracts. Interviewee 5 emphasizes the impact of customized green service innovations on shipper retention:

> We have worked with this customer for many years. The customer now bears additional costs partially because they explicitly want it. And, of course, the contracts are longer-term because this is a different kind of cooperation. For example, in the warehousing area, the contracts for this client are significantly longer-term than the market standard, just as we are developing an entire sustainable packaging strategy over the years…

4.3. The influence of external stakeholders

4.3.1. Political entities

The environmentally proactive stances adopted by the examined 3PL companies appear significantly shaped by pressures from regulatory actors at various levels. Ongoing and anticipated changes in regulatory frameworks, such as tax increases on fuel and electricity and stipulated recycling quotas, are confirmed as catalysts for green process innovations to enhance material and energy efficiency. On this note, Interviewee 7 explicitly highlights the potential implications of rising diesel fuel taxes, emphasizing their ability to make vehicles with alternative propulsion systems more economically viable:

> When I consider that the political plans for taxation and the diesel price in the next few years are such that it is going to go insanely upwards, then, of course, it is more and more a business case for alternative technologies, and that is why we are also under pressure to find a proper solution.

Regulatory pressures also guide companies toward incorporating renewable energy sources into the companies' core operations. The rising costs of energy supplies, driven by taxation and diminishing refunds for local electricity grid contribution, are recalibrating investment considerations, pushing 3PLs additionally to deploy renewable energy sources for onsite consumption. Interviewee 8 underscores the expected long-term economic benefits of this transition:

> …investment in a photovoltaic system should not be considered from the immediate return point of view. Our concern must be to cover our consumption…as the feed-in compensation is falling every year and…will

> probably be phased out entirely. However, when buying electricity on the free market, electricity is likely to become continuously more expensive in the future.

Moreover, all interviewees highlight evolving national political proposals, notably potential urban congestion charges and bans on diesel vehicles, as significant drivers for adopting alternative propulsion systems. Finally, the smaller 3PLs Delta and Epsilon additionally emphasize the European Parliament's motions to mandate banks to consider the environmental track record of loan applicants, as they often rely on bank loans for their investments.

In addition to concrete legislative measures and political discourses, governmental bodies influence 3PLs through clean technology and sustainability programs on different levels. For instance, federal governmental institutions recently approached Beta and Gamma to join field trial projects of pure electric and hybrid trucks. Similarly, Delta received invitations from regional governmental bodies to join sustainable development projects on a regional basis. According to the interviewees, such programs may be coupled with financial incentives and publicity opportunities; however, they also offer possibilities for exploring and understanding emerging clean technologies and influencing eventual future regulations, as Interviewee 6 illustrates:

> …and a working group (with German national authorities) has indeed emerged as a result. We are being listened to and find some of the things we advocated in our position paper reflected in the current subsidy regulations…. I think we have given a little impetus.

4.3.2. Associations

All interviewees emphasize the pivotal role of environmental discourses, particularly within associations, perceived as relevant in guiding companies toward greener operations. Alpha, Beta, Gamma and Delta followed the invitations and took proactive roles in forums organized by logistics and industrial associations. According to the interviewee, such engagements offer the benefits of jointly evaluating the impact of societal requirements on the 3PL industry and staying updated with technological advancements. Engaging in these debates and discussions has proven instrumental in prompting ideas for greener operations, as Interviewee 3 explicitly emphasizes:

> There have also been round tables where we have engaged with many other companies, competitors, shippers, supply partners…Our participation in discussions and research has broadened our perspective on many things; we have learned much about ongoing trends and technologies.

4.3.3. Environmental research groups

Notably, the examined large companies follow the invitations and contribute to forums initiated by universities or other environmental research groups, presenting an opportunity to influence the trajectories of technological developments and shape future conditions and standards. To illustrate, Alpha was recently invited to partner with other corporate entities and research groups to develop and test a globally recognized methodology for harmonized calculation and reporting of GHG emissions across multi-modal transport chains. Similarly, Beta was invited to join a national consortium led by a public university, focusing on researching and promoting fuel cell-propelled trucks. These collaborations have already manifested in tangible changes: Alpha has incorporated the newly minted methodology in its consultancy services, while Beta is actively experimenting with fuel cell trucks in its daily logistics operations. In summary, 3PLs proactive engagements in research groups appear as significant catalysts, steering 3PLs to adopt sustainable practices:

> The most important aspect is gathering experience, testing different things…, and making our own experiences…, which is often lacking, especially for new technologies. Often, hardly anyone has used these things, and then we try to be there early and make our own experiences if it is technically possible. (Interviewee 3)

However, the small companies Epsilon and Zeta do not prove any cooperation with universities or other research institutions, even though they closely monitor the involvement of other, larger companies and the publicly available research results.

4.3.4. Shippers

Interviewees consistently noted that shippers traditionally exert minimal pressure on green innovations. Shippers typically do not formulate detailed green requirements, focusing on cost, agility, speed, reliability, and damage avoidance in their partnerships. In particular, the small companies emphasize the low priorities of their shippers, as Interviewee 9 highlights in detail:

> Most customers (shippers) are not interested in this yet. Customers generally do not see transport operations as their resource or environmental problem since they do not occur in their own company. Price, punctuality, and damage minimization count in this respect.

Interviewee 10 argues similarly, seeing the company's highly specialized field of activity as the main reason for the lack of interest among its shippers:

> No, I do not think anything from the client side will come, at least for a while. This is simply because we provide a service unavailable on the market in this form…with all the bringing into the point of use… Customers rely on us to act accordingly, but I do not think they will take the initiative.

The large companies Alpha, Beta and Gamma interviewees identify instances where shippers introduce sustainability-related prerequisites before initiating tenders, primarily limited to specific green process innovations in warehouses and transportation. Examples include modernized lighting systems or deploying the newest diesel vehicles. However, such prerequisites are driven by cost concerns rather than shippers' ecological considerations.

While this study did not identify instances when green service innovations were introduced based on shippers' explicit requirements, emerging patterns are observed. Alpha and Beta report occasional requirements of shippers preferring 3PLs in tenders being able to calculate and report CO_2 emissions. Such an additional requirement appears driven by the ongoing social debates in Germany, which, according to the interviewees, are even expected to increase.

Moreover, Alpha, Beta and Gamma also report increased transportation-related sustainability queries, although these often lack specificity and require further clarification. Importantly, Beta and Gamma indicate that many of these inquiries stem from shippers in industries awaiting future heightened regulatory and societal pressure, such as the glass and steel industry. However, these shippers appear anxious and often lack knowledge about sustainable logistics processes. Recognizing this knowledge gap as an opportunity to seize new market shares in these sectors, Beta and Gamma aim to provide specialized consultancy services, thereby creating barriers to market entry for potential successors. The same logic applies when Beta and Gamma proactively approach shippers with sustainable packaging design advisory services. Interviewee 6 highlights this proactive approach to recognize market trends and adapt accordingly:

> Usually, they (shippers) assumed that we (3PLs) create a solution for them, and then they just take the cheapest. However, in the future, their customers may request them to look at their ecological footprint and improve their processes…at the same time, I often notice that many colleagues at our competitors lean back…this speaks for us as an innovator being already ahead and able to propose individual solutions that others cannot get so quickly…

In this sense, the adoption of customized green service innovations appears to be induced by expected future competition intensity instead of explicit pressure from shippers.

4.4. Factors of uncertainty

4.4.1. Unpredictability of technological development

The analysis revealed that unpredictable technological developments lead to uncertainties that, to some extent, deter 3PLs from introducing specific green process innovations. Interviewees highlight various unpredictable technological developments, including solar cell capacity, alternative packaging or construction materials.

However, the dominant concern revolves around the limitations and the uncertain future of electric and hydrogen trucks. Specifically, Delta, Epsilon and Zeta express reservations about adopting electric

trucks due to their insufficient range, especially for longer shuttle and long-distance transport. For companies such as Delta, which primarily operate in higher altitude regions, the unpredictability of battery operation compounds additional challenges. Interviewee 7 captures the current limitation of electric trucks in a somewhat polemical yet apt manner:

> As it stands today, it does not work…a truck you want to charge somewhere in the courtyard at minus ten degrees, the battery barely gets a charge in. And then you have to interview the driver: 'How cold was it for you today?' and 'How far do you get?' This is not effective.

Similarly highlighting the challenge, Interviewee 9 draws attention to the inadequacy of its region's electric infrastructure:

> Assuming that 80 heavy commercial vehicles are connected to the power grid on our company premises on Friday afternoons, the lights go out not only in the immediate neighborhood…

Given the lack of a reliable forecast on the availability of electric trucks with suitable ranges and loading infrastructure, these organizations have postponed further tests in everyday operations. At the same time, most interviewees confirm that the German 3PL industry remains uncertain when large electric or hydrogen trucks, particularly those with a gross vehicle weight of over 12 tons, will be available in series production. The prospects for hydrogen-powered vehicles present comparable uncertainties. However, Interviewee 7 sheds light on the additional economic ambiguities associated with such vehicles:

> We truly want hydrogen and are willing to invest in the infrastructure… However, what causes us the most headaches with fuel cells is the question: 'What does that mean in terms of maintenance?' We remember from previous issues that fuel cells are very costly to maintain; we cannot estimate that now.

4.4.2. Fluctuating public funding and subsidy regulations

Though intended to catalyze green innovations, specific government policies may also introduce uncertainties due to their inconsistent nature. The frequent changes and unpredictability in requirements pose challenges for decision-makers within the studied case companies. For example, Epsilon, while intending to upgrade its truck fleet to the newest generation of diesel trucks, encountered unforeseen requirements from the German government related to the use of low-rolling-resistance tires introduced just before a subsidy program's inception. This new mandate proved problematic for Epsilon, as their operations in areas where low-rolling-resistance tires are not suitable led the firm to reconsider its investment plans. Illustrating this, Interviewee 9 laments:

> … unfortunately, clear rules do not come from politics regarding environmental issues. At least not in such a way that an improvement is achieved; in general, it becomes more bureaucratic, and subsidies are distributed in such a complicated way that, in the end, no one can purposefully use them.

Similarly, Interviewee 7 points out the government's vacillation over subsidies for alternative propulsion systems, stating:

> We are also waiting for the subsidy program, but everything is not there yet; therefore, our investments are significantly slowed down. It seems that even the politicians do not know what to subsidize.

Adding to these concerns, Interviewee 8 remarks on the over-regulation in construction processes that do not take the logistics industry's practical needs into account:

> This is very much German building law: Simply something calculated, submitted, voted on, hooked on, wonderful. However, whether it works and who does it…these things do not matter in Germany…no one in the politics seems interested…

Overall, there is a clear sentiment among the interviewees that federal and regional government policies often lack clarity and consistency. Rather than aiding, certain political measures often appear to obstruct the integration of green process innovations, as Interviewee 5 aptly summarizes:

> I do not think that government agencies and advisory bodies contribute much…but they tend to confuse by not making clear statements in discussions or introducing distinct and practicable subsidies regulations.

4.4.3. Variability in shippers' demands and priorities

Shippers' inconsistent and frequently shifting priorities challenge case companies under investigation trying to invest in clean technology. This inconsistency often creates a dilemma for the case companies, especially when significant resources have been allocated at the request of specific shippers. Beta and Gamma, for example, recently made considerable efforts to develop innovations on behalf of selected, environmentally sensitive shippers. After the initial agreement, in both cases, shippers either postponed or dismissed the suggested innovations, leaving the efforts of Beta and Gamma underutilized. Similarly, when asked by a client to pilot an electric truck in the inner city for marketing purposes, Delta invested significant resources in selecting the supplier and determining the deployment period and location. However, the shipper's sudden pivot to a hydrogen-powered alternative and the inherent investment risks compelled Delta to reconsider its commitment. These examples highlight a broader pattern in the 3PL industry. Even though eco-conscious shippers have an increasing propensity toward sustainability, their inconsistent actions and priorities often reflect a prevailing sense of uncertainty and indecision about how best to engage in green logistics. Interviewee 4 observes this dichotomy, noting:

> Within the last two or three years, certain customers have approached us asking what we are working on and what we could do together. They often say that they would then also pay more. I have not yet experienced this in reality. However, the 'mindset' seems to be changing gradually, but it also leads to the customer changing his opinion or preferences again and again.

4.5. Factors of market-related complexity

4.5.1. Varying shippers' requirements across industries

Since case companies serve shippers in different industries simultaneously, industry-specific requirements appear to be a significant source of complexity, often limiting the scope for green innovation in the companies studied. To illustrate, when case companies attempt to deploy ecologically sustainable packaging materials, shippers' marketing or safety priorities may hinder the implementation. Interviewee 8 insightfully notes the significant role played by the marketing department within a nutrition production company:

> One client is interested….but its marketing departments are entirely 'resistant' to any advice. People in the logistics department of this specific company understand the subject, but our queries usually stop in the marketing department.

Shippers in the online retail industry explicitly prioritize the 'unboxing' experience for their customers, dismissing the need for rationalized packaging strategies (Alpha, Delta). Shippers in the pharmaceutical industry usually prefer new white packaging materials instead of recycled grey materials for safety reasons (Delta). The same applies to bulky medical, laboratory, graphical and optical equipment industries (Zeta).

Moreover, Delta and Epsilon emphasize that the cost-effectiveness of using sustainable packaging materials hinges on aggregating demands from multiple shippers, leading to bulk procurement. Also, regarding transportation and warehousing, shippers' varied nature and distinct needs introduce further constraints on adopting particular technologies and transportation modes. A prevalent observation is that a uniform service offering aids the seamless integration of green innovations. However, specific requirements of individual sectors that sometimes conflict with each other can impede such efforts, as Interviewee 1 succinctly expresses:

> In contract logistics, the clients often have their packaging systems or expectations of quality or appearance… however, line hauls only require a particular type of packaging…that is standardized…so we were able to implement some ideas there quite well.

4.5.2. Proliferation of environmental stakeholders' concern

Increasing the number of external stakeholders involved in implementing companies' environmental strategies increases complexity. For instance, Alpha, Beta and Gamma aim for CO_2-neutral warehouse operations. As energy production determines the carbon footprint of an energy source, integrating various types of renewable energy sources at the site level is essential for achieving this goal. However, different geological conditions prevail at the individual sites, requiring the involvement of suppliers of different technologies, adhering to varying municipal regulations, and cooperation with many smaller power plants locally. At the same time, federal regulations and European guidelines must be fulfilled, especially when applying for subsidies.

Alpha and Beta emphasize that interacting with multiple external stakeholders through various channels may significantly delay the deployment of renewable energy sources as such projects require acquiring new technical knowledge and additional qualified personnel at the individual sites and head office, creating relevant organizational changes. Such extensions entail new functions and imply changes in responsibilities, granting higher freedom of action locally. However, this decentralization implies intense company-wide internal coordination efforts, further increasing managerial complexity as Interviewee 5 concludes:

> Well, that is an extensive set-up, and we are also organized in a decentralized way, so everyone actually has a very free hand. However, that is always difficult to coordinate, and it is also a challenge to manage it so that you reach a common understanding straight forward. That is why we are moving a bit slowly.

4.5.3. Challenges in integrating and monitoring subcontractors

Integrating external partners within the value chain is paramount in achieving sustainability goals. This becomes evident when considering the approaches of Alpha, Beta, and Gamma. All three companies engage in contracts with external logistics service providers, incorporating them into their primary logistics processes.

To reduce the adverse impacts of their service bundles, these companies must ensure alignment with subcontractors on sustainability objectives. This alignment encompasses several facets: forwarders and carriers must share the same sustainability vision, invest in emerging clean technologies, consistently employ predefined standards for CO_2 emissions calculation and reporting, and establish technical connectivity for seamless data transfer.

The interviewees perceive this alignment as extraordinarily challenging due to the need for transparency and monitorability of service providers' actions. Interviewee 5 highlights this concern, noting:

> We are not yet advanced enough. We are merely examining the possibility of including subcontractors in calculating emissions in various business areas… because this is still very non-transparent, and we are often unable to work with primary data. We are discussing this internally and looking for partners who are willing and technically able to go further.

Alpha faces unique complexities in this realm. Its engagement with a multitude of small- to mid-sized external service providers across various transport modes and regions results in an intricate web of transactional relationships. Given this expansive and diverse network, ensuring all subcontractors' compliance becomes particularly challenging.

4.6. Factors of munificence

4.6.1. Shippers' perception and slack financial resources

Solvent shippers willing to pay a premium for greener services are essential to munificence in a natural business environment. In this regard, the perceptions vary among interviewees. Representatives from Delta and Epsilon report intense competition in their logistics segments, with shippers prioritizing speed, reliability and low costs, making it difficult to convince them to pay higher prices for more sustainable services or to share investment costs. As a result, these companies focus their financial reserves on potentially more profitable innovations, with a particular emphasis on digitalization projects that can

yield effectiveness gains. With these priorities in mind, projects aimed at greening the company's processes and services take a backseat in immediate future planning, as Interviewee 7 illustrates with the example of a hydrogen filling station:

> A hydrogen filling station costs millions of Euros…and we need immediately a number of vehicles we cannot afford if the customers (shippers) do not follow us… then we prefer to invest in other areas, such as digitization.

Similarly, Zeta emphasizes that its shippers do not value further differentiation in the company's already highly customized service portfolio.

> We provide a service that is simply unavailable on the market. With all the bringing in at the point of use. Not many do that. And as I said, we are the quality leader….

Thus, Zeta indicates not further to differentiate its service portfolio with additional green services:

> …we…do not have problems getting new customers…and I do not think shippers will do anything on their own.

On the contrary, Alpha, Beta and Gamma anticipate shippers' customer priority changes. These companies invest proactively, using their reserves, even if only a few clients are willing to pay premium prices, and only in exceptional cases. These three companies have seen significant growth in recent years, suggesting they may have substantial slack resources available for strategic investments toward long-term rewards. This is particularly necessary to finance the needed structural changes within the company, as Interviewee 1 explicitly emphasizes:

> …we also have the great advantage of the sheer volume of people and can afford to build up administrative and technical departments in a way that small companies cannot. We now have environmental officers to prepare protocols, reports, and subsidy proposals. Of course, a small company cannot do that.

4.6.2. Access to green-related knowledge

Access to external institutional actors with knowledge of sustainability and new technologies plays a critical role in munificence. Research consortia comprising original equipment manufacturer, universities and research groups, governmental bodies and sometimes NGOs appear to represent all the case companies' most crucial know-how sources. However, not all case companies have the same level of access. Epsilon and Zeta understand that their size and limited resources make them unattractive to universities and research groups, as Interviewee 9 explicitly highlights:

> Unfortunately, universities neglect small and medium-sized companies in particular. Usually, contact with large corporations is more prestigious and more rewarding in terms of funding. Therefore, close contact is often not established in this area.

Epsilon and Zeta notice that universities tend to cooperate with high-profile, larger companies, even if they intend to establish a research consortium only at a regional level. However, Zeta has occasionally succeeded in temporarily establishing short-term projects with local universities; Epsilon has not yet gained academic partners. Epsilon's challenges appear compounded by its location in a region without universities. Moreover, the nearest universities do not focus on green logistics issues. The lack of access to technological developments and know-how is explicitly shown by the fact that Epsilon could not install a photovoltaic system for its own use and instead rented out its hall roof a few years ago. Interviewee 9 simply remarks on this:

> We decided not to install and use this technology ourselves, not because we did not have the money to deploy photovoltaic systems, but we simply did not have the extensive know-how to do so.

On the other hand, Alpha, Beta and Gamma have established numerous national and international research projects. These firms ensure that the knowledge acquired in other countries is integrated into their headquarters, creating positions and departments designed to foster organizational learning across international subsidiaries.

4.6.3. Availability of specialized technology suppliers

The availability of specialized suppliers is crucial for implementing green innovations. The companies claim that specialized suppliers are readily available, but particularly for smaller firms, also necessary, as Interviewee 9 points out:

> For a medium-sized company such as us, the involvement of suppliers is necessary to obtain external innovations and buy-in knowledge and technology from other areas. Many available suppliers maintain close contact and offer new technologies.

Through their participation in working groups in associations, small- and mid-sized companies gain access to suppliers, some of whom are small but highly specialized. Larger companies also benefit from their internationally oriented procurement strategies, as they are updated on the latest technological developments worldwide, as Interviewee 4 points out:

> We have a long-term partnership with an OEM, where we have been one of the leading test partners for several years. We have been using vehicles in urban delivery for quite a while and are now rolling this out… we are gathering experience in a wide range of European cities and will also be doing so for other drive vehicles.

4.6.4. Availability of qualified personnel

All companies rate the current conditions of qualified personnel recruitment as highly problematic. In addition to the general demographic problems of an aging country like Germany, other sectors are perceived as more likely to attract qualified personnel because of higher margins and, thus, salaries.

For Epsilon, the lack of skilled personnel is particularly severe, leading, for instance, to delays in the modernization of its lighting installations. The company is keen to accelerate the process but fails to attract adequate staff for vocational training, as Interviewee 9 highlights:

> The implementation of this project has been delayed for a considerable period as there is an enormous shortage of electricians in our region. We employ three electricians and would like to train young people, but there is such a lack of trainees that we have been unable to expand our team for several years.

According to the interviewee, this shortage of potential trainees can be attributed to the structural deficiencies of the company's region.

5. Discussion

5.1. Green innovations and reasons for adoption (RQ1, RQ2)

In the evolving German logistics sector, 3PLs face increasing pressure to enhance efficiency and reduce costs. Consistent with the findings of Oberhofer and Dieplinger (2014) and Abbasi and Nilsson (2016), this research reaffirms the pivotal role of green process innovations in enhancing material and energy efficiency, thereby lowering operating costs and fees in the short term. However, the German 3PLs investigated also appear to prioritize measures emphasizing the sustainable use of natural resources, particularly integrating renewable energy sources. While previous studies have acknowledged 3PLs' efforts in integrating renewable energy (e.g., Islam et al., 2021; Ren et al., 2019), this study highlights a strategic shift toward energy independence, a facet previously underexplored in 3PL literature. In particular, the firms' anticipation of escalating energy supply prices channels their efforts toward integrating renewable energy sources. Propositions 1 and 2 summarize these results:

> **Proposition 1:** 3PL companies predominantly adopt green innovations enhancing material and energy efficiency for immediate short-term operating costs and fee savings.

> **Proposition 2:** 3PLs deploying renewable energy systems for self-consumption, motivated by the pursuit of long-term energy cost savings due to rising market prices for energy supplies.

3PL's efforts to integrate renewable energy sources offer long-term cost-saving potential and align with broader socio-economic trends within Germany, demonstrating strategic foresight in corporate environmental responsibility. However, this study also reveals a notable trend among the analyzed 3PLs: a

preference for green process innovations that enhance the sustainable use of natural resources. Examples include deploying sustainable fuel, clean vehicles, environmentally friendly filling and packaging materials, and efforts to preserve local biodiversity. Interviews and internal documents indicate 3PLs' recognition of societal expectations, where such innovations contribute to their environmental responsibility. Altogether, 3PLs' efforts align with broader objectives like increased market visibility and potential collaborative inquiries from shippers. Specifically, in the case of Gamma, the company's innovations garner significant media attention and are also expected to reinforce its reputation in the context of Germany's socio-political landscape, thus its appeal to younger talent (Sohn et al., 2015). These diverse efforts underscore that 3PLs are not just adopting green practices for immediate benefits. They strategically position themselves in a competitive business environment where environmental reputation is increasingly pivotal (Baah et al., 2020; Rapp et al., 2024), leading to the following proposition:

Proposition 3: 3PLs adopt green process innovations for the sustainable use of natural resources to enhance their environmental reputation, motivated by seeking alignment with socio-economic environmental trends.

While traditional logistics concerns such as price, speed, flexibility and reliability remain essential, the findings of this study also indicate that particularly large case companies are keen to distinguish themselves through green service offerings. Accordingly, they are pivoting toward offering services that allow shippers to make environmentally conscious decisions, particularly in transportation, where the firms' complementary services of measuring and reporting CO_2 emissions emerge as also vital. A further original finding of this study is that these firms anticipate regulatory changes and societal shifts in urban areas, positioning themselves as first-movers in emerging logistics segments. In particular, Beta's adoption of standardized CO_2-neutral last-mile delivery services represents an emergent business model that has yet to be thoroughly examined in the 3PL literature (Lauenstein & Schank, 2022). These findings demonstrate a strategic pivot among large 3PLs toward standardized, scalable, environmentally-focused service offerings catering to the growing demand for eco-conscious shipping solutions. The following proposition summarizes these results:

Proposition 4: Large 3PLs proactively develop standardized and scalable green service innovations, differentiating their transportation and distribution services to position themselves strategically in eco-aware shipper segments.

Leading in customized green service innovations also emerges in this study as a primary goal for large 3PLs. Findings indicate that these firms proactively gather practical experience and technical expertise. This paves the way for them to position themselves as leading consultants, particularly for customized low-carbon transportation and sustainable packaging solutions. However, these firms' motivations appear determined not by immediate gains but by forging lasting relationships and securing a competitive edge in an increasingly eco-aware market. As a result, these firms demonstrate the potential for extended contractual agreements through collaborative efforts with eco-conscious shippers, raising barriers to entry for competitors. As highlighted in recent studies (Jazairy, 2020; Jazairy & von Haartman, 2020, 2021; Rapp et al., 2024), such collaborative approaches and the focus on long-term relationships over immediate gains underscore the strategic value of customized green services in fostering the loyalty of shippers, thus potentially securing a competitive edge in eco-aware industries. This leads to the following proposition:

Proposition 5: Pioneering customized green services may strengthen large 3PLs' relationships with eco-conscious shippers through long-term contractual agreements.

5.2. External stakeholders' influence on 3PLs' green innovation adoption (RQ3)

This study explores how external stakeholder groups influence the adoption of green innovations in processes and services at 3PLs, revealing that various stakeholders play distinctive roles.

Consistent with prior studies done with German logistics firms (Maas et al., 2018; Rapp et al., 2024; Tacken et al., 2014), regulatory pressure remains a prominent driving force behind 3PLs' green innovations adoption. However, this research's case studies further contribute practical insights by revealing several policy options impacting the innovation behavior of 3PLs. Political entities influence case companies to adopt green innovations by constantly developing regulations and ongoing policy discourses. In particular,

anticipated changes in fuel and energy taxation, energy supply costs, electricity feed-in refunds, urban congestion charges, potential bans on diesel vehicles and dynamic recycling targets strongly influence case companies to reconsider their operational strategies. Usually, new regulations prompt companies to take a reactive stance, necessitating quick adjustments to meet new standards. However, case companies in this study manifest a proactive approach, preempting legal directives rather than a mere reactive stance to regulatory imperatives. Going beyond legal regulations and accounting proactively for upcoming political developments, they architect a comfort zone (Jazairy & von Haartman, 2020), yielding immediate and long-term advantages. The following proposition summarizes the insights from the case studies:

Proposition 6: Political entities influence 3PLs' proactive green innovation behavior by necessitating adaptation to evolving regulatory frameworks and public policy discourses.

Associations have emerged as a second salient external stakeholder group influencing the innovation behavior of the studied 3PLs. The role of associations is barely discussed in 3PL-related literature but emerges in this study as particularly important in bringing various stakeholders' concerns to their member firms' attention. In doing so, logistics associations enable their members to assess the implications of societal concerns on their industry. Thus, case companies' active participation in committees provides valuable insights into societal pressure, reinforcing 3PLs commitment to greening their operations. Furthermore, the proactive engagement of large case companies in different industrial associations, which represent the interests of shippers, helps to enhance a collective understanding of environmental requirements for the specific industry. This, in turn, guides and encourages 3PLs to adopt new technologies and innovative services. This dynamic underscores associations' critical role in influencing 3PLs' strategies for green innovations by translating societal and environmental concerns into practical insights. Altogether, the influence of associations might be summarized by the following proposition:

Proposition 7: Associations influence 3PLs' green innovation behavior by presenting and interpreting societal and environmental concerns as actionable insights, guiding them toward proactively adopting green innovations.

Complementing the collaborative efforts within associations, research groups led by universities, NGOs or commercial technology developers further amplifies the innovation potential of 3PLs. Participating in research consortia enables Alpha, Beta and Gamma to oversee current stages of technological and organizational developments, access new technologies and conduct joint development of sector-specific standards. The research projects in which these companies participate provide opportunities for gaining experience and supporting the implementation of new technologies that might enable new service offerings. The fact that organizational changes occur in the case companies during intensifying cooperation indicates adaptive behavior (Plaza-Úbeda et al., 2010). Engagement with external research groups is crucial in directing large 3PLs toward green innovations. It enhances the innovative capability of 3PLs by facilitating access to new green technologies and aiding in developing industry-specific standards critical for green innovation. However, small 3PLs may not collaborate actively but tend to monitor developments keenly. Altogether, these observations lead to the following proposition:

Proposition 8: Engaging with external research groups enhances 3PLs' innovation capacity by accessing new technologies and developing sector-specific standards.

According to the interviewee in this study, case companies traditionally experience direct pressure from shippers focusing on cost efficiency and service reliability. However, the interviewees also indicate a slight but observable shift. Certain shippers appear to recognize the need for sustainability in logistics, mainly reflected in a gradual increase in the inclusion of sustainability criteria in their tenders. This observation reinforces the tendency of generally growing purchaser interest in the sustainability behavior of 3PLs (Huge-Brodin et al., 2020; Jazairy & von Haartman, 2020, 2021; Moreira & Rodrigues, 2023). However, it also supports the assumption that shippers are mainly interested in 3PLs' environmental practices at the beginning of the purchasing process, confirming prior research (Bahr & Sweeney, 2019; Jazairy, 2020; Jazairy & von Haartman, 2021). This explains the primary focus of the 3PLs investigated on adopting highly visible, 'media-effective' process innovations ensuring the sustainable use of natural resources and

standardized service innovations such as CO_2-calculation and reporting services, thereby showcasing their environmental commitment.

On the contrary, the market reception of novel customized green services appears contingent upon shippers' propensity for collaboration anchored in their environmental philosophies and anticipated service value. This observation broadly aligns with findings from previous case studies involving German logistics providers (Jazairy & von Haartman, 2020, Tacken et al., 2014). However, insights of this study suggest that to maximize the benefits of their recently acquired sustainability knowledge and developed capabilities, 3PLs must proactively engage with shippers where downstream customers will likely exert future pressure. This result reinforces the recommendations of Sallnäs and Huge-Brodin (2018) and Huge-Brodin et al. (2020), who advocate for a network approach to achieve a competitive edge.

Against the background of prior empirical results, the present case studies' findings can be summarized with the following proposition:

Proposition 9: Shippers' increasing inclusion of sustainability criteria in tenders prompts 3PLs to adopt green process innovations aiming for the sustainable use of natural resources and scalable, standardized green services.

Proposition 10: Anticipated future demands of shippers serving eco-conscious downstream customers prompt 3PLs to proactively propose customized green service innovations.

5.3. Factors of market-related uncertainty, complexity, and munificence (RQ4)

This study identifies several factors increasing uncertainty among decision-makers, as shown by analyzing their perceptions and behavioral patterns. These factors include technology-related uncertainties linked predominantly to the anticipated evolution of transport vehicles, legislative uncertainties due to unpredictable changes in public funding and subsidy regulations, and shippers' hesitant behavior combined with volatile demand and preferences, leading to perceptions of high-risk investments. These factors complement contemporary literature pinpointing technological and legislative uncertainties and fluctuating commitment from shippers (Abbasi & Nilsson, 2016; Evangelista et al., 2019; Jazairy, 2020), collectively contributing to a heightened sense of uncertainty among 3PL decision-makers and impacting their willingness to invest in green innovations. This leads to the following proposition:

Proposition 11: The unpredictability of technological advancements, fluctuating public funding and subsidy regulations, and the variability in shippers' demands and priorities create external uncertainties that impede 3PLs' investment decisions in green innovations.

The analysis further points to the rising number of environmentally conscious stakeholders and their escalating concerns, increasing the complexity of 3PL's business environment. Rising complexity is well reflected by the increased coordination efforts needed to implement technical infrastructure projects at the individual site level, a complication not yet discussed in the 3PL literature. Moreover, integrating and monitoring subcontractors require significant coordination and added investments, confirming prior observations made by Tacken et al. (2014) among German logistics firms. Finally, serving shippers from different industrial sectors adds another layer of complexity. Shippers across different sectors appear to assign varying degrees of importance to green logistics, which limits 3PLs in adopting green innovation. In packaging services, for instance, differences across sectors are perceived as too significant to enable predictions about the environmental standards required. However, in the transportation domain, where shippers' needs can be considered relatively homogenous, case companies make progress in implementing green process innovations. Thus, it appears reasonable to assume that the more homogeneous the shippers' requirements are, the more green innovations 3PLs will be capable of adopting. These findings also contribute to understanding why 3PLs offering basic, standardized services may adopt more green innovations than those offering advanced, often customized logistics solutions (Maas et al., 2018). The complexity, stemming from diverse environmental concerns and varied shipper needs across industries, coupled with the challenges in subcontractor integration, significantly impacts the coordination efforts and investments required, leading to the following proposition:

Proposition 12: The increasing complexity due to diverse environmental stakeholder concerns, varying shippers' requirements across industries, and challenges in integrating and monitoring subcontractors act as external barriers, escalating coordination efforts and hindering the adoption of green innovations by 3PLs.

Finally, this study explores relevant factors of munificence in 3PLs' business environment, assuming that this quality facilitates the adoption of green innovations. With their recent growth and strong results, large case companies prove sufficient financial reserves for green innovations, echoing existing research from the German 3PL industry (Rapp et al., 2024; Tacken et al., 2014). However, compared with the established 3PL-related literature, the results of this study point to a further-reaching role of slack financial resources. Beta and Gamma diversify their investments in vehicles with different alternative propulsion systems to address uncertainties preemptively. Even without assured knowledge about the most feasible long-term option, these companies intend to acquire early experience and reduce perceived technology-related uncertainties. Likewise, large companies appear to overcome managerial complexity by decentralizing responsibilities on the one hand and setting up central roles to oversee external knowledge on the other. Such adjustments encompass additional organizational functions and staffing capacities requiring significant financial investments. Moreover, these companies also capitalize on their access to the international labor market to adopt skills and capabilities related to green innovations.

In comparison, the smaller companies considered in this study assess the degree of munificence differently. Despite having noteworthy financial reserves relative to their operations, Delta, Epsilon and Zeta face hurdles in accessing external knowledge. Their restricted geographical presence and comparatively low market relevance, especially of Epsilon and Delta, constitute two dominant limiting factors. Finally, it is also worth mentioning that all the companies analyzed consider the general availability of green technology suppliers as sufficient. However, this study also highlights a critical gap: smaller 3PLs serving shippers in specialized segments do not benefit equally from the general availability of green technology suppliers.

Moreover, the case studies identify a disconnect where governmental subsidies fall short in addressing the needs of small to mid-sized 3PLs, even though the German 3PL market is highly fragmented. These insights highlight the unique challenges for small to mid-sized 3PLs and call for a more inclusive approach to policy formulation, a relatively less-treaded territory in current research (Creazza et al., 2024). Propositions 13 and 14 summarize these results:

Proposition 13: In the 3PLs' business environment, the ability to adopt green innovations is facilitated by factors such as the shipper's willingness to pay premium prices, the availability of specialized technology suppliers, qualified personnel, access to green-related knowledge and slack financial resources.

Proposition 14: For small and mid-sized 3PLs, limited geographical presence and market relevance pose significant challenges, restricting access to external knowledge and qualified personnel, and thus creating market-related barriers to adopting green innovations.

Figure 2 illustrates this study's research findings and propositions, developing a comprehensive framework.

6. Conclusions

Amid growing concerns about environmental sustainability in logistics, 3PLs struggle with integrating green innovations into their operations. This study employs a multiple case study research design to explore the green innovations adopted (RQ1) and the reasons motivating the studied 3PLs to adopt specific sets of green innovations in processes and services (RQ2). Moreover, the study aims to understand how external stakeholders influence 3PLs' proactive innovation behavior (RQ3) and explore factors of market-related contingencies (RQ4). It contributes to the extant knowledge about developing environmental sustainability in logistics in a detailed empirical context by involving six environmentally proactive 3PLs in the German 3PL industry, considered the largest in the European Union.

6.1. Central findings and theoretical contributions

This study provides insights into 3PLs' responses to environmental challenges. It extends the scope of the existing 3PL-related literature on green innovations by emphasizing the distinctions between process- and service-oriented innovations and aligns with Hart's (1995) assertion that environmental challenges

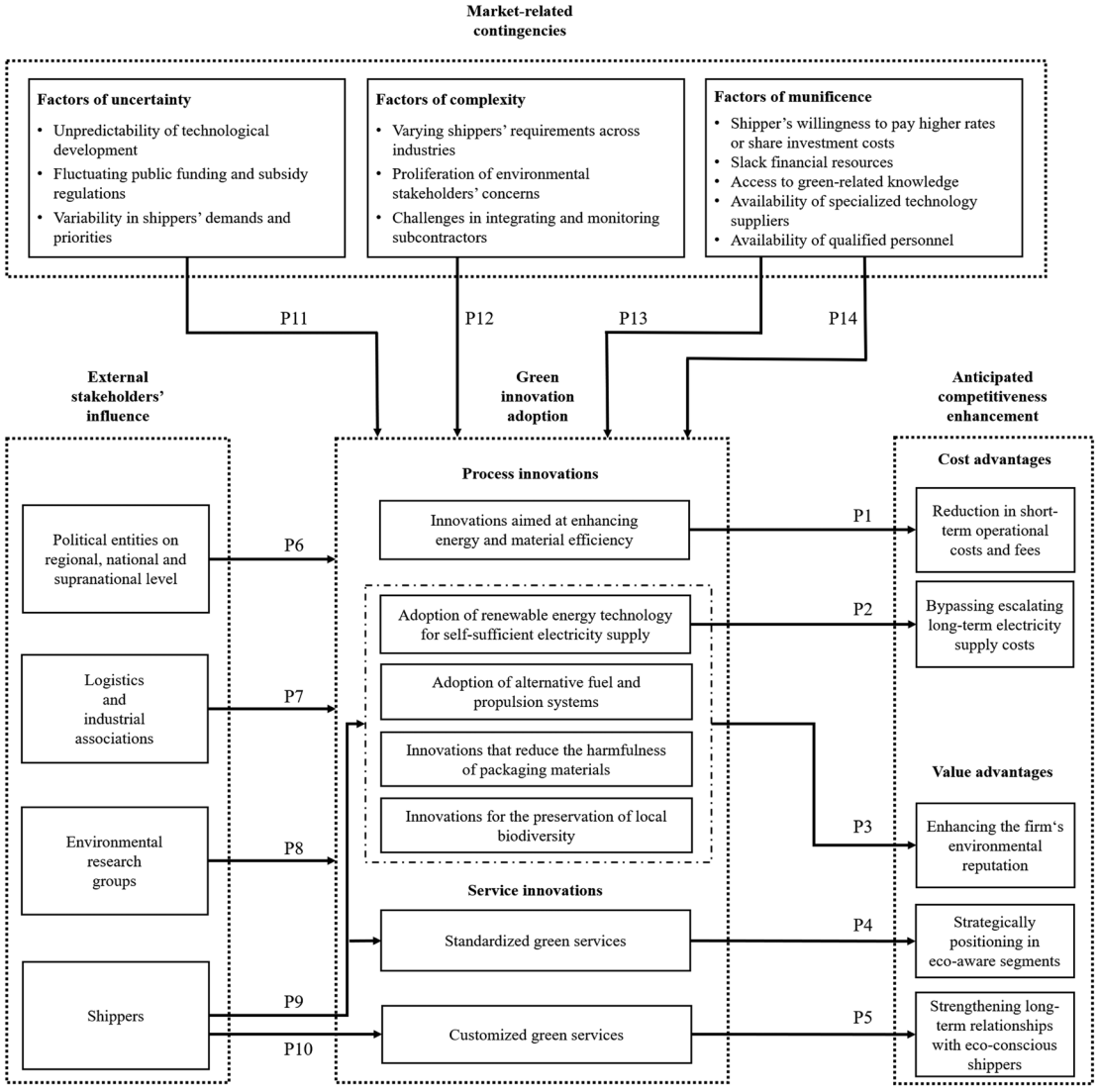

Figure 2. Summary of research findings.

represent opportunities for value creation. Findings indicate the need for such a differentiated view, as the levels of adoption vary even across environmentally proactive 3PLs. Although critical for assessing the benefits of green innovations, such an explicit distinction is yet to be thoroughly addressed in 3PL research.

Moreover, the study emphasizes the need to further discern between process innovations enhancing energy and material efficiency and process innovations enhancing the sustainable use of natural resources. Through an analytical lens of combining environmental management and competitiveness in 3PLs, it reveals that decision-makers predominantly perceive the former as a means for cost, fee, and fine reduction in the short term; the latter they consider an opportunity to circumvent increasing supply costs in the long term and to enhance the 3PLs' environmental reputation. With regard to green service innovations, the study identifies several new transportation- and distribution-related services offered by large case companies in a standardized and scalable way, serving as differentiating factors in transportation and distribution processes in intensely competitive segments. However, it also indicates that those large 3PLs consider customized green service innovations as potential avenues for long-term relationships with eco-conscious shippers.

In addition, this research contributes to the green logistics literature by examining the role of different external stakeholder groups that influence the innovation behavior of 3PLs. It reveals that despite the well-known environmental awareness and social commitment to sustainability in Germany, shippers exert less influence on 3PLs' green innovations than initially expected. This finding underscores the need for 3PLs to proactively engage shippers with green solutions rather than relying only on external pressure. In contrast, political bodies, logistics and industry associations, and environmental research groups were

identified as the most influential external stakeholder groups. They guide 3PLs toward greener operations, mainly by setting regulations, shaping policy discourses, assessing societal needs and technological developments, and promoting platforms for knowledge sharing and idea generation. These findings are consistent with Freeman's (1984) view of *stakeholder engagement* in strategic management. However, the findings in this study extend the understanding of stakeholder engagement in green logistics among 3PLs by pointing to the importance of managing relationships with secondary stakeholders. The mechanisms through which secondary stakeholders influence 3PLs' innovation behavior is an under-researched area in the literature on 3PLs (Prataviera et al., 2024), further highlighting the novelty and relevance of this study's findings.

Moreover, the study resonates with Aragón-Correa and Sharma (2003), namely the contingent resource-based view of proactive environmental strategy. It contributes to the existing 3PL-related literature by exploring market-related contingency factors causing uncertainties and heightening complexity in 3PLs' decision-making. Unpredictable technological developments, inconsistent governmental policies and inconsistent shipper preferences are identified to enhance uncertainty in 3PLs' investment calculations. In contrast, the industry-specific requirements of shippers, the proliferation of stakeholders and the incorporation of external value chain partners are perceived to enhance complexity in coordination, requiring additional organizational changes and investments.

At last, this study also systematically assesses relevant indications of market munificence. Factors indicative of high munificence enhancing green innovation adoption include shippers willing to pay higher prices and share investment costs, availability of external knowledge and technology suppliers, qualified personnel, governmental subsidies and firms' slack financial resources. In a novel discovery, small- and mid-sized companies perceive their business environments as more hostile than their larger counterparts. In particular, they find shippers less receptive and perceive it more challenging to access sustainability-related knowledge, attract qualified personnel and use governmental subsidies. They attribute these limitations to their highly specialized services, low market visibility and relevance to the public or regional orientation. These findings are underrepresented in the current literature and reflect a pivotal facet of operational realities. Even though this study focuses on the German 3PL market, the insights may also resonate with the challenges small and mid-sized 3PLs face in other developed countries.

6.2. Managerial implications

Germany provides a business environment where society shows a high degree of ecological awareness, and the government appears committed to the sustainable transformation of the economy. Thus, from a managerial point of view, 3PLs are well advised to take timely measures to reconcile the initially seemingly contradictory goals of economy and ecology. This study's findings reveal that green process innovations might offer possibilities for reducing costs and enhancing 3PLs' reputation. Study results should also encourage decision-makers at 3PLs to pursue green service innovations. Even if shippers are unwilling to pay higher prices, green service innovations may offer other strategic benefits, such as higher shippers' satisfaction and longer contract terms.

Considering green innovations' capital-intensive and time-consuming nature, a step-by-step approach is advisable. Initially, 3PLs should prioritize green process innovations that enhance energy and material efficiency. Once these foundational steps have been taken, a progression toward more long-term investments can be pursued, such as integrating renewable energy sources and launching comprehensive green service innovations. Such an approach should allow 3PLs to realize immediate benefits while strategically preparing for future demands.

Given the market-related uncertainties identified in this study, it might benefit 3PLs to partner with diverse research entities. Diverse partnerships can yield timely insights into diverse nascent technologies, enabling 3PLs to make informed strategic decisions. Moreover, considering the dynamic nature of regulatory frameworks, proactive engagement in research consortia and associations can provide early insights into potential legislative changes, thus preparing 3PLs for future strategic realignment. Finally, fostering direct and regular communication channels with shippers is essential to anticipate shifts in shipper behavior and requirements.

This study also underscores the necessity of adaptive operational strategies in coping with complexities associated with green innovations. By adopting a modular service approach, 3PLs could efficiently respond to the specific demands of differing shipper segments. Moreover, adopting advanced project management methodologies and prioritizing continuous staff training might help coordinate, especially when managing the intricacies of extensive infrastructure projects. For 3PLs integrating subcontractors, ensuring alignment with green innovation values and principles is paramount, which could be achieved through periodic assessments, audits, and shared training initiatives. Harnessing the benefits of market munificence requires 3PLs to allocate resources toward sustainability-driven initiatives consistently.

Finally, it can be difficult for small to medium-sized 3PLs to access external green-related knowledge and financial support from government agencies. Horizontal cooperation with other small to mid-sized 3PLs can lead to a unified voice when approaching political entities, facilitating interaction with research institutions and technology developers and sharing best practices.

6.3. Suggestions for future research

This study inhibits certain limitations. First, its qualitative orientation and focus on a subset of German 3PL companies inherently limit the scope of the findings. This exploratory research aims not to achieve generalizability but to provide initial insights and uncover context-specific factors related to green innovations in 3PLs. While this study offers initial indications of green innovations in processes and services, developing robust quantitative measurement instruments is a crucial direction for future research. Accordingly, large-scale questionnaire surveys should provide validation of the results.

Second, while the insights from this study are crucial for understanding the dynamics of green innovation within the German 3PL sector, a context characterized by societies' strong sustainability consciousness and ambitious government policies, these conditions may not be representative of other national or regional contexts where regulatory and market conditions may differ. As such, the findings of this study should be applied to other contexts with caution, given the potential impact of these differences on 3PLs' green innovation practices. Cross-national studies that contrast German practices with those in other environments would be valuable. Considering the rapid pace of technological and regulatory changes, longitudinal research is needed to observe the progress of 3PLs in adopting green innovations.

Third, this study underscores the multifaceted roles of external stakeholders. However, given the scarcity of available literature, delving deeper into the mechanisms influencing 3PLs' adoption of green innovations represents a promising research area for future investigations. The cooperative dynamics between 3PLs and secondary stakeholders merit particularly further scrutiny.

Fourth, future studies might also explore critical organizational routines within 3PLs to integrate stakeholders' views and needs and to absorb green-related knowledge for innovations.

Sixth, this study provides an expanded understanding of market-related contingencies, offering new opportunities for future research, such as investigating how these contingencies interact and influence each other in different geographical or regulatory contexts. Exploring the role of these contingencies in shaping the long-term sustainability and competitiveness of 3PLs has the potential to contribute significantly to the literature on green logistics.

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Authors' contribution statement

Martin Bálint: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Writing – original draft preparation, Visualisation, Project administration; João M. Vilas Boas da Silva: Methodology, Formal analysis, Writing – review and editing, Supervision; Monika Maria Möhring: Resources, Writing – review and editing, Supervision. All authors approved the final version to be published and agreed to be accountable for all aspects of the work.

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The authors report that there are no competing interests to declare.

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Data availability statement

Additional data related to this study are available in the appendices. Microdata collected and analyzed for this study are not publicly available due to confidentiality agreements with the involved parties. Upon reasonable request and under the constraints of these confidentiality agreements, further anonymized excerpts from the interviews, information about the study's methodology and high-level data may be provided. All inquiries should be directed to the corresponding author.

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