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# Integrating external stakeholders for green innovation in third-party logistics: the mediating role of green absorptive capacity

Martin Bálint
*Department of Management and Communication, Technische Hochschule Mittelhessen (THM), Friedberg (Hessen), Germany and Business Research Unit (BRU), Instituto Universitário de Lisboa (ISCTE-IUL), Lisbon, Portugal*
Luís Miguel D.F. Ferreira
*Department of Mechanical Engineering, CEMMPRE, ARISE, University of Coimbra, Coimbra, Portugal*
João M. Vilas-Boas da Silva
*Business Research Unit (BRU), Instituto Universitário de Lisboa (ISCTE-IUL), Lisbon, Portugal, and*
Monika Maria Möhring
*Department of Management and Communication, Technische Hochschule Mittelhessen (THM), Friedberg (Hessen), Germany*

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## Abstract

**Purpose** – This study addresses recent calls from scholars to broaden research on the organizational capabilities of logistics firms that facilitate the dynamic interaction between acquiring and utilizing intangible resources for green innovations. It builds on the integrative and organizational learning perspectives of the natural-resource-based view (NRBV) to evaluate how external stakeholder integration (SI) and green absorptive capacity (GAC), two distinct yet complementary strategic capabilities, interact to promote the adoption of green innovations in third-party logistics providers (3PLs).

**Design/methodology/approach** – A cross-sectional survey-based approach was adopted. Online questionnaires were distributed to top managers responsible for sustainability at German 3PLs. The collected data were processed using AMOS 26 for confirmatory factor analysis, and hierarchical regression analysis was employed to test the proposed hypotheses.

**Findings** – The findings reveal positive full mediation through GAC in the relationship between SI and the adoption of green innovations, with notable variations in mediation effect sizes across different innovation subsets, suggesting the need for context-specific approaches.

**Originality/value** – By empirically demonstrating how SI and GAC interact to shape green innovation outcomes, this study offers new insights into the internal organizational capabilities required for greening in 3PL firms. It is among the first to establish the mediating role of GAC on stakeholder-driven innovation in logistics, thus extending the green logistics literature and providing guidance for 3PL managers seeking a competitive edge through environmental sustainability.

**Keywords** Third-party logistics, 3PL, Environmental sustainability, Stakeholder integration, Green absorptive capacity, Green innovation, Mediation analysis, Germany

**Paper type** Research article



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## 1. Introduction

Third-party logistics providers (3PLs) deliver comprehensive logistics solutions by integrating various activities involved in managing and moving goods. They typically operate in a highly competitive and rapidly changing environment, where, besides costs, key factors for competitiveness often include speed, flexibility, safety, and reliability (Marchet *et al.*, 2018). However, recently, the dynamics of competitiveness have changed. Increasing focus on environmental sustainability among stakeholders makes it more critical for 3PLs, especially in Western countries, to incorporate green innovations into their strategic planning (e.g. Centobelli *et al.*, 2020).

Reflecting this urgency, research into the green practices of 3PLs has intensified in recent years (e.g. Islam *et al.*, 2021). Scholars have devoted considerable effort to understanding the complex environment in which 3PLs face external constraints and pressures when considering the adoption of green innovations. Studies focusing on external pressures highlight the significant role of regulatory bodies, market pressure, including imitation of rivals' strategies, and social pressure from environmental interest groups and the general public (e.g. Chu *et al.*, 2018; Layaoen *et al.*, 2024; Maas *et al.*, 2018). These investigations commonly adopt an institutional or stakeholder perspective, framing green innovations as strategic responses to maintain legitimacy and stakeholder approval.

However, a 3PL's adoption of green innovations can also stem from internal drivers, such as ethical considerations, leadership vision, and proactive strategic imperatives (Björklund and Forslund, 2019; Sallnäs and Huge-Brodin, 2018). The proactive environmental strategy of a 3PL is typically linked to seeking operational efficiencies and achieving service differentiation and future market positioning (Laguir *et al.*, 2021; Rapp *et al.*, 2023), indicating that external stakeholders play a more nuanced role beyond merely exerting pressure. Nevertheless, the 3PL sector still faces an *implementation disorder*, where awareness does not readily translate into tangible adoption (Huge-Brodin *et al.*, 2020). The real challenge for 3PLs is to determine how to integrate external stakeholder knowledge, technologies, and best practices into their core processes and service offerings (e.g. Centobelli *et al.*, 2020; Prataviera *et al.*, 2024).

Recent studies indicate that primary and secondary stakeholders can play a crucial role in helping proactive 3PLs adopt green innovations (e.g. Abbasi and Nilsson, 2016; Prataviera *et al.*, 2024). However, research also reveals various organizational barriers that may hinder 3PLs in translating external insights into concrete policies and structural changes, such as the lack of internal frameworks for cross-organizational interaction and ineffective communication (e.g. Isaksson *et al.*, 2017, 2019; Prataviera *et al.*, 2023; Wehner *et al.*, 2022). These challenges underscore the need for 3PLs to establish robust routines and cultural norms that synthesize external engagement with internal adaptive processes. A concept that addresses this need is stakeholder integration (SI), which is defined as a firm's strategic organizational ability to proactively include stakeholder knowledge, values, and resources into its internal decision-making processes, helping it adapt to changing environmental demands (Plaza-Úbeda *et al.*, 2010; Sharma and Vredenburg, 1998).

Research on 3PL also emphasizes the importance of strong management commitment and involvement, high employee awareness, and accumulating green knowledge to overcome internal resistance and organizational inertia (e.g. Evangelista *et al.*, 2017). However, poorly developed organizational structures that fail to communicate green awareness and disseminate green knowledge can lead to fragmented environmental efforts that are disconnected from the 3PL's broader environmental strategy (Björklund and Forslund, 2018; Isaksson *et al.*, 2017; Sallnäs and Huge-Brodin, 2018). In this context, green absorptive capacity (GAC) becomes a critical knowledge-processing capability that should allow 3PLs to purposefully incorporate and utilize external information for green innovations (Abareshi and Molla, 2013; Creazza *et al.*, 2024).

Taken together, numerous researchers have examined the external factors influencing the adoption of green innovation by 3PLs. Studies on internal factors indicate 3PLs need specific routines to support systematic greening. However, a gap persists concerning 3PLs' organizational capabilities that facilitate the dynamic interaction between acquiring and utilizing intangible resources for green innovations. This highlights the need to examine SI and GAC as strategic organizational capabilities that enable 3PLs to transform stakeholder inputs into tangible green innovations. Despite their potential, both capabilities are underexplored in the 3PL context; researchers have barely investigated SI and GAC together or compared their effects across innovation areas (e.g. Creazza *et al.*, 2024; Laguir *et al.*, 2021; Tetteh *et al.*, 2024). Therefore, this study addresses the following research questions:

*RQ1.* To what extent does SI directly influence the adoption of green process innovations in transportation, packaging, warehousing/buildings, and service innovations in 3PLs?

*RQ2.* Does GAC mediate these SI–green innovation relationships?

*RQ3.* Do these effects vary across different subsets of green innovations?

This study builds on the integrative and organizational learning perspectives of the natural-resource-based view (NRBV) to investigate how SI and GAC, distinct yet complementary strategic capabilities, interact to facilitate the adoption of green innovation in 3PLs. To the authors' knowledge, this is among the first empirical studies of SI and GAC interaction in the 3PL context. Using a survey approach, it distinguishes between subsets of green process innovations and the broader scope of green service innovations, building on previous research that often examines these areas in aggregate or separately. It provides empirical evidence on whether SI and GAC affect specific innovation domains differently. The German 3PL market, chosen for its maturity, diverse firm sizes, and high sustainability awareness (e.g. Rapp *et al.*, 2023), serves as the empirical setting.

This paper is organized as follows: Section 2 reviews the theoretical stances and examined constructs, and presents the hypotheses. Section 3 outlines the methodology, while Section 4 presents the results, followed by a discussion in Section 5. Section 6 concludes with the study's limitations and suggestions for future research.

## 2. Theoretical background and hypotheses

### *2.1 Theoretical positioning*

The present study adopts the NRBV as the overarching theoretical lens and concentrates on SI and GAC as two strategic capabilities for two interrelated reasons.

Firstly, the NRBV connects sustained competitive advantage to how firms manage the natural environment and ecological constraints (Hart, 1995; Hart and Dowell, 2011). This view is especially relevant to the logistics sector, where environmental externalities like energy consumption, GHG emissions, packaging waste, and resource depletion are measurable and increasingly reported (Karaman *et al.*, 2020). At the core of the NRBV is an organizational learning rationale, suggesting that firms must continuously acquire and apply environmental knowledge from stakeholders to maintain their advantage (Hart, 1995; Sharma and Vredenburg, 1998). Complementing the NRBV, March's (1991) exploration-exploitation lens explains why external knowledge creates value only when coupled with internal routines for understanding and use. This stakeholder-learning logic is salient for 3PLs, which rarely develop proprietary technologies and thus depend on rapid learning from external partners (Panayides, 2007).

Secondly, the constructs SI and GAC represent operationalizable micro-foundations that translate the NRBV and the more general dynamic capability (DC) framework into daily practice (routines). DC theory explains how firms gain advantages in volatile environments through sensing, seizing, and reconfiguring resources (e.g. Teece *et al.*, 1997). SI should enable firms to sense and seize green knowledge and opportunities through trusted stakeholders (Plaza-Úbeda *et al.*, 2010), while GAC should support the integration of diverse knowledge to reconfigure operations (Todorova and Durisin, 2007; Zahra and George, 2002). Since SI and GAC have been barely examined together in the 3PL context (e.g. Laguir *et al.*, 2021; Tetteh *et al.*, 2024), operationalizing them as complementary NRBV-DC micro-foundations addresses the capability gap identified. More specifically, SI may provide the framework for translating external stakeholder insights into formal policies and structural changes, while GAC encompasses the routines that internally spread green knowledge, stimulate idea generation, and coordinate cross-departmental implementation.

*2.2 Constructs' definition*

*2.2.1 Green innovations in third-party logistics.* 3PLs' green innovations may encompass a range of operational and service-based solutions, often distinguished by whether they primarily impact internal processes or extend outward through collaboration with shippers and other supply chain participants (e.g. Evangelista *et al.*, 2017). However, this approach appears vague, as, for instance, internal improvements often necessitate the acceptance and collaboration of external business partners (e.g. Rogerson and Sallnäs, 2017). In contrast, agreeing on shared green targets with external business partners may also lead to first changes that are primarily internal to the firm (Prataviera *et al.*, 2023). Therefore, the present study aligns with scholars who propose a distinction between green process innovations (GPI) in internal operations and green service innovations (GSIN) (e.g. Huge-Brodin *et al.*, 2020; Isaksson and Huge-Brodin, 2013; Wehner *et al.*, 2022).

The economic value of GPI should be evaluated based on the mechanisms that apply to mitigate the externalities of logistics processes. These entail improving energy and material efficiency, promoting the sustainable use of natural resources, and adopting renewable materials and energy sources (Deckert, 2018). Therefore, GPI can relate to the various functions of logistics, including transportation (GPITR), warehousing/buildings (GPIWB), and packaging (GPIPG). GPITR may incorporate innovations to reduce overall fuel consumption, enhance asset utilization, and optimize transportation policies to mitigate pollution (Evangelista *et al.*, 2017; Maas *et al.*, 2018). GPIPG may involve reducing waste and minimizing the amount and harmfulness of packaging materials (García-Arca *et al.*, 2017; Mahmoudi and Parviziomran, 2020). GPIWB may refer to 3PL's efforts to reduce electricity consumption, integrate renewable energy sources, recover rainwater, minimize the harmful impact of used construction materials, and protect local biodiversity (e.g. Bálint *et al.*, 2021; Laguir *et al.*, 2021).

In contrast, GSIN involves integrating new or different resources and capabilities, leading to an expanded or entirely new bundle of services, thus providing differentiated service offerings (Isaksson and Huge-Brodin, 2013). Such offerings may encompass low-carbon transportation and distribution, carbon footprint measurement and reporting, carbon offsetting, consulting and training, eco-friendly packaging design, or reverse logistics and recycling services (e.g. Evangelista *et al.*, 2017; Huge-Brodin *et al.*, 2020; Jazairy, 2020). Regardless of whether enhancing ordinary services or priced differently, the economic value of GSIN depends on its current and future effectiveness in aiding shippers to achieve their strategic goals (Huge-Brodin *et al.*, 2020).

*2.2.2 Stakeholder integration (SI).* Grounded in the NRBV, this study aligns with Hart's (1995) original notion of *Stakeholder Engagement Capacity,* which refers to a firm's ability to engage and learn from key stakeholders, such as suppliers and customers, ensuring that its environmental strategy aligns with broader societal values (Hart, 1995). Sharma and Vredenburg (1998) broaden this definition by highlighting the potential competitive advantage firms can gain from establishing trust-based relationships with both economic and non-economic stakeholders. They argue that firms with a well-developed SI capability can better identify and assess stakeholders' interests, which may help them to develop tailored strategies (Sharma and Vredenburg, 1998). Ayuso *et al.* (2006) additionally point out that keeping stakeholders informed and consulted on the progress of green innovations is crucial to maintaining an ongoing dialog and alignment. Intense reciprocal interaction may facilitate the joint creation of shared values and trust, which are essential for collaboratively generating knowledge on green issues (Watson *et al.*, 2018).

In this vein, Plaza-Úbeda *et al.* (2010) conceptualize SI as a gradual process in which aligning practices encompass three interrelated sub-dimensions, each defined by formal and informal organizational routines: (1) Knowledge of Stakeholders (KNOW), focusing on understanding stakeholders' interests, needs, and expectations, and gaining knowledge about their goals, capabilities, and the contexts in which they act; (2) Interaction with Stakeholders (INTER), focusing on the nature of the interaction with different stakeholders, including communication, collaboration, negotiation, and conflict resolution mechanisms to establish trust and mutual understanding for knowledge exchange and joint creation; (3) Adaptational Behavior (ADAP), referring to the organization's agility in responding to stakeholder needs and expectations, including its ability in anticipating future needs and modifying organizational structures and policies.

*2.2.3 Green absorptive capacity (GAC).* A company's ability to integrate and use external knowledge internally might be key to successful innovation. As such, Cohen and Levinthal (1990, p. 128) initially define Absorptive Capacity (AC) as *"the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends."* Zahra and George (2002) elaborate on this definition and conceptualize AC as a firm's dynamic knowledge-processing capability characterized by a series of routines that collectively facilitate knowledge acquisition, assimilation, transformation, and exploitation. Todorova and Durisin (2007) reconceptualize AC by arguing that assimilation and transformation should not be viewed as strictly linear, but rather as interrelated processes where knowledge can, and sometimes must, migrate for effective integration. This reconceptualization enables the utilization of external knowledge, even when it does not seamlessly fit within existing cognitive frameworks (Todorova and Durisin, 2007).

Following Todorova and Durisin's (2007) framework, this study adheres to contemporary research in environmental management (e.g. Song *et al.*, 2020) and defines GAC as a firm's capacity to *acquire* (Green Knowledge Acquisition – GKAC), *integrate* (Green Knowledge Integration – GKIN), *and* exploit (Green Knowledge Exploitation – GKEX) external green knowledge. Notably, it emphasizes the *integration* aspect as a combined construct that encapsulates routines for both assimilation and transformation. As such, it acknowledges the complex interplay between these processes and reflects the necessity of a more integrated perspective in managing external knowledge.

A 3PL may benefit from specific processes and routines that help it acquire relevant green knowledge in a rapidly evolving environmental context. For instance, it might establish internal procedures to observe and record environmental legislation, track technological advancements, analyze competitors' green strategies, conduct preliminary environmental reviews, and engage in benchmarking (Abareshi and Molla, 2013; Bálint *et al.*, 2021). Such routines strengthen the GKAC sub-dimension of GAC. They may enhance awareness of environmental issues that affect the 3PL's business, and the information gathered can later guide decision-making processes (Arfi *et al.*, 2018).

Routines that may contribute to a 3PL's strategic flexibility by enhancing its GKIN capacity may encompass establishing measurable environmental goals and associated training programs, implementing lifecycle analysis for operational impact evaluation, and improving collective understanding by collaboratively assessing initial ideas for green innovations (e.g. Abareshi and Molla, 2013; Creazza *et al.*, 2024). A firm's ability to integrate green knowledge is further supported by routines that combine new and existing insights, altering its understanding of the competitive business environment (e.g. Sun and Anderson, 2010). At 3PLs, such routines may include systematic environmental performance measurement, formal processes for sharing best practices, and the systematic conduct of internal environmental audits (Abareshi and Molla, 2013; Björklund and Forslund, 2018; Wehner *et al.*, 2022).

Lastly, leveraging green knowledge entails implementing routines that integrate into the firm's core operations. Such routines may include coordinated improvement and technology deployment plans across the company, which rely significantly on the knowledge, willingness, and influence of 3PL managers to embed environmental considerations into strategic decisions (Creazza *et al.*, 2024; Isaksson *et al.*, 2017). Recent studies also demonstrate how a 3PL can adopt environmentally friendly technologies in daily operations if trained personnel and centralized consultants consistently follow up to ensure ongoing learning (e.g. Bálint *et al.*, 2021), while employees' high operational flexibility promotes experimentation and encourages learning from mistakes (e.g. Centobelli *et al.*, 2020).

### *2.3 Hypothesis development*

*2.3.1 Stakeholder integration and 3PL's green innovation adoption.* Shippers are increasingly interested in green logistics, but are often hesitant to pay higher rates or co-finance investments; consequently, ambitious 3PLs bear the costs and long-term payback periods often alone (e.g. Abbasi and Nilsson, 2016; Björklund and Forslund, 2018). Additionally, integrating emerging technologies into core operations requires interdisciplinary expertise and extensive coordination among stakeholders, creating technological and managerial uncertainties that increase investment risks and make it harder to align with business goals (Centobelli *et al.*, 2020; Prataviera *et al.*, 2023).

Against this backdrop, research highlights the benefits of involving external stakeholders in green innovation processes. Early engagement with technology developers and suppliers provides valuable insights into emerging technologies, supports collaborative feasibility assessments and pilot selection, and reduces integration complexity and the risk of misguided investments, ultimately promoting the adoption of cost-intensive process innovations (Björklund and Forslund, 2018; Prataviera *et al.*, 2024). Likewise, collaborating on green service innovations with relevant external stakeholders may enhance competitive differentiation (Rapp *et al.*, 2023). Networks of key external informants can reduce complexity and lower uncertainty in management decisions, enabling 3PLs to implement their proactive sustainability strategies more effectively. Shippers and their customers can help identify current and future market needs (Huge-Brodin *et al.*, 2020; Jazairy and von Haartman, 2021), while governmental agencies, associations, research institutes, and environmental NGOs can guide regulation, secure external funding, and share best practices (Bálint *et al.*, 2021; Prataviera *et al.*, 2024).

Overall, the literature shows that 3PLs rely on specialized green knowledge from diverse external stakeholders. Integrating such knowledge enables the adoption of new processes and clean technologies, as well as the adjustment of service portfolios to evolving shipper needs. Effective access, however, depends on trust-based collaboration (Blomqvist and Levy, 2006), which is built on identifying external stakeholders with complementary competencies and establishing mechanisms for communication, knowledge sharing, and co-creation (Jazairy *et al.*, 2021; Prataviera *et al.*, 2024). Yet, research indicates that many 3PLs lack formal guidelines and frameworks to structure cross-organizational interactions, resulting in ad hoc collaborations and limited stakeholder input in decision-making. Evidence includes sustainability business cases that do not systematically involve suppliers and customers, thereby missing potential external expertise and co-financing opportunities (Björklund and Forslund, 2019), funding hesitancy where no formal collaborative strategy exists (Mak *et al.*, 2022), or isolated ad-hoc feedback sessions rather than formal working groups, which reduces decision transparency and broader environmental understanding (Björklund and Forslund, 2018, 2019; Prataviera *et al.*, 2023).

Deploying external green knowledge further requires internal alignment with stakeholder expectations. Routines should capture evolving goals and embed stakeholder-driven sustainability criteria in corporate strategy (Huge-Brodin *et al.*, 2020; Prataviera *et al.*, 2024). This usually involves modifying strategic review processes and funding criteria, meeting collaborative measurement and reporting standards, adjusting subcontracting policies (Abbasi and Nilsson, 2016; Björklund and Forslund, 2018; Prataviera *et al.*, 2024), and making organizational changes to enhance responsiveness. These changes include roles focused on environmental issues, cross-organizational innovation teams, and updating responsibilities between local branches and headquarters (Björklund and Forslund, 2018; Isaksson *et al.*, 2017).

Given these empirical indications and building on the theoretical foundation of the NRBV, this study suggests that a stakeholder-oriented capability such as SI should support a more comprehensive and risk-aware adoption of green innovations at 3PLs. Effective SI involves routines for monitoring market and regulatory changes, identifying stakeholders with complementary skills, and understanding evolving expectations (Sharma and Vredenburg, 1998). These routines reduce technological and regulatory uncertainty, as well as the risks of misalignment and conflicts with external stakeholders (Plaza-Úbeda *et al.*, 2010). Additionally, effective SI requires structured collaboration, such as cross-organizational review meetings and steering committees, that foster open knowledge-sharing and institutionalize learning processes, thereby building trust-based relationships (e.g. Sun and Anderson, 2010; Watson *et al.*, 2018). Shared decision-making allows stakeholder voices to be heard and integrated, encourages a sense of joint ownership of green initiatives, and leads to widely accepted outcomes (Plaza-Úbeda *et al.*, 2010; Sharma and Vredenburg, 1998). Predefined conflict resolution mechanisms (such as escalation procedures) prevent derailments and may even create opportunities to refine solutions and strengthen relationships (Sharma and Vredenburg, 1998; Watson *et al.*, 2018). Adaptive behavior refines internal policies and structures in response to stakeholder demands (Plaza-Úbeda *et al.*, 2010).

Accordingly, SI is expected to influence both process innovations (e.g. transportation, warehousing, packaging) and service innovations at 3PLs by aligning with evolving sustainability demands. Consequently, the following hypotheses are derived:

*H1.* SI has a positive effect on (a) GPITR, (b) GPIPG, and (c) GPIWB.

*H2.* SI has a positive effect on GSIN.

Although prior 3PL research acknowledges external stakeholder pressure, the internal routines that enable the effective use of stakeholder knowledge are rarely examined. This study goes beyond identifying external pressure. It explores whether SI, as a strategic organizational capability, impacts the adoption of internal, process-focused innovation (H1a, b, c) and extends to green service offerings (H2).

*2.3.2 Stakeholder integration, green absorptive capacity, and green innovation adoption.* GAC is pivotal for addressing environmental challenges that span organizational, functional, and interdisciplinary boundaries. Firms with strong GAC are better equipped to nurture creativity and generate innovative ideas to tackle environmental issues. This capability stems from access to external information related to sustainable practices and resources, as well as processes and routines that enable a firm to integrate environmental knowledge effectively (Sun and Anderson, 2010). Additionally, GAC enhances implementation by facilitating the sharing and utilization of environmental knowledge across internal units (Aboelmaged and Hashem, 2019).

However, the activation of knowledge absorption necessitates triggers from the external environment. These triggers often arise from a firm's increased embeddedness in societal environmental concerns, inducing it to rethink its strategic orientation toward environmental issues (Arfi *et al.*, 2018; Zahra and George, 2002). The firm's extensive engagement with external stakeholders may directly influence its GAC, as it contributes to defining what knowledge is considered "*valuable*" (Todorova and Durisin, 2007). Identifying and accessing relevant green knowledge sources outside the firm are crucial for effective accumulation over time (Watson *et al.*, 2018). The variety of sources can enhance a firm's GAC, increasing the chances of capturing new knowledge and transforming it into innovations (Arfi *et al.*, 2018). Incorporating stakeholders' views and needs provides opportunities for long-term, trust-based collaboration that may facilitate the development of tacit knowledge gained through experiential learning (Sun and Anderson, 2010). In response to external stakeholders, a firm may also establish flexible internal structures that are open to change. This can enhance information flow, foster the sharing of green knowledge, and integrate stakeholder-driven sustainability criteria into corporate strategy (Ayuso *et al.*, 2006). The continuous inflow of knowledge and an intra-firm knowledge-sharing culture promote the diffusion of green knowledge among functional units, aiding in the understanding, integration, and exploitation of newly acquired green knowledge (Song *et al.*, 2020; Todorova and Durisin, 2007).

Recent case-based investigations underline how 3PLs that systematically engage with external stakeholders succeed in clarifying what knowledge is valuable (e.g. Prataviera *et al.*, 2024; Creazza *et al.*, 2024). Research further confirms that structured interactions with shippers, carriers, technology suppliers, and NGOs promote green knowledge co-creation and encourage experiential learning (Bálint *et al.*, 2021; Prataviera *et al.*, 2024). However, scholars highlight that a 3PL's ability to turn externally gained knowledge into practical solutions depends on well-structured internal integration processes. Proactive 3PLs, for instance, maintain sustainability databases and utilize organized monitoring (e.g. carbon footprint assessments) to set benchmarks for evaluating external recommendations and identifying opportunities for emission and cost reductions (Bálint *et al.*, 2021). Cross-functional routines for analyzing external inputs translate expert knowledge into company-specific language, timelines, and budgets, while small-scale testing helps turn new ideas into validated, practical innovations (Björklund and Forslund, 2018; Creazza *et al.*, 2024; Prataviera *et al.*, 2024). Studies also emphasize the significance of environmental champions or coordinators who help translate stakeholder trends into internal guidelines, pilot projects, and cross-departmental initiatives (Creazza *et al.*, 2024; Prataviera *et al.*, 2024). Internal team members with cross-departmental expertise can coordinate knowledge flows to prevent external ideas from being lost in departmental silos (Prataviera *et al.*, 2024). Ongoing structured training and mentoring programs are essential for enabling employees to adopt new practices quickly (Creazza *et al.*, 2024; Prataviera *et al.*, 2024). Ultimately, engaging with shippers, technology developers, and environmental groups raises awareness and provides valuable insights into sustainable practices and technologies (Evangelista *et al.*, 2017; Prataviera *et al.*, 2024). Increased awareness encourages employees to pursue training and skill development in green practices (Arfi *et al.*, 2018). Meanwhile, managers with a firm grasp of sustainability are more likely to allocate resources to absorption routines and to promote and reward sustainability efforts (Darwish *et al.*, 2020).

Overall, theory and empirical insights suggest that stronger GAC positions 3PLs to identify and integrate green opportunities into core operations, thereby enhancing green innovation outcomes. SI, in turn, facilitates knowledge inflow via long-term stakeholder relationships and organizational adaptability and aids in establishing systems to process external information. Accordingly, incorporating stakeholder perspectives and adjusting to their needs should strengthen absorption routines by redirecting search and increasing the motivation and ability to interpret and use stakeholder-derived green knowledge. The following hypotheses, therefore, specify the mediation role of GAC:

*H3.* GAC positively mediates the relationship between SI and (a) GPITR, (b) GPIPG, and (c) GPIWB.

*H4.* GAC positively mediates the relationship between SI and GSIN.

Figure 1 illustrates the hypothesized relationships, emphasizing GAC's mediating role. The hypotheses extend evidence from a 3PL setting that GAC links external triggers to green adoption. Conceptualized as a knowledge-processing capability, GAC integrates and applies stakeholder-derived inflows generated by SI. Accordingly, H3 and H4 posit that GAC evolves through SI, leading to improved innovation outcomes in 3PL's green processes and services.

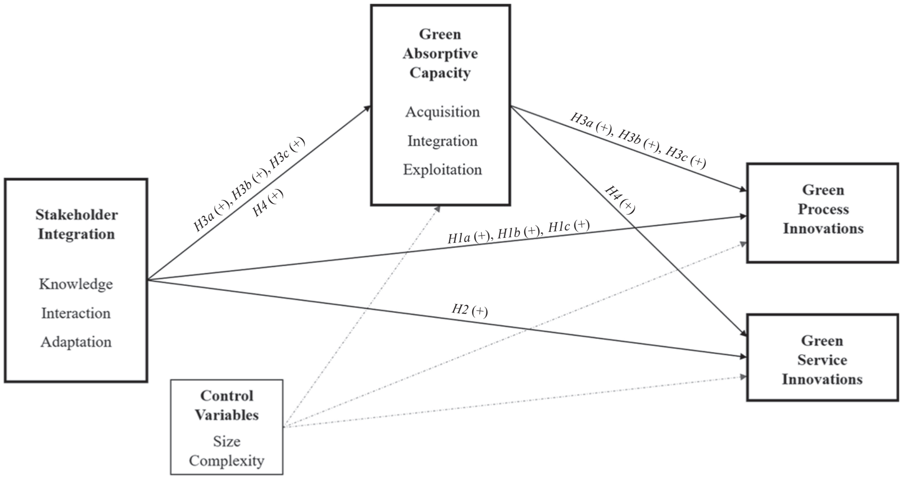


**Figure 1.** Conceptual model

## 3. Methodology

*3.1 Study setting, questionnaire design, and pretest*

The German logistics market was selected for this study because it provides a highly competitive business environment for 3PLs, where society exhibits a high sensitivity to environmental protection (Deckert *et al.*, 2021). Additionally, it is typically characterized by a predominance of small and medium-sized firms that align with regional production and consumption structures (Schwemmer *et al.*, 2020).

The authors developed a survey with four sections: firm characteristics, green innovations, GAC, and SI. Scales from prior studies were used to measure constructs whenever possible (see Table A1). SI was measured using instruments from Plaza-Úbeda *et al.* (2010) and GAC with adapted items from Abareshi and Molla (2013), Gluch *et al.* (2009), Lichtenthaler (2009), and Schmidt (2010), as well as two new items based on Bálint *et al.* (2021). A three-item measurement instrument was developed to assess GPITR, with items adopted from Chu *et al.* (2018), Laguir *et al.* (2021), and Lin and Ho (2011). The instrument encompasses multiple facets of resource efficiency, including innovations to reduce fuel consumption, improve asset utilization, and prevent pollution. Three items have been adopted from Chu *et al.* (2018) to measure GPIPG, thereby also addressing the facets of resource efficiency, such as 3PLs' efforts to reduce overall packaging material, employ reusable or recyclable materials, and alternative eco-friendly options (e.g. biodegradable materials). A five-item measurement instrument was developed to assess GPIWB, with three items from prior studies (Laguir *et al.*, 2021; Lin and Ho, 2011) on reducing electricity use, integrating renewable energy, and minimizing harmful construction materials, while two new items emerged from the qualitative work of Bálint *et al.* (2021) related to rainwater recovery and management and preserving the local biodiversity. All respondents' ratings were captured on a five-point Likert scale, ranging from *strongly disagree* to *strongly agree*. A six-item instrument was developed to assess GSIN, based on the work of Bálint *et al.* (2021) and Chu *et al.* (2018), which includes services such as reverse logistics, low-emission distribution, eco-friendly packaging, and CO2 calculation and offsetting. The development stage was rated on a five-point Likert scale, ranging from *not planned* to *fully implemented*.

Larger 3PLs are more likely to adopt green innovations due to their broader knowledge and greater slack resources (e.g. Chu *et al.*, 2018), while small 3PLs in niche markets often feel less pressure (e.g. Bálint *et al.*, 2021). Thus, the firm size (SIZE) was deemed a relevant control variable, measured by the *number of employees*. Studies also suggest that 3PLs providing cost-efficient, standardized services may benefit more from green innovations than those with more customized services (e.g. Maas *et al.*, 2018). Thus, the complexity of the 3PLs' primary service offerings (CPLX) was employed as a second control variable, assessed on a five-point Likert scale ranging from *fully standardized* to *fully customized*. Firm age was excluded due to incomplete registry data and managers' hesitation to disclose founding dates in pretest interviews. However, studies report that firm age contributes little after size and capability variables are controlled (e.g. Chu *et al.*, 2018; Jazairy *et al.*, 2021). Finally, a latent marker variable (MARK) was incorporated, comprising three items adapted from Daugherty *et al.* (2011) and measured on a five-point Likert scale, ranging from *strongly disagree* to *strongly agree*.

Before disseminating the survey questionnaire to the sample, a two-phase pretest was conducted to validate it. The questionnaire was developed in English and professionally translated into German. Then, two logistics practitioners and three researchers familiar with sustainability were consulted to ensure clarity. After adjusting the questionnaire and removing two ambiguous items, a professional translator translated it back into English to check if the meaning remained similar across both languages. In the second stage, an online survey was tested with six logistics practitioners before its online dissemination.

### *3.2 Data collection and clearance*

This study defines a 3PL as offering bundled services, such as transportation and warehousing, along with value-added activities, aligning with the general German business understanding. Most German 3PLs have emerged from the transportation sector, with non-asset-based 3PLs being the exception and not considered in this study. The sample for this study was obtained from the Dun and Bradstreet corporate database, which includes 5,006 German corporate profiles that provide transportation services for goods. A random sample of 1,400 firms was extracted and reviewed to determine if they meet the definition of a 3PL. Seventy-nine firms were identified as not meeting the definition, and 53 firm profiles were additionally found to be inactive. Consequently, the study targeted 1,268 3PL firms. Efforts were made to obtain the corporate emails of top management responsible for social responsibility or sustainability through websites, social media, or phone calls. When this was not viable, an invitation was sent to the CEO's office email.

A web link to the questionnaire and study info was emailed, emphasizing the importance of participation and anonymity. Data collection lasted 16 weeks with two reminders. Out of 1,268 firms, 156 completed the questionnaire; 18 responses were excluded due to missing values, and 6 for suspicious patterns. Finally, 132 valid responses remained, a 10.4% rate, comparable to other German logistics research (e.g. Maas *et al.*, 2018). This sample size is adequate for mediation analysis with percentile bootstrapping at 0.8 power (Fritz and MacKinnon, 2007). Table 1 presents the firm profiles.

### *3.3 Methodological procedure for data analysis*

To ensure measurement suitability, two Confirmatory Factor Analyses (CFAs) were conducted using AMOS 26: first on the first-order constructs (CFA Model 1), and then including SI and GAC as second-order constructs (CFA Model 2). Thresholds of Hu and Bentler (1999) have been applied to assess the goodness-of-fit indices of both models. Composite Reliability (CR) was calculated based on the CFA factor loadings, assuming all loadings exceeded the benchmark of 0.6 (Collier, 2020). Average Variance Extracted (AVE) was calculated to evaluate convergent validity, expecting that each latent variable explains, on average, at least 50% of the variance of its indicators (Collier, 2020). Discriminant validity was ensured by fulfilling the Fornell and Larcker (1981) criterion and Heterotrait-Monotrait (HTMT) ratio with the cut-off of 0.85 (Henseler *et al.*, 2015). The Target Coefficient (T) was calculated to validate the higher-order structure,

**Table 1.** Firm profiles

| Category | Number of respondents | % |
|---|---|---|
| *Number of employees (SIZE)* | | |
| Less than 51 | 31 | 23.5 |
| 51–100 | 25 | 18.9 |
| 101–500 | 47 | 35.6 |
| 501–1000 | 15 | 11.4 |
| More than 1000 | 14 | 10.6 |
| *Degree of complexity of primary service offerings (CPLX)* | | |
| Only fully standardized | 4 | 3.0 |
| Mostly standardized | 23 | 17.4 |
| Standardized and individualized (approx. to the same extent) | 45 | 34.1 |
| Mostly customized | 53 | 40.2 |
| Only fully customized | 7 | 5.3 |

**Source(s):** Authors' own work

representing the ratio of the $\chi^2$ for CFA Model 1 to the $\chi^2$ for CFA Model 2 (Segars and Grover, 1998).

Hypothesis testing was performed using the bootstrap estimation method with model 4 of Hayes' PROCESS macro, version 4.1, in SPSS 28. Indirect effects often do not follow a normal distribution, especially in smaller samples; thus, bootstrapping is recognized as a robust method for estimating Confidence Intervals (CI) (Hayes, 2022). Moreover, when assessing influence mechanisms, such as in mediation analysis, the bootstrap estimation method is considered not inferior to structural equation modeling (Hayes *et al.*, 2017). In this study, 5,000 bootstrap samples were generated to produce a 95% bias-corrected CI, with significance determined by CIs that do not encompass zero. Since the PROCESS macro is limited to single outcome variable models, four distinct mediation models were run for each green innovation scale: GPITR, GPIPG, GPIWB, and GSIN. A common seed for the random number generator during bootstrapping ensured consistency across the CI of the four mediation models. As the same predictor and mediator are used in all models, the direct and indirect effects on the four outcome variables are the same regardless of whether they are calculated separately or simultaneously (Hayes, 2022). Both control variables, SIZE and CPLX, were included as covariates for the mediator (GAC) as well as for each of the four green-innovation outcomes, ensuring that every path estimate is adjusted.

The mediation analysis initially focused on the direct relationship (path c) between SI and the outcome variable for each mediation model, addressing hypotheses H1a, H1b, H1c, and H2. Then, the effect of SI on the proposed mediator, GAC (path a), was assessed, as a significant effect is a prerequisite for mediation analysis (Hayes, 2022), and, in each model, SI's direct effect on the outcome (path c') was estimated in the presence of the mediator GAC (path b). A bias-corrected bootstrapping mediation test was used to ascertain the significance of the combined paths a*b, thereby addressing hypotheses H3a, H3b, H3c, and H4. Finally, the Completely Standardized Indirect Effect (CSIE) was calculated to compare the mediation effects among different green innovation subsets (Preacher and Kelley, 2011).

## 4. Analysis and results

### *4.1 Common-method bias and non-response bias*

To address Common Method Variance (CMV), this study followed Podsakoff *et al.* (2003). Procedural measures included maintaining respondent anonymity by not collecting personal details and ensuring responses could not be linked to individuals or firms. Respondents were instructed to answer based on their firm's stance on environmental issues, not personal beliefs or values. The questionnaire separated dependent and independent variables, counterbalanced measurement order, used examples to reduce ambiguity, and included several inverse items.

An ex-post analysis involved a rigorous marker variable test (Simmering *et al.*, 2014). Initially, this approach involves adding the marker variable to the first-order confirmatory factor model, showing it freely influences other latent construct indicators, known as the unconstrained model. In the second step, all paths from the marker variable to the indicators are constrained to zero. A chi-square difference test delivered a *p*-value above 0.05, suggesting no significant response bias in the measurement model. Thus, it is reasonable to assume that CMV does not substantially threaten the study's findings.

Moreover, assuming that late respondents are likely to exhibit similar response behavior to non-respondents, a wave analysis (Wagner and Kemmerling, 2010) was conducted to assess potential non-response bias. A comparison of the mean values of early and late respondents delivered no significant differences, suggesting that non-response bias is not a substantial threat to the findings.

### *4.2 Measurement model assessment*

The analysis initially focused on first-order constructs (CFA model 1: $\chi 2 = 1085.530$; df = 799; CFI = 0.917; SRMR = 0.060; RMSEA = 0.052; PClose = 0.310) and incorporated SI and GAC later as second-order constructs (CFA model 2: $\chi 2 = 1146.879$; df = 827; CFI = 0.907; SRMR = 0.071; RMSEA = 0.054; PClose = 0.174). All goodness-of-fit indices of both CFA models exceed the commonly accepted thresholds suggested by Hu and Bentler (1999), thus supporting the hypothesized measurement models. Tables A1 and A2 provide a detailed overview of the deployed items and their loadings. All loadings exceed the benchmark of 0.6 ($p < 0.001$) (Collier, 2020). Table A2 also presents the regression weights of GAC and SI on their sub-dimensions (CFA Model 2), all of which indicate statistical significance at $p < 0.001$.

In both CFA models, all latent constructs yielded CR values exceeding the commonly accepted benchmark value of 0.7 (Collier, 2020), thereby reinforcing the internal consistency of the deployed items. Again, in both CFA models, all AVE values meet the expected minimum threshold of 0.5 (Collier, 2020). Data analysis revealed acceptable discriminant validity in both CFA models, as the square root of the AVE for each latent construct exceeded its correlation with the others (Fornell and Larcker, 1981). The results of the validity analyses are presented in Tables 2 and 3. The square root of AVE appears along the diagonal, while the correlations between the constructs are shown below the diagonal. The HTMT ratio for SI and GAC is 0.49 (<0.85), confirming discriminant validity between the constructs (Henseler *et al.*, 2015). Finally, $T = 0.946$, which is above the 0.7 threshold, justifying the use of the second-order model (Segars and Grover, 1998).

### *4.3 Hypothesis testing*

In line with recent literature, hypotheses H1a, H1b, H1c, and H2 propose a direct relationship between SI and the various subsets of 3PLs' green innovation. By controlling for the covariates SIZE and CPLX, the statistical results initially revealed a positive direct effect of SI on all dependent variables. However, a significant coefficient for path c is observed only for GPIPG ($\beta = 0.291$, $p < 0.05$) and GSIN ($\beta = 0.381$, $p < 0.01$), thus supporting H1b and H2. The coefficients for GPITR ($\beta = 0.130$, $p = 0.24$) and GPIWB ($\beta = 0.092$, $p = 0.765$) prove insignificant, indicating a lack of support for hypotheses H1a and H1c.

The relationship between SI and GAC (path a) proves significant ($\beta = 0.371$, $p < 0.001$), which fulfills the precondition for mediation. In the presence of the mediator, the direct effect of SI on the dependent variables (path c') is, in all cases, insignificant. Mediation analysis in all four models revealed a significant indirect effect (paths a*b), indicating that GAC fully mediates the relationship between SI and the various green innovation subsets. These findings

**Table 2.** Validity analysis for CFA model 1 (first order constructs)

| Constructs | M | SD | CR | AVE | MSV | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GPITR (1) | 4.012 | 0.880 | 0.776 | 0.537 | 0.323 | *0.733* | | | | | | | | | | |
| GPIPG (2) | 3.186 | 0.969 | 0.784 | 0.547 | 0.196 | 0.416$^{**}$ | *0.740* | | | | | | | | | |
| GPIWB (3) | 3.051 | 0.994 | 0.843 | 0.518 | 0.323 | 0.569$^{***}$ | 0.419$^{***}$ | *0.720* | | | | | | | | |
| GSIN (4) | 2.577 | 1.118 | 0.847 | 0.583 | 0.392 | 0.442$^{***}$ | 0.343$^{**}$ | 0.539$^{***}$ | *0.764* | | | | | | | |
| KNOW (5) | 3.223 | 0.897 | 0.855 | 0.597 | 0.582 | 0.198 | 0.207 | 0.310$^{**}$ | 0.410$^{***}$ | *0.772* | | | | | | |
| INTER (6) | 2.872 | 0.882 | 0.930 | 0.726 | 0.582 | 0.194 | 0.216$^{*}$ | 0.201 | 0.377$^{***}$ | 0.763$^{***}$ | *0.852* | | | | | |
| ADAP (7) | 3.371 | 0.830 | 0.905 | 0.704 | 0.445 | 0.185 | 0.280$^{*}$ | 0.099 | 0.196 | 0.532$^{***}$ | 0.667$^{***}$ | *0.839* | | | | |
| GKAC (8) | 3.075 | 0.863 | 0.768 | 0.524 | 0.422 | 0.402$^{**}$ | 0.438$^{***}$ | 0.516$^{***}$ | 0.626$^{***}$ | 0.574$^{***}$ | 0.317$^{**}$ | 0.309$^{**}$ | *0.724* | | | |
| GKIN (9) | 3.071 | 1.193 | 0.923 | 0.706 | 0.470 | 0.296$^{*}$ | 0.443$^{***}$ | 0.506$^{***}$ | 0.586$^{***}$ | 0.577$^{***}$ | 0.441$^{***}$ | 0.163 | 0.649$^{***}$ | *0.840* | | |
| GKEX (10) | 3.268 | 0.877 | 0.871 | 0.629 | 0.470 | 0.435$^{***}$ | 0.376$^{**}$ | 0.473$^{***}$ | 0.523$^{***}$ | 0.412$^{***}$ | 0.348$^{**}$ | 0.247$^{*}$ | 0.581$^{***}$ | 0.685$^{***}$ | *0.793* | |
| MARK (11) | 3.005 | 0.783 | 0.769 | 0.531 | 0.048 | 0.096 | 0.032 | 0.169 | 0.220 | 0.002 | 0.168 | 0.124 | 0.106 | 0.189 | 0.056 | *0.729* |

**Note(s):** $n = 132$; ***$p < 0.001$; **$p < 0.01$; *$p < 0.05$

**Source(s):** Authors' estimation based on AMOS 26

**Table 3.** Validity analysis for CFA model 2 (SI and GAC as second order constructs)

| Constructs | M | SD | CR | AVE | MSV | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GPITR (1) | 4.012 | 0.880 | 0.776 | 0.537 | 0.325 | *0.733* | | | | | | |
| GPIPG (2) | 3.186 | 0.969 | 0.785 | 0.549 | 0.261 | 0.416$^{***}$ | *0.741* | | | | | |
| GPIWB (3) | 3.051 | 0.994 | 0.843 | 0.518 | 0.375 | 0.570$^{***}$ | 0.411$^{***}$ | *0.720* | | | | |
| GSIN (4) | 2.577 | 1.118 | 0.847 | 0.583 | 0.504 | 0.443$^{***}$ | 0.341$^{**}$ | 0.539$^{***}$ | *0.764* | | | |
| GAC (5) | 3.138 | 0.856 | 0.847 | 0.648 | 0.504 | 0.445$^{***}$ | 0.511$^{***}$ | 0.612$^{***}$ | 0.710$^{***}$ | *0.806* | | |
| SI (6) | 3.134 | 0.749 | 0.860 | 0.676 | 0.312 | 0.217 | 0.252$^{*}$ | 0.245$^{*}$ | 0.412$^{***}$ | 0.559$^{***}$ | *0.822* | |
| MARK (7) | 3.005 | 0.783 | 0.769 | 0.532 | 0.048 | 0.091 | 0.019 | 0.165 | 0.220 | 0.160 | 0.139 | *0.730* |

**Note(s):** $n = 132$; $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

**Source(s):** Authors' estimation based on AMOS 26 support hypotheses H3a, H3b, H3c, and H4, as detailed in Table 4. Noteworthy differences in CSIE highlight the magnitudes of GAC's mediating role on the influence of SI across the green innovation subsets. Therefore, discussing the results separately for each green innovation subset is reasonable.

Finally, SIZE proves to be a statistically significant covariate for GAC ($\beta = 0.228$, $p < 0.001$) and GPIWB ($\beta = 0.148$, $p < 0.05$), indicating a meaningful role in the relationships being studied. In contrast, CPLX proves to be insignificant in all models. The two control variables are effectively independent of one another ($r = 0.05$, $p = 0.60$). Collinearity diagnostics with maximum VIF = 1.46 and a minimum tolerance of 0.68 fall well below accepted cut-offs (Collier, 2020), confirming that neither SIZE, CPLX, nor the main predictors distort the path estimates.

*4.4 Endogeneity*

Capabilities in routine-based literature are viewed as stable, path-dependent constructs that develop over time and precede discrete innovation events (e.g. Eisenhardt and Martin, 2000; Teece *et al*., 1997). Similarly, the NRBV (e.g. Ayuso *et al*., 2006; Hart, 1995; Sharma and Vredenburg, 1998) and organizational learning theory (March, 1991) emphasize that external exploration necessitates internal exploitation routines for innovation, highlighting capabilities as key antecedents. In this study, both SI and GAC are understood as evolving through the accumulation of organizational experience and sustained stakeholder engagement. It is theoretically implausible that a single innovation event could materially reshape either capability in the short term (cf. Panayides, 2007).

To assess reverse causality between GAC and SI, a supplementary mediation model was estimated for each innovation subset, with GAC as the predictor and SI as the mediator. Control variables (SIZE and CPLX) were retained in all models. Across all four models, indirect effects were small and statistically non-significant (largest CSIE = 0.032, all CIs included zero). Meanwhile, GAC's direct effects on innovation outcomes remained positive and significant ($\beta$ range = 0.291–0.677, $p < 0.01$), indicating that SI does not carry the causal influence of GAC.

Overall, the theoretical rationale and the absence of empirical support for reverse causality suggest that SI and GAC can be interpreted as plausible exogenous antecedents to green innovations. In line with the recommendations of Ketokivi and McIntosh (2017), the authors adopt a pragmatic approach, acknowledging that while endogeneity cannot be entirely ruled out, the combined theoretical and empirical evidence suggests that its influence is unlikely to bias the findings.

## 5. Discussion and implications

*5.1 Discussion*

*5.1.1 Green process innovations in transportation (GPITR).* This study reveals a small, insignificant direct effect of SI on GPITR (H1a), suggesting that external stakeholders may exert less direct influence on this category of green innovations. Prior research highlights that transportation's operational and technological intricacies are often not fully apparent to external stakeholders (e.g. Sanchez-Rodrigues *et al*., 2010). What may begin as strong environmental demands can fade if shippers or other parties lack deeper insights into the 3PL's operational reality (Sallnäs and Huge-Brodin, 2018). The insignificant effect of SI on GPITR in this study suggests that, although external stakeholders express concerns regarding the environmental impact of transportation, other factors (e.g. technological suitability or economic considerations) may outweigh the importance of a 3PL's ability to incorporate external stakeholder perspectives and requirements.

This study employs a cross-sectional survey, so the coefficients indicate associations rather than proven temporal causality; however, they enable the examination of indirect effects.

**Table 4.** Summary of mediation analyses

| Testing paths | SE | CI (95%) Lower bound | Upper bound | $\beta$ | t-value | Conclusion |
|---|---|---|---|---|---|---|
| *Mediation model 1* | | | | | | |
| Path c: "DV: GPITR" $R^2 = 0.068$; $F = 3.15^{*}$ | | | | | | |
| IV: SI | 0.112 | −0.901 | 0.351 | 0.130 | 1.159$^{n.s.}$ | H1a => not supported |
| Path a: "DV: GAC" $R^2 = 0.315$; $F = 19.66^{***}$ | | | | | | |
| "IV: SI" | 0.093 | 0.186 | 0.556 | 0.371 | 3.978$^{***}$ | |
| Path b and c': "DV: GPITR" $R^2 = 0.124$; $F = 4.495^{**}$ | | | | | | |
| IV: SI (c') | 0.115 | −0.207 | 0.250 | 0.021 | 0.185$^{n.s.}$ | |
| IV: GAC (b) | 0.103 | 0.087 | 0.496 | 0.291 | 2.826$^{**}$ | |
| Indirect effect (a*b) | | 0.028 | 0.219 | 0.108 | | H3a => supported, full mediation |
| CSIE | | 0.023 | 0.188 | 0.092 | | |
| *Mediation model 2* | | | | | | |
| Path c: "DV: GPIPG" $R^2 = 0.067$; $F = 3.08^{*}$ | | | | | | |
| IV: SI | 0.123 | 0.472 | 0.535 | 0.291 | 2.361$^{*}$ | H1b => supported |
| Path b and c': "DV: GPIPG" $R^2 = 0.173$; $F = 6.66^{***}$ | | | | | | |
| IV: SI (c') | 0.123 | −0.118 | 0.370 | 0.125 | 1.017$^{n.s.}$ | |
| IV: GAC (b) | 0.110 | 0.227 | 0.664 | 0.445 | 4.037$^{***}$ | |
| Indirect effect (a*b) | | 0.053 | 0.293 | 0.165 | | H3b => supported, full mediation |
| CSIE | | 0.039 | 0.232 | 0.128 | | |
| *Mediation model 3* | | | | | | |
| Path c: "DV: GPIWB" $R^2 = 0.145$; $F = 7.275^{***}$ | | | | | | |
| IV: SI | 0.121 | −0.147 | 0.332 | 0.092 | 0.765$^{n.s.}$ | H1c => not supported |
| Path b and c': "DV: GPIWB" $R^2 = 0.269$; $F = 11.73^{***}$ | | | | | | |
| IV: SI (c') | 0.119 | −0.326 | 0.144 | −0.091 | −0.763$^{n.s.}$ | |
| IV: GAC (b) | 0.106 | 0.283 | 0.704 | 0.494 | 4.647$^{***}$ | |
| Indirect effect (a*b) | | 0.068 | 0.323 | 0.183 | | H3c => supported, full mediation |
| CSIE | | 0.049 | 0.248 | 0.138 | | |
| *Mediation model 4* | | | | | | |
| Path c: "DV: GSIN" $R^2 = 0.170$; $F = 8.769^{***}$ | | | | | | |
| IV: SI | 0.134 | 0.115 | 0.646 | 0.381 | 2.837$^{**}$ | H2 => supported |
| Path b and c': "DV: GSIN" $R^2 = 0.354$; $F = 17.45^{***}$ | | | | | | |

(*continued*)

**Table 4.** Continued

| Testing paths | SE | CI (95%) Lower bound | Upper bound | $\beta$ | t-value | Conclusion |
|---|---|---|---|---|---|---|
| IV: SI (c') | 0.126 | −0.120 | 0.378 | 0.129 | 1.025$^{n.s.}$ | |
| IV: GAC (b) | 0.112 | 0.454 | 0.900 | 0.677 | 6.021$^{***}$ | |
| Indirect effect (a*b) | | 0.101 | 0.421 | 0.251 | | H4 => supported, full mediation |
| CSIE | | 0.064 | 0.286 | 0.168 | | |

**Note(s):** $n = 132$; $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$; n.s. = not significant; CSIE = Completely Standardized Indirect Effect

**Source(s):** Authors' estimation based on Hayes' PROCESS macro 4.1 in SPSS 28

Mediation analysis reveals that SI influences GPITR indirectly through GAC, indicating full mediation. Although small (CSIE = 0.092), the effect is significant, implying that SI can have an impact if a 3PL's GAC routines respond effectively. This aligns with Navarro *et al*. (2018) and Navarro and Haag (2024), demonstrating that freight firms can convert even modest external insights into environmental improvements by integrating knowledge and quality management methods.

Supporting this view, this study found high GPITR maturity among 3PLs (M = 4.012), which aligns well with previous research (e.g. Laguir *et al*., 2021). Earlier research also shows that external stakeholders often have the most influence on the adoption of green innovation during its early stages (Björklund and Forslund, 2018; Jazairy and von Haartman, 2021). It is likely that input from external stakeholders played a significant role in shaping the development of GPITR at an initial stage among the surveyed 3PLs. However, evolving collaboration mechanisms may improve and standardize innovations, prompting 3PLs to meet industry benchmarks (Jazairy *et al*., 2021), such as adopting fuel reduction and transport optimization technologies (Centobelli *et al*., 2020). Consequently, GPITR may increasingly rely on operational proficiency, technological advancements, and strategic positioning, which could explain GAC's comparatively weak mediation among the 3PLs surveyed. Moreover, the observed maturity level (M = 4.012) may represent rather the upper end of industry practices, as the sample in this study overrepresents larger 3PLs that typically deploy advanced fleet- and fuel-efficiency management systems (e.g. Evangelista *et al*., 2018).

*5.1.2 Green process innovations in warehousing/buildings (GPIWB).* Green process innovations related to warehouses/buildings exhibit an overall moderate mean value (M = 3.0515) in this study, indicating further potential for adoption. Deployed items measuring GPIWB levels address reducing electricity use, integrating renewables, rainwater management, minimizing building material footprints, and promoting biodiversity. Such process innovations require broad expertise from architects, environmental consultants, energy specialists, and regulatory bodies (Grant *et al*., 2022). The statistical analysis, however, revealed a weak and insignificant direct relationship between SI and GPIWB, indicating 3PLs' innovation efforts may not directly resonate with external stakeholders. Warehouses emit fewer emissions than transportation, so greening has been less prioritized by many 3PLs (Bartolini *et al*., 2019). Their complex operations often also go unnoticed by external stakeholders due to less visibility and immediacy compared to consumer-facing initiatives (Goh, 2019). Their design generally follows industry standards (Grant *et al*., 2022). The study's single-country scope may partially contribute to this finding. Germany's comparatively strict building codes may limit stakeholder leverage once regulatory compliance is achieved. Smaller 3PLs or those with leased facilities face challenges in implementing green improvements because of limited capital, shorter planning horizons, and reliance on landlords (Goh, 2019).

This study reveals a positive and significant full mediation through GAC (CSIE = 0.1385), underscoring the critical mechanisms through which SI translates into tangible innovations. The literature recognizes that facility-oriented improvements may demand cooperative, partnership-based approaches. Colicchia *et al.* (2013) showcase that energy-efficiency retrofits require co-development agreements among the 3PL, landlords, and technology suppliers. Similarly, Sallnäs and Huge-Brodin (2018) emphasize that simple demands from a distant stakeholder rarely suffice when significant investments or joint problem-solving are required. 3PLs must collaborate closely with property owners, energy suppliers, and shippers for significant building-related green innovations. Yet, large-scale warehouse innovations at 3PLs still hinge on internal prioritization and routines for cross-functional coordination; otherwise, partnership efforts stall at the conceptual stage (Creazza *et al.*, 2024; Evangelista *et al.*, 2017; Goh, 2019).

Hence, this study suggests that unlocking SI's potential for GPIWB depends on 3PLs' efficacy in combining external partnerships with intense, building-oriented knowledge-processing routines. Enabling 3PLs to meaningfully embed environmental imperatives into warehouse design, landscaping, retrofits, and ongoing operations should require an advanced internal apparatus capable of understanding, processing, and applying green knowledge based on external feedback. However, given the moderate adoption level (M = 3.0515) and the sample size composition in this study, these conclusions should be treated cautiously for small and micro-sized 3PLs, which typically lease rather than own facilities.

*5.1.3 Green process innovations in packaging (GPIPG).* Packaging has become a key component of bundled, value-added services typical of modern 3PL contracts, thereby spurring also the strategic importance of eco-friendly alternatives (Mahmoudi and Parviziomran, 2020). In this study, GPIPG includes items that reduce packaging materials by using reusable, recyclable, and eco-friendly options, such as recycled plastics or biodegradable materials. The result exhibits a moderate overall mean value (M = 3.1869), indicating further potential for adoption. This is reasonable, given that sustainability in packaging remains a relatively new topic for many German 3PLs (Deckert *et al.*, 2021). The significant relationship between SI and GPIPG reflects the surveyed 3PLs' alignment with their external stakeholders' expectations by implementing actionable measures in response, which resonates with recent investigations in the German logistics industry (e.g. Rapp *et al.*, 2023). Nevertheless, the sample is dominated by medium- and large-sized 3PLs that typically handle packaging internally. Thus, the significant effect in this study may overstate the strength of the relationship for smaller 3PLs.

This study reveals a positive and significant full mediation through GAC (CSIE = 0.1279), indicating the critical role of GAC in this context. Adopting eco-friendly materials requires an in-depth understanding of material science and machinery adjustments to accommodate such materials. Additionally, 3PLs must consider consumer preferences for market-friendly packaging designs and conduct internal testing of potentially new packaging solutions to ensure the efficient and safe handling, transportation, and storage of goods (García-Arca *et al.*, 2017; Mahmoudi and Parviziomran, 2020). Given these complexities, GAC is vital as it represents a 3PL's ability to recognize, acquire, integrate, and exploit new green knowledge in packaging operations.

In this context, external stakeholders, particularly research institutes, material suppliers, and shippers, should be more than just information providers; they may also serve as orientation guides, helping 3PLs navigate the complex landscape of multidisciplinary knowledge. A well-developed SI capability should ensure ongoing interaction and enhance 3PLs' strategic flexibility and ability to respond to environmental challenges. Shippers, however, often seem reluctant to share knowledge because they may still view green packaging as their eco-design responsibility (Jazairy *et al.*, 2021). Nevertheless, as outsourcing progresses, shippers' needs will likely evolve, and 3PLs that proactively gather and integrate green knowledge will be best positioned to respond to shippers' upcoming requirements most swiftly (Borgström *et al.*, 2021).

*5.1.4 Green service innovations (GSIN).* This study assesses the development of GSIN among German 3PLs through items related to low- or zero-emission distribution, carbon footprint reporting and offsetting, reverse logistics, and recycling services. Recent case studies show a rising trend among German 3PLs toward stakeholder-centric strategies (e.g. Rapp *et al.*, 2023). In contrast, this study demonstrates a comparatively low mean value for GSIN (M = 2.5777) but reveals a full mediation between SI and GSIN through GAC, with a relatively strong effect size (CSIE = 0.1686). This suggests that, despite 3PLs' organizational ability to collaborate and adapt, strong internal knowledge routines are essential for turning external insights into market-ready green services.

These findings are reasonable since green service innovations involve multiple phases and require significant coordination efforts (Björklund and Forslund, 2018). Creating new green services demands cross-disciplinary expertise beyond standard 3PL capabilities and involves advanced technologies that are typically beyond their usual scope. For example, estimating a shipment's carbon footprint accurately requires expertise in algorithms, big data, and environmental science, making reliance on in-house resources challenging for 3PLs (Abbasi and Nilsson, 2016). The ability of 3PLs to combine green innovations is essential for developing comprehensive solutions that address multiple environmental issues. This highlights the importance of long-term partnerships with technology companies, research institutes, and offset providers to share and implement green technologies and practices (Centobelli *et al.*, 2020; Prataviera *et al.*, 2024; Jazairy *et al.*, 2021).

However, GSIN is defined not only by novelty and environmental alignment but also by commercial feasibility. In Germany, a trend is emerging where 3PLs are shifting their operational focus to meet green demands through collaboration, such as co-funded projects and risk-sharing (Jazairy and von Haartman, 2020; Rapp *et al.*, 2023). This shift may require internal changes, such as hiring staff with analytical skills to turn sustainability inputs into service innovations. Although GSIN maturity is low in this sample, the mediation of SI through GAC highlights the importance of internal capacity-building.

### *5.2 Theoretical implications*

This research, grounded in the integrative and organizational learning perspectives of the NRBV, contributes to discourse on environmental management in the 3PL industry. It offers empirical insights into the organizational factors that foster green innovations. While previous studies have recognized that external stakeholders exert pressure and may encourage greener solutions among 3PLs (e.g. Chu *et al.*, 2018; Jazairy and von Haartman, 2020), this study examines two strategic organizational capabilities, SI and GAC, in a 3PL-specific context. In particular, it highlights that a 3PL's aptitude for understanding and adapting to external stakeholder knowledge and demands (SI) alone is rarely enough to ensure the adoption of green process or service innovations unless internal routines (GAC) can integrate and exploit those external inputs. This result refines the conversation around how stakeholder-driven environmental demands translate into implementation when organizational learning routines (March, 1991; Panayides, 2007), such as those related to SI and GAC, are developed.

Prior research has acknowledged the general importance of GAC in 3PL settings (e.g. Abareshi and Molla, 2013; Creazza *et al.*, 2024); however, this study empirically evidences its mediating role between SI and multiple green innovation domains. The study reveals differing CSIE sizes, indicating variations in GAC's mediating strengths across green process innovation areas, such as transportation, packaging, warehousing/buildings, and green services. This variation suggests that GAC's transformative potential depends on context and maturity. It highlights the need for tailored strategies in adopting diverse green innovations and calls for further research in the 3PL context.

Finally, this study's operationalization of GAC and distinct green innovation subsets provides a valuable framework for future research. The scales used to assess GAC and measure the subsets of green innovations provide a strong methodological foundation for future studies, potentially encouraging a more standardized approach to evaluating different types of green innovation in the 3PL context.

### *5.3 Managerial implications*

This study provides valuable insights for practitioners in the 3PL industry, highlighting the importance of a strategic approach to SI in promoting green innovation. Such an approach involves building relationships with external stakeholders and integrating their views into green innovation processes. Managers should allocate resources to identify and analyze the interests and expertise of stakeholders. Long-term relationships with key stakeholders can help in better understanding their needs and facilitate knowledge sharing, thereby staying ahead of trends and aligning strategies with environmental and societal expectations.

The findings also emphasize the significance of developing GAC as a strategic capability that translates external insights into tangible innovations. Managers of 3PLs should enhance their firm's GAC through training programs that improve employees' proficiency in specific sustainability areas, ensuring that environmental knowledge can be transformed into tangible innovations. This should be complemented by routines that facilitate knowledge sharing and learning, along with infrastructure that captures and distributes green expertise and best practices.

Having underscored the significance of SI and GAC in promoting green innovation, the findings also reveal that their impact varies across different types of green innovations. These results suggest that 3PLs should adopt tailored approaches to meet the specific needs of their shippers. For instance, strategies for green innovations in transportation might differ from those in warehousing or packaging. Accordingly, different intensities of engagement with various stakeholder groups may be reasonable, depending on the innovation focus, while adopting unique knowledge management practices may be required. Managers should recognize these nuances, which can help allocate resources efficiently and develop innovation strategies that are more likely to succeed.

It is essential to note that 3PLs vary in terms of size and financial resources. Large 3PLs often enhance stakeholder engagement through dedicated innovation teams and cross-functional groups. Indeed, data analysis revealed SIZE as a significant covariate for GAC, suggesting stronger routines for integrating green knowledge. However, smaller 3PLs may still advance through gradual, network-oriented steps, e.g. by joining industry forums and associations, forming local partnerships, and collaborating with other smaller 3PLs, to manage limited resources while benefiting from external knowledge. Smaller 3PLs can further build internal capacity by sending key personnel to external workshops and courses and establishing a small group of influential green champions to develop and coordinate routines for knowledge dissemination and collaborative interpretation. Even if partially informal, such measures may help smaller 3PLs to integrate environmental expertise into day-to-day operations.

Ultimately, a long-term commitment to sustainability is crucial for advancing green innovation, regardless of the size and scope of 3PLs. Managers should align innovation with strategic goals and ensure shared commitment to sustainability. However, while larger 3PLs can implement comprehensive sustainability plans, smaller ones may set incremental targets aligned with their current operational strengths in their field of specialization.

## 6. Conclusions, limitations, and future directions of research

While 3PLs recognize the need to reduce environmental impacts, they struggle to operationalize these insights. There is consensus on sustainability goals, but little clarity on integrating them into daily practices (e.g. Centobelli *et al.*, 2020; Prataviera *et al.*, 2024). This implementation disorder (Huge-Brodin *et al.*, 2020) underscores the importance of examining organizational capabilities that transform external environmental needs into tangible innovations (e.g. Laguir *et al*., 2021; Tetteh *et al*., 2024). Using the organizational learning perspective of the NRBV, this study examines how two strategic capabilities (SI and GAC) support the adoption of green innovations in the 3PL industry; an area that has been underexplored in prior research.

The results indicate that 3PLs' success in green innovation hinges on systematically embedding external insights into the firm's core processes and service offerings. Therefore, the findings confirm that stakeholder input alone is rarely sufficient for the adoption of green innovation. Instead, SI stimulates external knowledge inflow, which 3PLs evaluate, integrate, and exploit through robust GAC routines. Mediation analyses revealed that GAC fully mediates the relationship between SI and each subset of green innovations. These results align with organizational learning theories (March, 1991; Panayides, 2007), emphasizing the need for 3PLs to develop internal routines that translate external stakeholder expectations into green innovations, rather than relying solely on external influence as a driver. However, the magnitude of the mediation effects (CSIE) differs, indicating that GAC's transformative capacity can vary depending on the complexity and maturity of each innovation domain.

This study also acknowledges limitations that must be noted when interpreting the results. Although the sample size is sufficient for conducting mediation analysis with bootstrapping estimation, it limits the generalizability of the results. Replicating the study with a larger sample size could allow a more refined understanding of the investigated relationships. Additionally, the sample included a variety of 3PLs, but it did not separately analyze subgroups such as those based on firm size, specialization, and operating mode. Further research should explore smaller 3PLs more explicitly to uncover how limited resource capacity or specific market niches may influence the proposed relationships. For instance, some smaller 3PLs may outsource packaging; thus, the SI to GPIPG relationship observed among predominantly larger, in-house operators may be weaker in that segment. Targeted studies on small-sized 3PLs should clarify such nuances.

Moreover, this study's single-country focus (Germany) may limit the applicability of the findings. Cultural and regulatory factors vary in other countries. Future research should replicate the framework across multiple countries to validate its applicability and generalizability. Investigating whether external stakeholders play a more prominent role in stakeholder-oriented economies than in shareholder-oriented ones could be particularly revealing.

This study's cross-sectional, quantitative approach also limits its ability to capture dynamic organizational processes involved in green innovation adoption over time. Longitudinal and qualitative methods, such as interviews and ethnographic studies, can provide valuable insights into how SI and GAC evolve, particularly during market shifts, the introduction of new regulations, or the emergence of disruptive technologies. Qualitative studies may also provide deeper insights into how top managers and employees evaluate trade-offs, such as cost, feasibility, and stakeholder interests, particularly for profit-constrained 3PLs.

(The Appendix follows overleaf)

## Appendix

**Table A1.** Constructs and items used in the survey

| Constructs | Item | | References |
|---|---|---|---|
| Stakeholder Integration (SI) | | | |
| Knowledge (KNOW) | KNOW1 | In our company, we keep documented information on the previous relationships with relevant stakeholders (important meetings, conflicts, agreements, judicial or extrajudicial demands, etc.) | Plaza-Úbeda *et al*. (2010) |
| | KNOW2 | In our company, we collect knowledge of all stakeholders and their demands | |
| | KNOW3 | In our company, we have a lack of information and documentation on stakeholders' demands (r) | |
| | KNOW4 | In our company, we dedicate little time and few resources to knowing the characteristics of our stakeholders (r) | |
| Interaction (INTER) | INTER1 | In our company, we conduct frequent meetings with our relevant stakeholders | |
| | INTER2 | In our company, we dedicate time and resources to assessing and prioritizing the demands of the different stakeholders | |
| | INTER3 | In our company, we often consult the relevant stakeholders and ask them for information before making decisions | |
| | INTER4 | In our company, we proceed with intense formal or informal cooperation with the relevant stakeholders | |
| | INTER5 | In our company, we ensure that relevant stakeholders participate in the decision-making processes | |
| Adaptation (ADAP) | ADAP1 | In our company, we make a special effort to prepare the information for the different stakeholders[b] | |
| | ADAP2 | In our company, we have frequent managerial debates about the demands of the relevant stakeholders | |
| | ADAP3 | In our company, we are willing to change our objectives and priorities in line with relevant stakeholders' demands | |
| | ADAP4 | In our company, we are willing to implement organizational changes following key stakeholders' demands | |
| | ADAP5 | In our company, we dedicate little time and few resources to adapting to relevant stakeholders' demands (r) | |
| Green Absorptive Capacity (GAC) | | | |
| Green knowledge acquisition (GKAC) | GKAC1 | Our company acquires information on society's environmental demands, legislation, and technological development | Abareshi and Molla (2013), Bálint *et al.* (2021), Gluch *et al.* (2009), Lichtenthaler (2009), Schmidt (2010) |
| | GKAC2 | Our company carries out initial environmental reviews[a] | |
| | GKAC3 | Our company is aware of competitors green technologies/ practices | |
| | GKAC4 | Our company carries out market research for sustainability-related issues[b] | |
| | GKAC5 | Our company carries out ecological benchmarks | |
| Green knowledge integration (GKIN) | GKIN1 | Our company has set up measurable environmental goals | |
| | GKIN2 | Our company encourages its employees to participate in environmental training programs | |
| | GKIN3 | Our company applies routines for assessing the environmental impact of its operations and services, e.g., through life cycle analysis | |
| | GKIN4 | Our company has routines for collaborative interpretation and assessment of changing market demands and technological developments[b] | |
| | GKIN5 | Our company has routines for collective understanding and evaluation of initial ideas for green innovation[a] | |
| | GKIN6 | Our company regularly performs environmental audits | |
| | GKIN7 | Our company systematically uses key indicators to monitor its environmental performance | |
| | GKIN8 | Our company applies routines for sharing expertise/experience to develop new green practices[a] | |

(*continued*)

**Table A1.** Continued

| Constructs | Item | | References |
|---|---|---|---|
| Green knowledge exploitation (GKEX) | GKEX1 | Our company utilizes environmental considerations in its strategic decisions | |
| | GKEX2 | Our company applies new knowledge and technologies to its green practices | |
| | GKEX3 | Our company applies company-wide coordinated improvement and technology implementation plans to improve its environmental performance | |
| | GKEX4 | Our company encourages its employees to experiment and learn from mistakes as part of implementing environmentally friendly practices | |
| Green Innovations | | | |
| Green Process Innovations in Transportation (GPITR) | GPITR1 | Our company takes measures to reduce its fuel use in transportation (e.g., through eco-driving training programs, telematics-based routing, the newest low-emission vehicles, aerodynamic measures, etc.) | Bálint *et al.* (2021), Chu *et al.* (2018), Laguir *et al.* (2021), Lin and Ho (2011) |
| | GPITR2 | Our company optimizes its transport practices to improve asset utilization (e.g., through measures that increase the load factor, GPS-supported fleet management, loading technology, changes in the swap bodies size, etc.) | |
| | GPITR3 | Our company optimizes its transportation policies to prevent pollution (e.g., reducing the demand for freight transportation, switching to lower-carbon energy, etc.) | |
| Green Process Innovations in Packaging (GPIPG) | GPIPG1 | Our company continuously makes efforts to reduce the overall packaging material | |
| | GPIPG2 | Our company uses reusable and/or recyclable packaging materials | |
| | GPIPG3 | Our company uses environmentally friendly packaging materials (e.g., recycled plastic, bio-, paper-based or compostable materials) | |
| | GPIPG4 | Our company introduced individual waste collecting and sorting systems[a] | |
| Green Process Innovations in/around Warehouses/Building (GPIWB) | GPIWB1 | Our company makes efforts to reduce its electricity consumption in its warehouses/buildings (e.g., modernizing illumination, insulating the walls and roofs, heat recovery of ventilation and/or refrigerating systems, etc.) | |
| | GPIWB2 | Our company aims to integrate renewable energy sources into its core operations (e.g., photovoltaic systems, geothermal energy, wind power, and/or hydropower) | |
| | GPIWB3 | Our company makes efforts for rainwater recovery and management (e.g., using rainwater for landscape irrigation, watering the green roof of warehouses, and/or for cleaning purposes) | |
| | GPIWB4 | Our company aims to reduce the harmfulness of used material for building warehouses and/or thermal insulation of current warehouses | |
| | GPIWB5 | Our company takes measures to preserve the local biodiversity around its properties | |
| Green Service Innovations (GSIN) | GSIN1 | Low-emission transportation/distribution services | |
| | GSIN2 | Individual environmentally friendly packaging solutions[b] | |
| | GSIN3 | Sustainable (e.g., CO2-neutral) warehousing solutions[a] | |
| | GSIN4 | Reverse logistics and/or recycling services (self-performed and/or externally contracted) | |
| | GSIN5 | Shippers' carbon footprint calculation services | |
| | GSIN6 | Carbon-offsetting services | |
| Marker Variable | | | |
| Specialisation (MARK) | MARK1 | Our firm has a large number of "specialist" employees who perform narrowly defined sets of activities | Daugherty *et al.* (2011) |
| | MARK2 | We expect our employees to be experts only in their areas of responsibility | |
| | MARK3 | Most of our firm's employees are generalists who perform a wide variety of tasks (r) | |

**Note(s)** [a]Dropped in the pretest stage;
[b]Dropped in the subsequent validation stage; (r) = inverse item.

**Source(s):** Authors' own work

**Table A2.** Constructs and items used in the surveyStandardized regression weights

| Constructs | Item | CFA model 1 (first order) | CFA model 2 (second order) |
|---|---|---|---|
| *Stakeholder integration* | | | |
| KNOW | | | *0.835* |
| | KNOW1 | 0.734 | 0.742 |
| | KNOW2 | 0.825 | 0.838 |
| | KNOW3 | 0.803 | 0.787 |
| | KNOW4 | 0.723 | 0.717 |
| INTER | | | *0.925* |
| | INTER1 | 0.851 | 0.847 |
| | INTER2 | 0.906 | 0.907 |
| | INTER3 | 0.863 | 0.864 |
| | INTER4 | 0.839 | 0.843 |
| | INTER5 | 0.796 | 0.796 |
| ADAP | | | *0.688* |
| | ADAP2 | 0.846 | 0.881 |
| | ADAP3 | 0.846 | 0.821 |
| | ADAP4 | 0.852 | 0.875 |
| | ADAP5 | 0.812 | 0.781 |
| *Green absorptive capacity* | | | |
| GKAC | | | *0.792* |
| | GKAC1 | 0.722 | 0.717 |
| | GKAC3 | 0.712 | 0.704 |
| | GKAC5 | 0.738 | 0.748 |
| GKIN | | | *0.853* |
| | GKIN1 | 0.862 | 0.870 |
| | GKIN2 | 0.844 | 0.842 |
| | GKIN3 | 0.853 | 0.844 |
| | GKIN6 | 0.829 | 0.835 |
| | GKIN7 | 0.811 | 0.809 |
| GKEX | | | *0.768* |
| | GKEX1 | 0.814 | 0.813 |
| | GKEX2 | 0.822 | 0.814 |
| | GKEX3 | 0.832 | 0.844 |
| | GKEX4 | 0.698 | 0.696 |
| *Green innovations* | | | |
| GPITR | | | |
| | GPITR1 | 0.771 | 0.780 |
| | GPITR2 | 0.671 | 0.665 |
| | GPITR3 | 0.753 | 0.749 |
| GPIPG | | | |
| | GPIPG1 | 0.721 | 0.741 |
| | GPIPG2 | 0.726 | 0.734 |
| | GPIPG3 | 0.771 | 0.748 |
| GPIWB | | | |
| | GPIWB1 | 0.689 | 0.686 |
| | GPIWB2 | 0.697 | 0.698 |
| | GPIWB3 | 0.751 | 0.752 |
| | GPIWB4 | 0.736 | 0.737 |
| | GPIWB5 | 0.725 | 0.725 |

(*continued*)

**Table A2.** Continued

| Constructs | Item | CFA model 1 (first order) | CFA model 2 (second order) |
|---|---|---|---|
| GSIN | | | |
| | GSIN1 | 0.703 | 0.706 |
| | GSIN4 | 0.680 | 0.679 |
| | GSIN5 | 0.806 | 0.806 |
| | GSIN6 | 0.852 | 0.850 |
| *Marker variable* | | | |
| MARK | MARK1 | 0.700 | 0.686 |
| | MARK2 | 0.612 | 0.609 |
| | MARK3 | 0.854 | 0.869 |

**Note(s):** All regression weights are significant at $p < 0.001$
**Source(s):** Authors' own work

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**Corresponding author**
Martin Bálint can be contacted at: martin.balint@muk.thm.de