What drives the adoption of Logistics 4.0 by Logistics Service Providers? An Innovation Diffusion Theory perspective

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Abstract: This paper aims to investigate the adoption of Logistics 4.0 by logistics service providers (LSP) in logistics distribution processes. Although the promise of Logistics 4.0 to improve the efficiency, effectiveness, and sustainability of logistics, LSP still struggle in integrating 4.0 concepts into their operations. Thus, the need emerged to support companies in the adoption and exploitation of Logistics 4.0. The adoption of Logistics 4.0 innovation goes beyond the acquisition of technology, as it is a complex process that starts with the identification and evaluation of organisation needs and available 4.0 solutions, goes on with the actual adoption of the 4.0 solutions through accessing and integrating them into the organisation's processes, and ends when 4.0 is widely used as an integral part in a firm's value chain activities. In this regard, understanding the factors affecting Logistics 4.0 adoption might be critical to improving its diffusion rate for LSP. So far, research has just started investigating the diffusion of Logistics 4.0 innovation among LSP. To advance research in this area, the present paper develops a conceptual model based on the Innovation Diffusion Theory (IDT) to investigate the factors affecting the successful adoption of Logistics 4.0 solutions, by building on established Logistics 4.0, Industry 4.0, and innovation diffusion literature. With our research, we contribute to a better theoretical understanding of Logistics 4.0 and innovation diffusion and provide insights to LSP from a practical perspective.

Keywords: Logistics 4.0, Innovation Diffusion Theory, Logistics Service Providers, Conceptual modelling

1.Introduction

The increased competitiveness of today's globalized, demanding market (Hofmann and Rüsch, 2017) turned innovation-orientation into an unavoidable practice for logistics service providers (LSP) (Marchet et al., 2017). Logistics 4.0 represents the latest evolution of logistics and supply chain management practices. Regarded as a complementary approach to Industry 4.0, Logistics 4.0 consists of introducing cyber-physical systems (CPS) into logistics processes to optimize them through intelligent systems, embedded in software and databases from which relevant information is provided and shared, achieving a significant automation degree (Barreto, Amaral and Pereira, 2017). Logistics 4.0 is expected to provide LSP with the instruments to cope with the increasing complexity of the external environment. Yet, Logistics 4.0 implementation remains expensive, risky, and difficult to achieve (Winkelhaus and Grosse, 2020). The causes lie in its complexity. Being considered similar to technological innovation, Logistics 4.0 adoption is subjected to the innovation diffusion process (Hazen, Overstreet and Cegielski, 2012), that is the "process through which an individual (or other decision-making units) passes from first knowledge of an innovation to forming an attitude toward the innovation, to a decision to adopt or reject, to implementation of the new idea, and confirmation of this decision" (Rogers, 1995, pg. 163). Each step of this complex process is critical for the adoption of an innovation. Various elements might foster the adoption of Logistics 4.0 along the innovation diffusion process, including the technological characteristics of the 4.0 solutions (e.g., Rogers, 1995; Mathauer and Hofmann, 2019), the organisational characteristic of the LSP (e.g., Sony and Naik, 2020), the external environment in which the LSP operate (e.g., Moeuf et al., 2020), and their relations with supply chain partners, or other external actors (e.g., Sriram and Vinodh, 2020). However, the current literature is fragmented or unclear in its investigation of 4.0 adoption and lacks a solid viewpoint on logistics when study the factors affecting Logistics 4.0 adoption (Mathauer and Hofmann, 2019). An investigation that considers the overall composite process of innovation diffusion might help the successful implementation of Logistics 4.0, enabling companies to achieve the expected performance improvements.

Given these premises, the present paper aims to investigate the factors affecting the successful adoption of Logistics 4.0 for each of the innovation diffusion steps. Two research questions drove the study:

1. What are the factors affecting Logistics 4.0 adoption?
2. How do these factors influence the Logistics 4.0 adoption process?

Specifically, through a literature review on Logistics 4.0, Industry 4.0, and innovation diffusion, we identified for each of the Logistics 4.0 adoption steps the associated relevant factors. Moreover, we provide a conceptual model by linking steps and related factors which might offer a basis for further studies about the topic. In

defining the Logistics 4.0 adoption steps, the Innovation Diffusion Theory (IDT) was selected as the theory of reference for this work. Indeed, evidence exists about the value of this theory in innovation studies for different supply chain practices (e.g. Wamba and Queiroz, 2020).

The remainder of this paper is organised as follows. Section 2 present a theoretical background on the research area of the study, while in Section 3, we describe the methodology adopted. Section 4 illustrates the conceptual model, including the identified theoretical propositions. We conclude the paper by discussing our findings and proposing directions for further research in Section 5.

2.Theoretical background

Understanding the numerous factors that affect the Logistics 4.0 adoption might be critical to improve its diffusion rate for LSP. Nevertheless, the topic has attracted little research attention so far: only two papers were found discussing 4.0 adoption for LSP. The first focused on knowledge absorption capacity as a determinant of the successful Logistics 4.0 implementation (Stachowiak et al., 2019); the second investigated the effect of different technology access modes on the successful integration of technological innovation (Mathauer and Hofmann 2019). More attention has been devoted to study adoption factors in the context of Industry 4.0. Sony and Naik (2020), who examined how to successfully implement Industry 4.0 with a systematic review of the extant literature, highlighted the role that employees' qualification has in 4.0 implementation. In his study about the impact of organisational size on Industry 4.0 adoption, Hopkins (2021) found that larger firms were better prepared than smaller firms for Industry 4.0 technology adoption, while Moeuf et al. (2020), who focused their study on small and medium enterprises (SMEs), identified the top management support as a critical success factor for Industry 4.0 adoption. Innovation diffusion and adoption issues have also been studied in the context of IT and e-business projects. For example, Zhu and Kraemer (2005) focused their research on e-business adoption and studied the factors that might affect the last steps of the e-business diffusion process. Instead, Russell and Hoag (2004) focused their study on the overall process of IT innovation implementation by analysing the challenges in IT implementation and identifying the related success factors.

The analysed literature unveiled a duality in researchers' choices. From one side, scholars studied 4.0 adoption by choosing a specific set of innovation diffusion process steps and evaluating the impact that specific factors have on these steps (e.g. Zhu and Kraemer, 2005; Vogelsang et al., 2018; Mathauer and Hofmann, 2019). Most of these studies focused on the last steps of the innovation diffusion process, representing the incorporation of innovation into an organisation (Hazen, Overstreet and Cegielski, 2012). From the other side, researchers investigated adoption factors considering the overall innovation diffusion process (Russell and Hoag, 2004). In this regard, most of the authors investigated factors affecting the overall 4.0 innovation diffusion process without clearly specifying what "adoption" means in their research (e.g., Mahmood and Mubarik, 2020; Moeuf et al., 2020; Sriram and Vinodh, 2020; Hopkins, 2021). Among the authors who have defined the meaning they gave to 4.0 adoption, Stachowiak et al. (2019) associated Logistics 4.0 adoption to organisational maturity along the dimensions "material flow management", "information flow management", and "management method", Patterson, Grimm and Corsi (2003) defined adoption as "the generation, development and implementation of the technology" (pg. 98), while Russell and Hoag, (2004) considered adoption as "individuals within the organisation "using" the innovation on a regular basis" (pg. 106). In addition, Wamba and Queiroz, (2020) developed a multi-stage innovation adoption model explaining the determinants of blockchain diffusion in the supply chain.

To improve the adoption rate of Logistics 4.0 solutions among LSP, understanding the factors that might help (or hinder) its diffusion has some relevance (Rogers, 1995). Since innovation diffusion is a complex process with sequential steps that are all necessary to successfully adopt an innovation (Wamba and Queiroz, 2020), it might be of some merit to find specific adoption factors for each step. Indeed, in each step, the decision-makers have a different role towards the innovation; in the first stages, they have mainly a passive role, as they are being exposed to the innovation; in more advanced stages, they achieve an increasingly active attitude towards the innovation, being required to choose, adopt and implement it. Consequently, each step is related to different factors that might ease or prevent its achievement (Rogers, 1995), and essential differences exist among them (Wamba and Queiroz, 2020).

3.Methodology

To address the aim of this research, i.e. to investigate factors driving the adoption of Logistics 4.0 solutions by LSP, we relied on a thorough review of the literature on Industry 4.0, Logistics 4.0, and innovation diffusion research.

The literature search was performed through a structured approach, summarized in Table 1. First, keywords related to the topic of interest such as "Logistics 4.0", "Industry 4.0", "innovation diffusion", "logistics service providers", "third party logistics", "adoption", and related synonyms were combined and searched for using Scopus database. Papers published in English in international peer-reviewed journals were selected as contributions of reference for this research. Then, the literature was carefully examined, and the relevant contributions were selected. Finally, forward and backward reference searching was performed to enlarge the sample retrieved. Papers related to Logistics 4.0 diffusion and Industry 4.0 innovation diffusion providing logistics insights were investigated, focusing on LSP, leading to the identification of the main factors affecting 4.0 adoption in logistics and highlighting the innovation diffusion steps they might influence. For each article analyzed, statements were identified concerning the

factors affecting the implementation of 4.0 innovation. Each statement was assigned to one distinct impact factor, and each factor was build up from numerous statements (Vogelsang *et al.*, 2018). We detected 18 independent factors affecting the implementation of Logistics 4.0.

Based on this analysis, a conceptual model was then developed by structuring the significant factors into four relevant clusters (i.e., technological, organisational, environmental, relational) and by relating each cluster to the correspondents IDT adoption steps (i.e. knowledge, persuasion, decision, implementation, confirmation). Propositions describing the relationship among clusters and adoption steps were further formulated.

Table 1: Review protocol and literature summary

Step	Description	Results
1	Keywords search	119
2	Contributions published in english in international peer reviewed journals	108
3	Screening by title and abstract	84
4	Screening by full text	10
5	Forward-backward reference searching	4
	Contributions included	**14**

4.Conceptual model

We propose a conceptual model (Figure 1) that aims to support the implementation of Logistics 4.0 solutions by LSP by identifying and structuring the factors affecting Logistics 4.0 adoption at each innovation diffusion step. Since the concepts and technologies related to Logistics 4.0 are perceived as new by most of LSP, which are nowadays approaching the transition towards this new logistics system (Hofmann and Rüsch, 2017), Logistics 4.0 can be compared to an innovation, as defined by the IDT (Rogers, 1995). Therefore, IDT is adopted as a theoretical lens to ground the study. The model is structured as follows. The dependent construct is the "Logistics 4.0 adoption", which is split into the five innovation diffusion steps presented in Section 4.1, i.e. knowledge, persuasion, decision, implementation, confirmation. As independent constructs, we consider the four clusters used to categorize the factors identified in literature, "technological", "organisational", "environmental", "relational". Besides, the propositions based on the review of the literature concerning the relations among them are presented.

4.1 Logistics 4.0 adoption

Logistics 4.0 emerged as the application of the core concepts of Industry 4.0 – CPS – to logistics operations (Barreto, Amaral and Pereira, 2017). CPS link real objects with virtual objects via information networks to bring together physical with digital systems. In this way, they allow communication and cooperation with each other and with humans in real-time and enable data-driven decentralized decisions, thus improving the performance of the logistics processes (Hofmann and Rüsch, 2017). Understanding what Logistics 4.0 innovation means is not straightforward – the comprehensive nature of its definition requires companies to individually define what Logistics 4.0 means to them, as Hofmann and Rüsch (2017) pointed out. For the purpose of this work, we consider as "Logistics 4.0 innovation" every solution, project, process, tool, system, or method that aims to introduce and implement CPS-related concepts (i.e., physical-digital systems coupling, real-time data gathering and analysis, systems and actors collaboration, decision decentralization) into logistics processes, by adopting digital technologies (Frank, Dalenogare and Ayala, 2019).

Researchers recognised that organisations' decision about adopting innovation is a complex process that consists of a series of actions (Rogers, 1995). The IDT is a robust theory that considers a new idea, process, or technology innovation and describes its adoption process from the organisation's exposure to the innovation, to its adoption, and dissemination through the organisation (Wamba and Queiroz, 2020). Many researchers adopted the IDT as a theoretical lens to study the diffusion of innovation in supply chains, covering different aspects such as production and operations management (Wagner *et al.*, 2011), green supply chain (Asif *et al.*, 2020), and supply chain digitalisation (Wamba and Queiroz, 2020). Although most of the analysed literature defines IDT starting from Rogers (1995), many of the innovation diffusion process steps are described using various overlapping terms and definitions (Hazen, Overstreet and Cegielski, 2012). For this reason, we decided to clarify the meaning of each step, as defined in this paper. Since this work is grounded on Rogers' definition, five steps were recognised characterizing the innovation diffusion process:

- *Knowledge*, occurring when a decision makes gains understanding of the innovation existence and how it works;
- *Persuasion*, representing the moment when a decision-maker shapes its attitude (positive or negative) towards the innovation;
- *Decision*, occurring when a decision-maker analyses the advantages and disadvantages of the innovation, leading to the choice about the adoption or rejection;
- *Implementation*, representing the moment in which the innovation is put into use; here, a high level of uncertainty exists about its effective results and doubts arises about going back to the old technology;
- *Confirmation*, occurring when innovation becomes incorporated into the regular activities; in this phase, the decision already made about the innovation can be reversed if exposed to conflicting messages about the innovation (e.g. the performance improvement expected is not met).

4.2 Factors affecting Logistics 4.0 adoption

A variety of factors were identified that may affect an organisation's decision to adopt a particular technological

innovation, summarized in Table 2. Many authors attempted to identify and classify these factors that potentially influence innovation adoption. The dominant classification framework used is the technology, organisation, environment (TOE) framework (Tornatzky, Fleischer, and Chakrabarti, 1990). Nevertheless, Mathauer and Hofmann (2019) recognised the importance of extending this classification to include relation-related factors, especially for supply chain studies (Mathauer and Hofmann, 2019). In the remainder of this section, the conceptual model relating factors and IDT steps is illustrated and propositions highlighted (see Table 3).

Table 2: Factors affecting Logistics 4.0 adoption

Cluster	Factor	References
Technological	IT infrastructure	Carson, 2002; Vogelsang *et al.*, 2018; Mathauer and Hofmann, 2019; Sriram and Vinodh, 2020; Szász *et al.*, 2020; Wamba and Queiroz, 2020; Chauhan, Singh and Luthra, 2021
	Modularity and standardization	
	Perceived benefits	
	Technology trust	
	Technology trialability	
Organisational	Absorptive capacity	Vogelsang *et al.*, 2018; Mathauer and Hofmann, 2019; Masood and Sonntag, 2020; Moeuf *et al.*, 2020; Sony and Naik, 2020; Sriram and Vinodh, 2020; Szász *et al.*, 2020; Wamba and Queiroz, 2020; Bag *et al.*, 2021; Hopkins, 2021
	Employee qualifications	
	Employee empowerment	
	Management support	
	Innovation strategy	
	Innovation tendency	
	Company size	
	Financial capability	
Environmental	Competition and pressure from competitors	Vogelsang *et al.*, 2018; Mathauer and Hofmann, 2019; Bhatia and Kumar, 2020; Moeuf *et al.*, 2020; Sriram and Vinodh, 2020
	Legal aspects	
Relational	Relationship with suppliers	Bhatia and Murrell, 1969; Vogelsang *et al.*, 2018; Mathauer and Hofmann, 2019; Sriram and Vinodh, 2020
	Relationship with customers	
	External support	

Technological factors

A great share of the Logistics 4.0 potential is embedded into the adoption of digital technologies connected with this new paradigm. Authors recognised that the characteristics of these innovative digital technologies deeply affect the successful implementation of Logistics 4.0 (Russell and Hoag, 2004). Among these, the presence of *IT infrastructure* is considered by many authors a facilitator across the overall diffusion of 4.0 innovation, being crucial to persuade, decide and implement Logistics 4.0. The presence of servers, databases and adequate transfer speed is a prerequisite to enable the advantages brought by the digital technologies and eases the decision about 4.0 adoption (Sony and Naik, 2020; Sriram and Vinodh, 2020). Technology *modularity and standardization* is recognised as a critical Logistics 4.0 adoption factor, since it reduces the complexity of technology implementation and improves the technology confirmation (Sriram and Vinodh, 2020), by increasing its "ease of use" (Mathauer and Hofmann, 2019). IDT posits that the "perceived" attributes affect innovation adoption (Rogers, 1995). Literature confirmed that the *perceived benefits* of technology represent a critical factor of 4.0 adoption, as they can persuade the decision-maker and influence its adoption decision (Szász *et al.*, 2020). Once the 4.0 innovation is introduced, they represent a benchmark with its actual performance, so they also affect the confirmation stage (Chauhan, Singh and Luthra, 2021). The trust in the technology is recognised to speed the 4.0 adoption process; in this regard, literature affirms that a high t*echnology trust* helps persuade the decision-maker and drive its acceptance decision (Vogelsang *et al.*, 2018; Sriram and Vinodh, 2020). *Technology trialability* enables pilot projects and improves the quick identification of sources of error and their correction before the entire company is affected. It therefore facilitates the implementation and confirmation stages of adoption, by increasing the quality of the deployed 4.0 solution and its acceptance (Vogelsang *et al.*, 2018; Mathauer and Hofmann, 2019).

Against this backdrop, the following propositions are formulated:

P1. *Technological factors, including IT infrastructure, perceived benefits, and technology trust, positively affect the persuasion to adopt Logistics 4.0*;

P2. *Technological factors, including IT infrastructure, perceived benefits, and technology trust, positively affect the decision to adopt Logistics 4.0*;

P3. *Technological factors, including IT infrastructure, modularity and standardization, and technology trialability, positively affect the implementation of Logistics 4.0*;

P4. *Technological factors, including modularity and standardization, perceived benefits and technology trialability, positively affect the confirmation of Logistics 4.0*.

Organisational factors

Scholars discussing the diffusion of innovation views innovation adoption as a social and communications problem (Russell and Hoag, 2004). The literature analysed confirms that social factors related to organisational culture and organisation characteristics deeply affect Logistics 4.0 adoption, being the ones affecting all the steps of the innovation diffusion process. Among them, great attention is devoted to knowledge *absorptive capacity*, namely the organisation's ability to obtain internal and external information, which is recognised as an essential element in all five innovation diffusion steps (Stachowiak *et al.*, 2019; Wamba and Queiroz, 2020). Organisation's

employees play a significant role in the introduction of Logistics 4.0. In particular, researchers recognise the role that *employees empowerment*, in terms of involvement in the innovation process, has in creating organisation's awareness about the existence of new 4.0 technologies (Vogelsang *et al.*, 2018). Logistics 4.0 implementation creates a challenging working environment for the workers (Sony and Naik, 2020); thus, *employees' qualification and* ability to work with the new digital technologies represent essential levers for the 4.0 transition. A higher employees' qualification might persuade the decision-maker to introduce Logistics 4.0, and drive its acceptance decision (Bag *et al.*, 2021). Moreover, the fittest employees' skills level is linked with more successful implementation and confirmation of Logistics 4.0 solutions (Mathauer and Hofmann, 2019). Many studies confirm *management support* as relevant factors in the introduction of Logistics 4.0 (Stachowiak *et al.*, 2019; Sony and Naik, 2020; Wamba and Queiroz, 2020). Top managers might play the role of Logistics 4.0 champions, thus facilitating the persuasion and the decision to adopt Logistics 4.0 (Vogelsang *et al.*, 2018; Wamba and Queiroz, 2020). Moreover, the ability of managers to provide Logistics 4.0 innovation projects with the necessary resources and support greatly improve the implementation of Logistics 4.0 (Sony and Naik, 2020). The definition of an *innovation strategy* that aligns the Logistics 4.0 transition with the organisation's strategic goals eases the decision about the introduction of Logistics 4.0 solutions (Moeuf *et al.*, 2020; Sony and Naik, 2020). Moreover, the organisation's *innovation tendency* intended as the organisational readiness to changes and continuous improvement, ease the persuasion and the implementation of Logistics 4.0 solutions, making companies more reactive. Finally, some authors agreed that organisations characteristics, such as *company size* and *financial capability* could ease the decision to adopt Logistics 4.0 solutions, as big organisation with considerable financial capabilities are more likely to invest in innovation (Rogers, 1995; Masood and Sonntag, 2020; Hopkins, 2021). Therefore, the following propositions are derived:

P5. *Organisational factors, including absorptive capacity and employees empowerment positively affect the knowledge of Logistics 4.0 solutions*;

P6. *Organisational factors, including absorptive capacity, employees qualification, management support, and innovation tendency positively affect the persuasion to adopt Logistics 4.0*;

P7. *Organisational factors, including absorptive capacity, employees qualification, management support, innovation strategy, company size, and financial capabilities positively affect the decision to adopt Logistics 4.0*;

P8. *Organisational factors, including absorptive capacity, employees qualification, management support, and innovation tendency positively affect the implementation of Logistics 4.0*;

P9. *Organisational factors, including absorptive capacity, employees qualification and management support positively affect the confirmation of Logistics 4.0*.

Environmental factors

Researchers proved that the external environmental settings in which the companies operate could ease or hinder the adoption of innovation (Mathauer and Hofmann, 2019). From the analysed literature, two environmental factors were deemed as relevant for the adoption of Logistics 4.0. The first is represented by the *competition and pressure from competitors*. A stronger competition increases the acceptance of Logistics 4.0 in the decision and implementation steps of the diffusion process, as companies lagging behind their competitors are more prone to react (Moeuf *et al.*, 2020; Sriram and Vinodh, 2020; Szász *et al.*, 2020). The second is represented by the *legal aspects* connected, for instance, with IT security and privacy issues and with policy issues. The introduction of security systems and regulations that ensure worker and data safety is expected to ease the implementation of Logistics 4.0 solutions (Bhatia and Kumar, 2020). Moreover, government support can facilitate the decision and the implementation of Logistics 4.0 solutions through policymaking (Bhatia and Kumar, 2020).

The findings on the environmental factors are summarized in the following propositions:

P10. *Environmental factors, including competition and pressure from competitors and legal aspects positively affect the decision to adopt Logistics 4.0*;

P11. *Environmental factors, including competition and pressure from competitors, and legal aspects positively affect the implementation of Logistics 4.0*;

Relational factors

Recently, the relationship between supply chain partners gained attention in innovation diffusion studies, as authors proved that cooperation and collaboration in a supply chain context can improve the successful integration of 4.0 practices and related technologies (Mathauer and Hofmann, 2019). Regarding Logistics 4.0, LSP supplier and customers represent key supply chain partners for 4.0 adoption. Both the *relationship with suppliers*, especially technology ones, and the *relationship with customers* are expected to increase the possibility for LSP to acquire knowledge about new Logistics 4.0 solutions, as high interconnectivity enables a more extensive exchange of ideas (Vogelsang *et al.*, 2018). A stronger relationship with suppliers can help to align the organisations' 4.0 transition objectives, thus improving decisions about Logistics 4.0 adoption (Sriram and Vinodh, 2020). Moreover, the collaboration with technology suppliers is expected to ease the implementation of 4.0 solutions (Mathauer and Hofmann, 2019). Logistics 4.0 adoption is also positively affected by customers' relation, as customers might speed acceptance decision and implementation of 4.0 solutions by the LSP by giving them clear indications about their needs (Mathauer and Hofmann, 2019). Besides supply chain partners' relationship, studies identified *external support* as relevant in introducing 4.0 solutions. External support from academics and consultants can trigger technology transfer mechanisms, thus improving the LSP awareness about new Logistics 4.0 solutions.

Against this backdrop, the following propositions are formulated:

P12. *Relational factors, including relationship with suppliers, relationship with customers and external support positively affect the knowledge of Logistics 4.0 solutions*;

P13. *Relational factors, including relationship with suppliers and relationship with customers positively affect the decision to adopt Logistics 4.0*;

P14. *Relational factors, including relationship with suppliers and relationship with customers positively affect the implementation of Logistics 4.0*

Table 3: Propositions relating factors and Logistics 4.0 adoption steps

Factors	Knowledge	Persuasion	Decision	Implementation	Confirmation
Technological		P1	P2	P3	P4
Organisational	P5	P6	P7	P8	P9
Environmental			P10	P11	
Relational	P12		P13	P14	

5.Conclusions

The present research provides an overview of the factors that might drive the adoption of Logistics 4.0 by LSP. In doing so, it uses the IDT to define, and de-compose Logistics 4.0 adoption into five steps, i.e. knowledge, persuasion, decision, implementation, confirmation, and it investigated for each step the relevant factors driving its successful accomplishment.

Starting from the previous literature about Industry 4.0, Logistics 4.0, and innovation diffusion, significant success factors of Logistics 4.0 adoption are identified. Factors were then allocated to four major clusters: technological, organisational, environmental, and relational. These posed the basis for developing a conceptual model to explain how to successfully accomplish each of the five Logistics 4.0 adoption steps. According to literature findings, each cluster was related to one or more steps in the conceptual model, and propositions were drafted explicating these relationships.

Results present both theoretical and practical implications. From an academic viewpoint, the present study contributes to the emerging research stream of Logistics 4.0 by highlighting the relevant factors affecting the different steps of the Logistics 4.0 adoption process. Regarding previous studies about 4.0 diffusion, the present paper gives a clear and complete overview of which factor might drive the different steps of Logistics 4.0 adoption since it focuses on the overall innovation diffusion process as proposed by Rogers (1995). The developed conceptual model represents the first stage in a further thorough investigation of factors driving Logistics 4.0 adoption, as it provides an initial starting point to develop more detailed analyses on the topic. In particular, results are helpful for LSP willing to start or currently undertaking the transition process towards Logistics 4.0. Managers might use this research to better understand the different factors impacting Logistics 4.0 adoption. Moreover, LSP willing to adopt Logistics 4.0 can gain valuable insights into how to drive the 4.0 adoption process successfully, according to the step they are currently facing.

We acknowledge two main limitations of our study. First, we do not have any empirical evidence about the extent to which the factors, clusters, and proposition presented in the conceptual model reflect reality. Nevertheless, the model was derived from current literature and has a solid theoretical background. Future research could be devoted to empirical validation of the proposed conceptual model. Second, it develops factors mainly relying on Industry 4.0 literature. This was unavoidable, being literature about Logistics 4.0 adoption still underdeveloped given the newness of the topic (Winkelhaus and Grosse, 2020). Notwithstanding, Industry 4.0 and Logistics 4.0 present many overlapping concepts. In this sense, empirical validation of the model could shed further light on the differences between the two topics.

The conceptual model developed by reviewing the extant literature has provided a set of testable propositions, aimed at understanding the relationship between factors driving Logistics 4.0 adoption and Logistics 4.0 adoption steps. These propositions were developed from articles discussing Industry 4.0, IT, e-business, and conceptual articles discussing Logistics 4.0, so many of them have not been empirically tested in a logistics setting. Future research could be directed toward testing the propositions offered in this research. In this regard, future research should be aimed at developing appropriate measures for both factors and Logistics 4.0 adoption steps, as empirical testing will require measures specifically build for logistics innovation. This might be particularly meaningful, being the meaning of Logistics 4.0 still blurred among companies (Hofmann and Rüsch, 2017). As suggested by Patterson, Grimm and Corsi (2003), developing measures that are specific per each innovation diffusion step might also improve response reliability, by avoiding confusion and helping managers to perform clear distinctions.

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