A maturity model to assess the adoption of "Logistics 4.0" technologies in the 3PL industry

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Abstract: The transformations started with the advent of the paradigm of Industry 4.0 have also influenced the logistics sector, leading to the creation of the concept of Logistics 4.0 (i.e. the transformation from hardware-oriented logistics to software-oriented logistics empowered by digital competences). This new "vision" of logistics, initially championed by manufacturing companies, has recently taken hold also in the third-party logistics (3PL) industry, driven by the boost of the e-commerce market, the progressive diffusion of "disruptive technologies" (e.g. drones, cognitive computing and artificial intelligence) and the new challenges brought by exogenous factors (e.g. COVID-19), which push 3PL providers to go beyond their traditional focus and capabilities towards a digital transformation. However, it is still unclear how diffused the concept of Logistics 4.0 among 3PLs is and how its adoption takes place in this industry in terms of technologies, services and capabilities. A better understanding of the current situation of diffusion and adoption could help 3PL providers to assess their own position with respect to the concept of Logistics 4.0 and seize the opportunities offered by its adoption (e.g. higher efficiency, better visibility, improved service level, increased safety and security). For this reason, the paper develops a maturity framework to support 3PL providers in this sense and develops a road map to identify the areas in which invest to improve the logistics service offered to clients through a Logistics 4.0 approach. By means of an extensive literature review on Logistics 4.0 technologies and on maturity models, it was possible to develop a novel maturity framework that combines the dimensions of "Logistics 4.0 technological maturity" and level of adoption of technologies to ultimately lead to the identifications of potential services to be offered by 3PL providers.

Keywords: Logistics 4.0, Outsourcing logistics, Third-party logistics provider, 3PL, maturity model

1.Introduction

The "third-party logistics" (3PL) market has continuously grown, thanks to the increasing demand for outsourced logistics services (Hofmann & Osterwalder, 2017). Nowadays, 3PL providers are facing new challenges and opportunities started with the advent of the Industry 4.0 paradigm (Kucukaltan et al., 2020). The Industry 4.0 is a recent paradigm introduced for the first time in 2011 (Winkelhaus & Grosse, 2020), and its application of the logistics sector has led to the creation of the Logistics 4.0 concept. It can be broadly defined as the optimisation of inbound and outbound logistics supported by intelligent and autonomous systems and data-enabled technology systems aimed at sharing relevant information to achieve a major automation degree (Moldabekova et al., 2021). The technologies adopted in the concept are several, the most cited are cyber-physical systems (CPS), Internet-of-Thing (IoT), but also digitalization, cloud computing, data analysis tool and big data along with digital competences (Bag et al., 2020; Barreto et al., 2017; Oleśków-Szłapka & Stachowiak, 2019; Stachowiak et al., 2019; Strandhagen et al., 2017), even though it appears that a clear classification of these technologies does not exist yet too. Logistics 4.0 technologies have a strong potential to influence the logistics industry and bring benefits, such as better flexibility (the adjustment to the market changes that makes the company closer to the customer needs), proactivity and visibility; reduced design costs thanks to simulation tools; reduced operational imprecision and cost thanks to better productivity, safety and performance (Bag et al., 2020; Oleśków-Szłapka & Stachowiak, 2019; Barreto et al., 2017). So, the adoption of Logistics 4.0 technologies makes it possible to improve the level of customer service, the optimization of the logistics activities and reducing the costs of storage and picking. However, Logistics 4.0 is still an emerging concept, and it is not clear how diffused the adoption of Logistics 4.0 technologies is in the 3PL industry and what kind of benefits these can bring to 3PL providers and how. Papers on Logistics 4.0 strictly related to the 3PL industry are limited in literature (Kucukaltan et al., 2020). However, 3PL providers are playing a vital role in the supply chain network and their ability to disseminating efficiency and effectiveness among the supply chain actors should be taken in consideration in the future studies. The lack of studies presenting Logistics 4.0 in the 3PL industry can be also due to its low implementation level (Corrêa et al., 2020). Currently, digitalisation and big data implementations are still at their initial stage (Kucukaltan et al., 2020), therefore, the industry needs help to understand benefits and impacts of Logistics 4.0 more than ever. New studies in this area are needed in order to help 3PL providers to fully seize the opportunities of Logistics 4.0 technologies, gain benefits from its adoption (Kucukaltan et al., 2020).

A better understanding of the current situation of diffusion and adoption could help 3PL providers to assess their own position with respect to the concept of Logistics 4.0 and seize the opportunities offered by its adoption (e.g. higher efficiency, better visibility, improved service level, increased safety and security). For this reason, the present research aims to build a maturity framework – namely a set of elements that describes in a structured way an evolutionary path of improvement from immature processes to mature, effective, and qualitatively better processes (Facchini et al. 2020) - to support 3PL providers to identify the areas in which invest to improve the logistics service offered to clients through the implementation of Logistics 4.0 technologies. Based on this objective, the research questions of this study are:

(RQ1) What Logistics 4.0 technologies do exist at the disposal of 3PL providers?

(RQ2) How can the level of adoption and of Logistics 4.0 technologies for 3PLs be evaluated and related to the maturity of organizations?

To provide an answer to the research questions a study based on the structured literature review method was performed. The present research helps to enlarge the body of knowledge about "Logistics 4.0". It contributes to the existing literature on the field of logistics providing more clarity and awareness of the key dimensions of Logistics 4.0 and related technologies that can be used to ascertain the level of adoption of Logistics 4.0 by 3PL providers. From a managerial perspective, the developed maturity framework could be used by 3PL providers as a tool to position their business against the identified maturity dimensions and develop a road map to the potential improvement of their logistics services through investments in a Logistics 4.0 technologies.The remainder of the paper is organised as follows. The following section describes the adopted methodology. Section 3 includes a literature review of the Logistics 4.0 technologies, while Section 4 presents the maturity framework developed. Final remarks conclude the paper, including recommendations for further studies in the field (Section 5).

2. Methodology

To address the research questions (RQ1 and RQ2) a systematic literature reviews of the scientific knowledge on Logistics 4.0 was carried out.

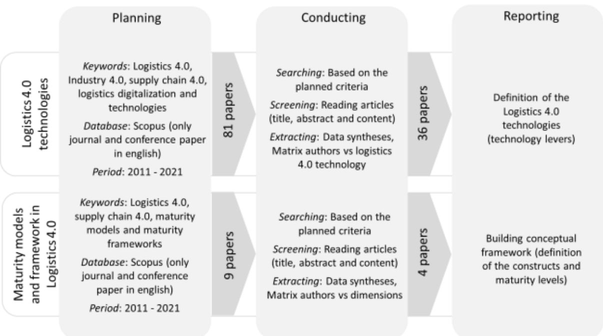

Figure 1. Methodology

Given the objectives of the work, the review focused on two specific areas within Logistics 4.0: Logistics 4.0 technologies (to address RQ1) and Maturity models and frameworks for Logistics 4.0 (to address RQ2). According to Wilding and Wagner (2014) a systematic literature review is a robust and auditable method that facilitates the development of theories and reaching conclusions. The systematic literature reviews were structured in three phases following the process developed by Tranfield et al. (2003): (1) planning phase, (2) conduction phase and (3) reporting phase.

RQ1: Logistics 4.0 technologies

Planning. The first step was to define the keyword to look at in the search according to the objective of the research. The keywords identified (i.e. "logistics 4.0", "logistics and industry 4.0", "supply chain 4.0", "logistics technologies" and "logistics digitalization") and their combinations were used as search terms in Scopus, as it is one of the most used scholar citation databases (Strozzi et al., 2017). The set of papers that resulted were reduced by introducing some inclusion/exclusion criteria: the papers had to be written in English, the source consisted only of journals only peer-reviewed articles, and the subject areas were engineering and management. Conference papers were also included as they might report the latest trends. The selected time window was from 2011 to 2020 as Industry 4.0 was launched in 2011 (Winkelhaus & Grosse, 2020).

Conducting. The entire analysis eventually led to the identification of 81 papers. After the screening process - i.e. selection of relevant paper aligned with the object of the research through the reading of title, abstract and potentially the entire manuscript - a subset of 36 paper was identified. The papers identified were very recent, despite the search period starts from 2011 (Figure 2).

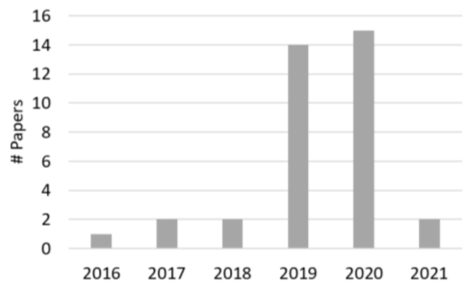

Figure 2. Time distribution of publications

The first contribution is dated in 2016, meaning that the interest in the topic is still very high (the largest number of contributions is registered in 2020 while in the first two months of 2021 two papers have been already published). The number of publications are expected to increase in the years to come since there is still room for more research. Figure 3 presents the number of papers for each publication source. It shows that the studies on Logistics 4.0 are still limited, few journals are publishing this content (only 16 papers are published in journals vs 20 articles, which are conference papers).

Reporting. From the analysis of the articles, the application/focus areas of each research work were extracted using the approach proposed by Frederico et al. (2019) and reported in Table 1 (see in Section 3). Two main categories (physical and digital world) and 9 sub-categories (tracking, transportation automation, warehouse automation, smart pallet, augmented reality, blockchain, data analysis/big data/artificial intelligence, simulation/digital twin and cybersecurity) were identified to classify the technologies in the Logistics 4.0 literature, along with the indication of the technological specifications and related application.

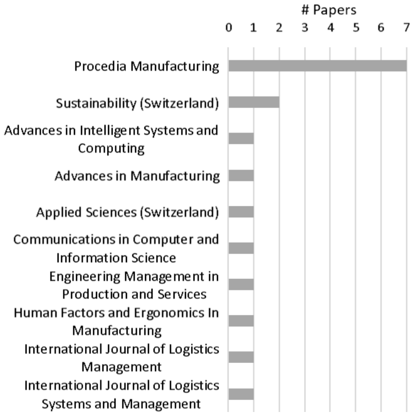

Figure 3. Papers (#) in top 10 journals and conference

RQ2: Logistics 4.0 adoption and maturity frameworks

Regarding RQ2, the aim was to identify the most important contributions in terms of maturity evaluation applied in the context of Logistics 4.0. Maturity models or frameworks are used to capture the evolutionary nature of various phenomena. The same process used for RQ1 was adopted.

Planning. The keywords identified (i.e. "logistics 4.0", "supply chain 4.0", "maturity model*" and "maturity framework*") and their combinations were used as search terms in Scopus. The papers were selected according the same inclusion/exclusion criteria defined for RQ1.

Conducting. The search returned 9 papers. After the screening process a subset of 4 papers was identified. The papers identified were published in the last few years (from 2019), showing that it is a recent and fairly niche topic that can be expanded in future research. However, the limited literature on this topic makes the identification of maturity frameworks a hard challenge.

Reporting. Each paper of the subset was analysed and the main features were reported in Table 2 (see Section 3), according to an original classification developed by the authors and that, besides an indication of the sources, includes two elements that seem to represent the typical factors discriminating the various maturity models for Logistics 4.0 proposed in the literature (i.e. number of levels/stages in the model and constructs used in the model). The work of Facchini et al (2020) is based on the maturity model of Oleśków-Szłapka and Stachowiak (2019). They consider three dimensions for Logistics 4.0: management, flow of material and information flow and 5 level of maturity. Even if they analysed the Logistics 4.0 technologies, they do not clearly state for each maturity level the Logistics 4.0 technologies available, the requirements to meet nor the outcome reached. The Werner-Lewandowska and Kosacka-Olejnik's (2019) maturity model is focused only on IT solutions and tools, without considering other components or requirements for Logistics 4.0. Finally, Frederico's et al. (2019) work gives a comprehensive and robust framework, even if it is not focused in the logistics field but deals with a more general topic (Supply Chain 4.0). Starting from this latter contribution, the maturity model was built grounded on the Logistics 4.0 literature.

3. Descriptive findings: Logistics 4.0 technologies

Logistics 4.0 is a new challenge emerged thanks to the advent of Industry 4.0. It does not have a clear definition widely diffused since it is still at its initial stage (Stachowiak et al., 2019). Logistics 4.0 is defined by Timm & Lorig, (2015) as the transformation from hardware-oriented logistics to software-oriented logistics. It is known to apply the concepts of Industry 4.0, i.e. smart factory, cyber-physical systems (CPS) and internet of things (IoT), to the logistics field. Therefore, Logistics 4.0 can be summarised as the optimisation of inbound and outbound logistics which is supported by intelligent and autonomous systems and data-enabled technology systems aimed to share relevant information to achieve a major automation degree though the support of digital capabilities (Moldabekova et al., 2021). In line also with the definition provided by Barreto et al., (2017), Logistics 4.0 uses new technologies such as CPS (i.e. physical and engineered systems, whose operations can be monitored, coordinated, controlled and integrated by a computing and communication system) to enhance the flexibility, move human resource to more intelligent rather than automatic process and, finally, increase the customer service. Among all the benefits cited in literature, Logistics 4.0 gives the opportunity to control in real time the logistics process, increase flexibility and visibility, decrease design costs thanks to simulation tools, decrease operational imprecision and increase productivity, safety and performance (Bag et al., 2020; Oleśków-Szłapka & Stachowiak, 2019; Barreto et al., 2017). Even if the advantages from the implementation of Logistics 4.0 are several, there are some disadvantages as well. For example, the implementation requires advanced IT hardware (e.g. high-performance communication technologies), it can give problems with availability of data (e.g. data should be integrated and shared among supply chain companies) and some IT solutions have high implementation costs (Oleśków-Szłapka & Stachowiak, 2019).

A digital transformation of the organization is needed too. Strandhagen et al. (2017) give a representation of the new environment created by the application of Logistics 4.0 technologies: (1) routing for material transportation are optimised with real time big data analytics, (2) warehouse has less space dedicated to store products due to on-site and on-demand manufacturing, (3) autonomous robot and vehicles in warehouses help to track and facilitate fast decisions to keep control over inventory, (4) information are exchanged all over the supply chain, reducing the bullwhip effect and finally (5) the information flow remains intact thanks to smart products and cloud-supported networks. Barreto et al. (2017) also identify 5 main applications for Logistics 4.0 technologies: (1) Resource Planning, (2) Warehouse Management Systems, (3) Transportation Management Systems, (4) Intelligent Transportation Systems and (5) Information Security. For each of these applications, Barreto et al. (2017) present some examples of devices used. However, they focus only on CPS and miss to analyse also all the data analysis tools.

Table 1. Logistics 4.0 technologies

Main categories	Sub-categories	Technologies included	Applications	Reference
Physical world	Tracking	Web app, RFID, API	Last mile delivery, store location assignment, flow analysis	Cimini et al. (2021); El Hamdi et al. (2020); Corrêa et al. (2020); Yavas et al. (2020); Bigliardi et al. (2020); Stachowiak et al. (2019); Werner-Lewandowska et al. (2019); Bujak (2018); Strandhagen et al. (2017); Barreto et al. (2017)
	Transport Automation	Unmanned aerial/ground vehicle; Self-driving technology, truck platooning, drone	Transport automation (last mile and long haul)	Cimini et al. (2021); El Hamdi et al. (2020); Corrêa et al. (2020); Yavas et al. (2020); Bigliardi et al. (2020); Stachowiak et al. (2019); Werner-Lewandowska et al. (2019); Bujak (2018); Strandhagen et al. (2017); Barreto et al. (2017)
	Warehouse Automation	IoT (RTLS, camera on board, sensors), technology "goods-to-man" (e.g. pick-to-light, sorter), stock automation, drone, collaborative robot, AGV or AIV	Warehousing (all activities from inbound to outbound), handling, fleet management, safety, inventory	Cimini et al. (2021); El Hamdi et al. (2020); Corrêa et al. (2020); Markov et al. (2020); Yavas et al. (2020); Bigliardi et al. (2020); Stachowiak et al. (2019); Ferreira et al. (2019); Kozma et al. (2019); Werner-Lewandowska et al. (2019); Karunarathna et al. (2019); Melacini et al. (2019); Bujak (2018); Strandhagen et al. (2017); Barreto et al. (2017)
	Smart pallet	RFID or beacon	Pallet management	Yavas et al. (2020); Bigliardi et al. (2020); Stachowiak et al. (2019); Werner-Lewandowska et al. (2019)
	Augmented Reality (AR)	Wearable (e.g. smart glasses)	Pick-by-vision, quality check, driving assistant	Cimini et al. (2021); Yavas et al. (2020); Stachowiak et al. (2019); Werner-Lewandowska et al. (2019);Bujak (2018); Strandhagen et al. (2017)
Digital world	Blockchain		Monitoring stock level, increasing visibility,reducing human errors	Cimini et al. (2021); Corrêa et al. (2020); Yavas et al. (2020); Kodym et al. (2020); Bigliardi et al. (2020); Stachowiak et al. (2019)
	Data Analytics, big data, artificial intelligence	Data analytics, advance algorithm, machine learning, data mining, artificial intelligence	Warehouse and transportation to optimize routing and performance	Cimini et al. (2021); El Hamdi et al. (2020); Corrêa et al. (2020); Markov et al. (2020); Woschank et al. (2020); Yavas et al. (2020); Bigliardi et al. (2020); Bukowski (2019); Stachowiak et al. (2019); Kozma et al. (2019); Olesskóм-Szłapka et al. (2019); Strandhagen et al. (2017); Barreto et al. (2017)
	Simulation and digital twin		Warehouse planning (re-arrangements and redesign) or for decision-making	El Hamdi et al. (2020); Yavas et al. (2020); Bigliardi et al. (2020); Stachowiak et al. (2019); Barreto et al. (2017)
	Cybersecurity		Risk management	Yavas et al. (2020); Bigliardi et al. (2020); Stachowiak et al. (2019); Barreto et al. (2017)

Table 2. Details of Logistics 4.0 maturity model analysed in literature

Authors	Title	Journal/ Conference	Number of levels in the maturity model	Constructs used in the maturity model
Facchini et al. (2020)	A maturity model for logistics 4.0: An empirical analysis and a roadmap for future research	Sustainability (Switzerland)	5 (ignoring, defining, adopting, managing, integrated)	Management, flow of material, flow of information
Frederico et al. (2019)	Supply Chain 4.0: concepts, maturity and research agenda	Supply Chain Management: An International Journal	4 (initial, intermediate, advanced, cutting-edge)	Managerial & capability supporters, technology levers, performance requirements, strategic outcomes
Werner-Lewandowska and Kosacka-Olejnik (2019)	Logistics 4.0 maturity in service industry: Empirical research results	Procedia Manufacturing	6 (level 0, level 1, level 2, level 3, level 4, level 5)	IT solutions and tools
Oleśków-Szłapka and Stachowiak (2019)	The framework of logistics 4.0 maturity model	Advances in Intelligent Systems and Computing	5 (ignoring, defining, adopting, managing, integrated)	Management, flow of material, flow of information

These tools can be used by practitioners to examine the data gathered by the CPS, to understand the status of the logistics system under assessment and to improve the decision-making process (e.g. easy decisions can be replaced by automated systems while sophisticated simulation tools can help to solve complex problems). Indeed, according to Bag et al., (2020), Logistics 4.0 helps to make better logistics decisions through the use of supply chain analytics and predictive analytics (e.g. cloud computing and big data). Specifically, Logistics 4.0 help to gather information from various sources and use it for the decision-making process at different level (i.e. strategic, operational, and tactical levels). The implementation of CPS and IoT but also of cloud computing and data analysis tools is fundamental to reap the full benefits coming from Logistics 4.0 concept (Bag et al., 2020). For example, managers should enhance the big data analytics capability and digital capabilities of their companies to enhance operational decision-making proficiency and improve the level of logistics services (Wamba et al., 2018).

In Table 1, the various Logistics 4.0 technologies and their applications are reported. The technologies were classified in two main categories (digital and physical world). This classification is in line with the definition provided of Logistics 4.0. The definition brings together the "digital world" - i.e. cloud computing, data analytics tools, big data, etc. - and the "physical world" - i.e. sensors, robots, smart trucks, etc. (Amr et al., 2019; Bukowski, 2019).

4. Maturity Framework

The literature does not present any Logistics 4.0 maturity model applied to the 3PL industry, something that the present paper addresses to support 3PL providers to identify the areas in which they could potentially invest to improve the logistics service offered to clients through a Logistics 4.0 approach. To build the maturity framework, the work started from Frederico's et al. (2019) publication. It was chosen since it offers a comprehensive analysis of the constructs and maturity levels for describing a "4.0" concept. It analyses not only the technologies (as for Werner-Lewandowska and Kosacka-Olejnik, 2019) but also their requirements and the outcomes that a company could get with their implementation. Therefore, the maturity framework was built taking into account four maturity levels: initial, intermediate, advanced and cutting-edge. The constructs used are an adaptation of the one presented by Frederico et al. (2019): they are set in the literature analysed previously on Logistics 4.0 (see Section 3) and modified according to the features of the 3PL industry. The constructs are:

(a) Managerial & capability supporters: it includes the organizational skills; the level of coordination and collaboration (3PL vs client); leadership support; awareness regarding the benefits of Logistics 4.0 and strategic vision.

(b) Logistics 4.0 technologies: it includes all the technologies (both digital and physical worlds) arising from the literature review (see Table 1).

(c) Requirements: it includes technical requirements for the implementation of the technologies. Communication technologies are key enablers for Logistics 4.0 (Stachowiak et al., 2019), since they allow to connect together different technologies (e.g. sensors and handling equipment). Moreover, the source of data and the integration among different information systems and companies enable the use of data analysis tools and other IT tools (Bag et al., 2020).

(d) Strategic outcomes: it describes which type of logistics service can be offered by a 3PL that implements Logistics 4.0 technologies.

The maturity framework developed has an evolutionary nature, meaning that 3PL providers with up-to-date Logistics 4.0 technologies are the ones with the highest maturity level and the one that can offer the best and complete logistics service. Specifically, four types of 3PL providers are presented:

(1) initial: a 3PL provider that has basic IT infrastructure and capabilities, it is not able to integrate and manage different source of data. It uses the basic technologies (such as radio frequency terminals) to track the position of the product inside the warehouse. However, with basic digital, analytics and data science capabilities it is not able to track and trace the products in all the logistics process. It is able to offer the traditional logistics service (i.e. warehousing and transportation).

(2) intermediate: a 3PL provider that uses warehouse automation to manage daily activities, it is not yet able to exploit data for simulations or forecasting. The data collected and extracted from information systems (e.g. WMS) are used to optimise the day by day activities and improve the service offered. It uses Logistics 4.0 technologies such as: RFID and IoT for tracking purposes and warehousing automations (i.e. AGV, collaborative robots, mini loads, sorter, etc.) to increase productivity. IoT could also be used to improve safety inside and outside the warehouse (i.e. sensors installed on forklifts or AGVs able to stop the halt the vehicles movements when someone is approaching). As it can control the traditional logistics activities (i.e. warehousing and transportation), this 3PL provider can put an effort to offer value-added services (i.e. kitting/labelling, postponement, customer service, reverse logistics, etc.). The 3PL provider is aware of the benefits of Logistics 4.0 implementation even if it is still not the priority.

(3) advanced: a 3PL provider has the capability to use all the data related to the logistics activities performed. It uses descriptive data analytics tools to measure the current state of the logistics performance (as for the intermediate 3PL provider) but also predictive data analysis to forecast volumes and flows. Moreover, it starts to simulate and design the new operations based on the results of the forecasting activities. It implements Logistics 4.0 technologies in all logistics process – even for the pallet management – that make it able to optimise all the activities (traditional and value added) and become more flexible and in some cases even proactive with regard to clients (i.e. proposing solutions to customers before disservice occur). Examples of this proactive attitude include the development of web apps to help the customer service department to detect in real time the location of a delivery. Other examples include the use of augmented reality with smart glasses and smart watches for picking activities. While smart pallets (i.e. beacon inserted in the pallet) are used to

monitor humidity, temperature and damage occurred to the packaging.

(4) cutting-edge: an early adopter 3PL provider, which has an advanced IT infrastructure that enables the implementation of disruptive technologies. It makes full use of the Logistics 4.0 technologies already adopted in the previous levels and it is more aware of the potential of data analysis tools, big data analytics and blockchain. It recognises the importance of cybersecurity as it is starting to manage large amounts of sensitive data. Thanks to Logistics 4.0 technologies adopted it can offer tailor-made services since it has a high visibility on the supply chain and can use data analysis tools to forecast and fully control the physical flows. Moreover, it can implement Logistics 4.0 technologies also to transportation, starting to test drones, electrics trucks, truck platooning, etc.

Strategic Outcomes		Traditional service (warehousing and transportation)	Traditional service is improved and optimised. Starting to implement new value-added serevices	Value –added services are improved and new services are developed thanks to the optimised activities	Flexibility and visibility is added to logistics activities. It is possible to be proactive and develop a tailor-made service to meet shippers' need.
Requirements	Communication technologies requirements	No wireless connectivity or radio frequency connectivity (only for radio frequency terminals)	Short-range network technologies as RFID, NFC, Bluetooth	Local area network technologies as Wi-Fi, Li-Fi, UWB	Wide area network technologies such as 4G, 5G and NB-IoT or satallite networks
	Data Integration	Limited integration (information systems interface with radio frequency terminals, with restricted vision)	Partial integration between the different logistics activities (e.g. integration between WMS and TMS)	Full integration of information systems and partial visibility with shippers and suppliers	Full integration in the supply chain with shared data for forcasting and continuous improvement
Logistics 4.0 Technologies	Physical world	Tracking (Bar Code)	Warehouse automations Tracking (RFID, IoT)	AR, Smart pallet Warehouse automation Tracking (RTLS, web app)	Transport Automations AR, Smart pallet Warehouse automation Tracking (RTLS, web app)
	Digital world		Data analytics & Big data (Descriptive)	Simulation and AI Data analytics & Big data (Predictive)	Blockchain and cybersecurity Simulation and AI Data analytics & Big data (Prescriptive)
Managerial & Capability supporters		Limited coordination and collaboration between 3PL and clients, the 3PL is not aware of the Logistics 4.0 benefits and its adoption is not supported by leaders because no organizational skills to implement Logistics 4.0	Logistics 4.0 is part of the strategy but not the priority: the 3PL is aware of the Logistics 4.0 benefits but it does not support Logistics 4.0 initiative because it is still developing organizational skills.	Logistics 4.0 is highly supported. The 3PL is aware of the advantages provided by Logistics 4.0 and the people can implement new solutions thank also to the high degree of collaboration with clients	Logistics 4.0 is the main strategic driver with high priority. The organization is aware and has the capability to fully support and implement any type of Logistics 4.0 solution. The 3PL has a partnership with client and it is able to have a complete visibility on the supply chain
Maturity Level		**Initial**	**Intermediate**	**Advance**	**Cutting-edge**

Figure 4. Maturity model

5. Conclusions

The present research aims to enlarge the existing literature on Logistics 4.0 technologies in the 3PL industry. A better understanding of the current situation of diffusion and adoption could help 3PL providers to assess their own position with respect to the concept of Logistics 4.0 and seize the opportunities offered by its adoption. For this reason, the paper develops a maturity framework to support 3PL providers in this sense and develops a road map to identify the areas in which invest (i.e. technologies (digital or physical world) or requirements (data integration or communication technologies)) to improve the logistics service offered to clients through a Logistics 4.0 approach. The maturity model presented differs from the ones reported in Table 2 since it applies the concept and the technologies of Logistics 4.0 to the 3PL industry, helping them to develop the levers that increase their competitive advantage. By means of extensive literature reviews on Logistics 4.0 technologies and on maturity models, it was possible to structure a novel maturity framework that combines the dimensions of Logistics 4.0 technological maturity and the level of adoption of technologies to ultimately lead to the identifications of potential services to be offered by 3PL providers.The present work has both practical and theoretical implications. From a theoretical perspective, the findings address an identified gap in the existing literature, which lacks analysis in the 3PL industry (Kucukaltan et al., 2020). It opens new discussions on the application of Logistics 4.0 technologies in the 3PL industry and how logistics firms could exploit this concept to add value and create competitive advantage using innovation and technologies as main levers. Moreover, it presents a novel maturity framework which considers not only the IT solutions or tools included in the Logistics 4.0 paradigm but also its requirements and the outcomes reached for each maturity level. From a managerial perspective, the maturity model developed could be used as a road map to identify the areas in which invest to improve the logistics service offered to clients through a Logistics 4.0 approach. It helps to identify the requirements defined for the implementation of a specific level of Logistics 4.0 technology and it also gives the outcome that could be reached with a correct implementation and exploitation of the technology. Moreover, the model highlights the importance of collaboration and partnerships (relational factors), they should be recognised by managers as strategic levers to improve the service offered.

The work described in this paper presents some limitations that should be noted. First, the maturity framework developed is grounded in the literature but needs to be validated through field data collected from samples of organizations and other stakeholders (i.e. 3PL providers and experts in the industry). The Logistics 4.0 technologies presented are extrapolated from articles and conference papers which focus on logistics but are not specific of the 3PL industry. Second, the maturity framework presented has not been tested or applied to any 3PL provider. Third, the maturity framework does not highlight the level of exploitation of Logistics 4.0 technologies implemented by the 3PL providers. Further research can be suggested. A validation of the maturity model is suggested to increase the robustness of the framework. An empirical analysis could be useful to overcome the limitations on the application of the maturity model. It could be used to ascertain in a qualitative and quantitative way the diffusion of the Logistics 4.0 paradigm in the 3PL industry. Case studies or surveys could be useful methods to offer interesting insights on the phenomenon. Using an empirical analysis, it is possible to determine, not only the adoption of the technologies but also challenges and opportunities, advantages, and disadvantages of the adoption of Logistics 4.0 technologies for 3PL providers.

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