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Opportunities of Product-Service System in Physical Internet

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Abstract

Product-Service System (PSS) has shown great potential in supply chain and logistics management. The potential is even more evident for the recent paradigms of sustainable logistics, for example the Physical Internet that advocates the interconnection and interoperability of logistics networks. Generally, these paradigms aim at enhancing flexibility, agility and sustainability of logistics services, based on the seamless sharing of resources and services, and on decentralized real-time decision-making. To this end, these paradigms are requiring and inciting a number of innovations of PSS and services (including new business models) in supply chain and logistics management. This paper discusses the new opportunities and perspectives of PSS in Physical Internet that is one of the most recent breakthrough paradigms. We also investigate some recent innovative business models, services and practices relevant to PSS and PI, in order to point out emerging research avenues and opportunities.

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Keywords: Product-Service System; Physical Internet; Logistics; Service-oriented Supply Chain; Business model;

1. Introduction

Facing the fast changing and fierce competitive business environment, supply chain (SC) and logistics play a more and more critical role in the success of companies [1]. To improve the productivity, the organization of SC and logistics has been evolving during the last decades, i.e., from in-house to outsourced logistics [2], from vertical to horizontal collaboration [3], and more recently interconnecting interoperable networks as Physical Internet [4]. Furthermore, the evolution has also been driven by the increasingly demanding logistics services that are required to be faster, more flexible, agile, efficient, and eco-friendly for shippers and clients. In this vein, it turns out that today's SC and logistics must be focused on both productivity and services. Fig. 1 gives an overview and short description of the historical evolution of supply chain and logistics organizational models (more detailed discussion can be found in *Pan* [5]).

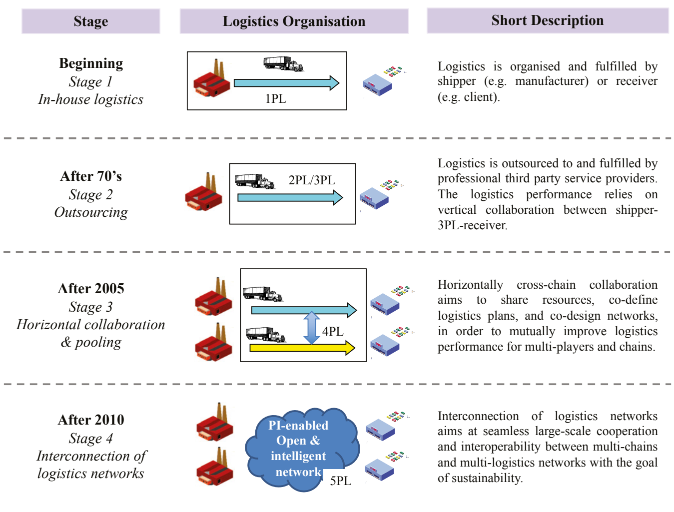

Fig. 1. Evolution of supply chain and logistics organizational models (adapted from *Pan* [5]).

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Furthermore, the new organizational models and paradigms are requiring as well as inciting new logistic professions and business models. On the one hand, new logistics professions have been raised along with the evolution. For example, the emergence of 3PL in 80' being professional asset-based logistics service providers, 4PL after 2000 being asset-free flow orchestrator [6–8], or more recently 5PL as providers of solutions (including strategic, technique, or technological) for logistics performance improvement [9]. On the other hand, the evolution incites a number of service innovations as well as business models. Examples include the *Fulfillment By Amazon - FBA* service or on-demand logistics services (e.g., *cubyn.com*), online freight marketplaces (e.g., *uship.com*, *anyvan.com*), cloud-based warehousing service (e.g., *stock-booking.com*, *flexe.com*). The organization development and service innovation together create virtuous circle for improving SC and logistics productivity and services.

Following the trend, this paper aims to investigate the new perspectives and opportunities of Product-Service Systems (PSS) in SC and logistics management, and particularly for a recent breakthrough paradigm called Physical Internet (PI). Briefly, the two concepts can be described as follows:

- PSS "*is a marketable set of products and services capable of jointly fulfilling a user's need*", stated the first and most cited definition proposed by *Goedkoop et al.* [9]. Then, the definition has been broadly extended, for example associated with sustainability, dematerialization, strategy or business model innovation for competitiveness enhancement (see *Baines et al.* [10], *Mont* [12] and *Annarelli et al.* [30] for the state-of-the-art). According to the most common definitions in the literature, there are always three key elements of PSS, that are *tangible product* that fits user's need, *intangible service* that is an activity having economic value, and *system* that collects all elements as well as their relations. Moreover, sustainability has become the most important goal of PSS.
- PI is, as a metaphor from digital internet to logistics service networks, "*an interconnected global logistics system enabling seamless asset sharing and flow consolidation, founded on universal physical, digital, operational, business and legal interconnectivity achieved through standard open protocols, encapsulation, certification, performance assessment and monitoring*", as firstly defined by *Montreuil* [15] and by *Ballot et al.* [14]. Such definition implies that PI represents an open, global, interconnected, and sustainable logistics system providing logistics services for customers' needs (shippers, receivers, flow controllers, service providers, etc.).

Obviously, the two concepts may have joint potential for today's SC and logistics management that is more and more service-oriented. First, both of them focus on asset-based services providing, as well as innovations in services and business models. Second, both suggest system-wide asset/service management to optimize both system and assets performance and the value offered. However, the questions of how the two concepts are relevant, and especially how PSS can contribute to PI development and implementation, have never been addressed in the literature. This work is thus motivated by these trends and gaps in SC and logistics management.

The paper is organized as follows. After the introduction section, Section 2 gives a brief literature review of PSS in SC and logistics management, and of the PI related research. Section 3 discusses some undergoing researches and innovative practices relevant to PI and PSS, in order to describe the state-of-the-art and outline research perspectives and directions. Finally, Section 4 concludes this work.

2. Brief Literature Review

2.1. PSS in supply chain and logistics management

PSS can be seen as a special case of *servitization* as it aims at integrating tangible products and intangible services, and values asset performance (e.g., utilization and productivity) rather than ownership [10]. The concept is naturally of interest to SC and logistics management, and for service-oriented SC in particular. Different from the traditional SC management that is usually focusing on resources or assets performance, service-oriented SC management focuses more on managing and deploying logistics organizations or systems capacity, expertise and knowledge, with the objective of improving service to clients. Meanwhile, such change advocates assets and services sharing through logistics collaboration between organizations or networks rather than having individual ownership of assets. It is coherent with the business model of PSS [16]. As a result, PSS in mostly applied in SC and logistics management for resource and service sharing, for example, in automotive industry [17], in supply hub in industrial park [16], in mold and die production [18]. IoT technologies and data techniques are also applied to efficiently and effectively manage the shared assets. More recently, lifecycle management is another hot topic related to PSS [13]. All of the studies has clearly indicated the benefits and importance of PSS in SC and logistics management. However, more research is needed and encouraged to investigate the concept in the most recent breakthrough logistics paradigms.

2.2. Physical Internet

Since its first appearance in 2010 [19], the concept of PI has become one of the hottest research topics in SC and logistics management; and it has attracted growing attention from both academia and industry. Readers may refer to [20–22] for the state-of-the-art.

For academia, PI offers a new and fruitful research field; and it inspired a growing amount of worldwide research and projects. The research involves three mainstreams. The first is concerned with conceptual models and aims at developing and enhancing the concept of PI [15,23,24]. The second focuses on performance assessment and decision-making tool development, mainly based on OR approaches or simulation models [25,26]. For example, Fig. 2 illustrates a case study of applying PI to the Fast moving consumers goods (FMCG) industry in France. More results can be found in *Sarraj et al.*

[24]. The third concerns deployment and implementation of PI, for example PI-network, hubs, or container design and deployment, as well as business model development [27,28]. Besides, the PI concept has been studied for both long-haul transport and city logistics [24]. More recently, *Oger et al.* [24] propose to enhance the concept from interconnection to hyperconnection and they claim that "*a system is said to be hyperconnected when its components and actors are intensely interconnected on multiple layers, ultimately anytime, anywhere; interconnectivity layers including digital, physical, operational, transactional, legal and personal layers*". This proposal is making another step forward and merits more research attention.

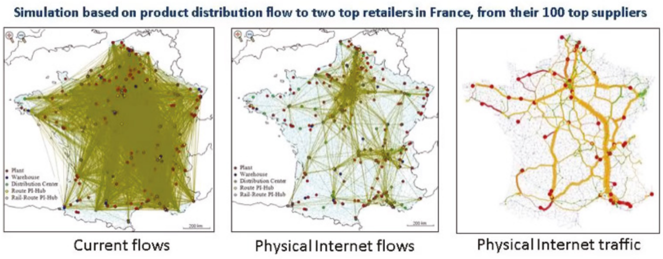

Fig. 2. Illustration of Physical Internet (adapted from *Ballot et al.* [14]).

For logistics industry and practitioners, PI is a pragmatic concept in the sense that it provides a theoretical and practical paradigm towards sustainable SC and logistics. Fig. 3 presents a roadmap towards sustainable logistics system of zero emission in Europe by 2050, via fully implementing PI by 2030. The roadmap is jointly designed by major logistics players and researchers in Europe who are involved in the European Technology Platform *ALICE* (etp-logistics.eu). Five axes have been identified for achieving the goal: 1) information systems & technologies for interconnected logistics; 2) global supply network coordination and collaboration; 3) sustainable logistics supply chains; 4) corridors, hubs and synchromodality; and 5) urban logistics. After that, a number of working groups have been created for each axis to address related research questions and implementation issues.

Overall, it is evident that PI as a paradigm and concept is a real game and mindset changer, for both academics and practitioners.

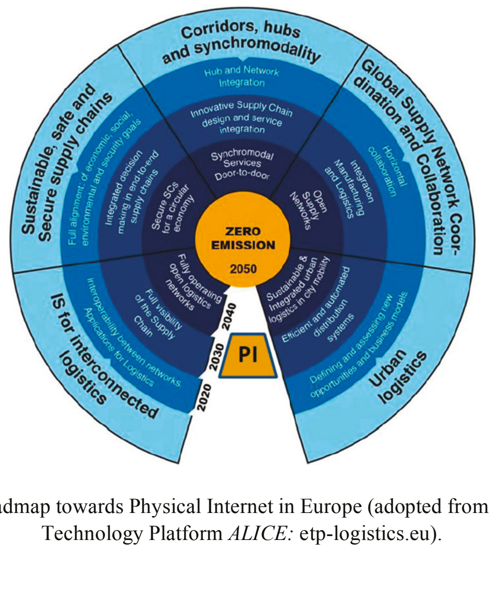

Fig. 3. Roadmap towards Physical Internet in Europe (adopted from European Technology Platform *ALICE:* etp-logistics.eu).

3. PSS in Physical Internet: opportunities and perspectives

The section discusses the state-of-the-art, and opportunities and perspectives of PSS in Physical Internet as a specific scenario of the future logistics. Four primary topics are investigated here to identify the next research directions and implementation issues. It should be noted that this section does not aim to provide an exhaustive discussion of all opportunities, but identify the first important and significant topics for investigation.

3.1. PI-container

PI-container is a key component of PI since freight transported in PI is encapsulated in standardized and modular units – namely PI-container, for the interoperability between networks. Two major features associated with such container are discussed here: physical adaptation and intelligence. Physical adaptation consists of the physical design, including size standards and modularity, material and mechanical issues associated to return and reusability (see [30,31]). *Montreuil et al.* [27] claim that there should be three categories of PI-container: transport, handling and packaging containers. And they should be adaptable to freight, transport means, and PI-containers themselves. Fig. 4 cites two examples designed from two EU projects related to PI. The second feature is intelligence of PI-container that aims to enhance the tracing and tracking, or decision making [16,17,32,33].

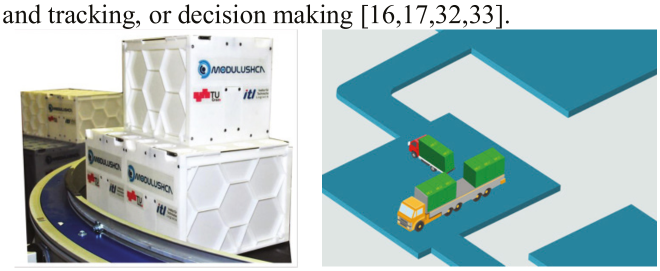

Fig. 4. Modular container designed for PI (left: M-Box handling container designed in the FP7 project MODULUSHCA [30]; right: NMLU transport container designed in the H2020 project Clusters 2.0, see clusters20.eu)

Obviously, PI-container concept may offer great opportunities to PSS business model. First, suppliers of PI-containers may have three modes to fulfilling a user's need: sell, rent, or pay-per-use (also called metered services). The first two modes commonly exist in today's (wooden or plastic) pallets or boxes market, for example the case of the company *CHEP*. However, the third mode is relatively rare in logistics and transport industry (it is close to maritime container shipping service, but it is different in the sense that shippers pay for the transport service rather than the container rental service). Currently, some IoT technology-based startups pay more attention to pay-per-use mode, as containers equipped with IoT devices may provide higher value services to clients and collect data for further use (for example *livingpackets.com*). In the context of PI, the business models associated to PI-container could be even more complex. Because it will depend on many criteria such as use cases, transport mode, return and reusability, as well as the SC type that could be open, semi-open, or closed-loop. Besides, intelligence service integrating IoT technology, data techniques and platforms will also enhance PI-container's value. This can refer to the concept of Smart PSS, which is defined as "*the integration of smart products and e-services into single solutions delivered to the market to satisfy the needs of individual consumers*" in [34]. It is also called active PI-container in [35]. This kind of intelligence is important not only for users but also policy makers, for example city logistics in particular. To go further, some important topics related to PI-container merit more research, for example, lifecycle management and circular economy, IoT technologies equipped (for long or short transport distance), new business models for product and data services, or asset management.

3.2. PI-hub

PI-hub is another key component of PI since the latter is basically composed by a number of PI-hubs (like routers in digital internet). A PI-hub may provide various logistics services based on client's need, including packaging and sorting, freight transit and rerouting, transport modal shift, warehousing or inventorying. PI-hub also aims to provide open and interoperable logistics center that can be used by multi-SC and multi-network, based on the *plug-and-play* principle. According to current practices, generally there are two types of logistics platform: warehouses (for cross-docking or inventorying) that are rarely shared between different SC, and terminals (including railway, waterway, port, airports) that are used by different SC for freight transit. The model of PI-hub is close to the latter (even it can provide more logistics services), but could be applied for all kinds of transport including inland transport of short/long distance. Fig. 5 shows a conceptual overview of a road-based PI-Hub for freight transit in crossdocking.

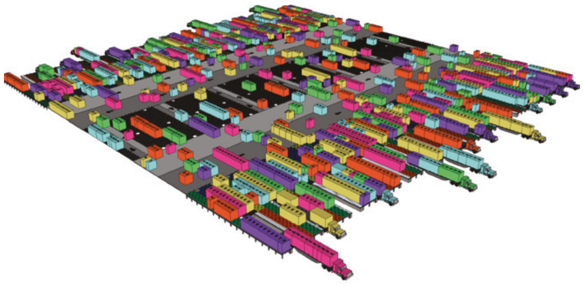

Fig. 5. Overview of a road-based crossdocking PI-Hub (adopted from [36] and from project PI-NUTS).

PI-hub can also be seen as PSS in the sense that it is a system integrating tangible products and intangible services. This is particularly important for facility and service sharing. We refer to the startup *CRC Services* (CRC for Collaborative Routing Center, see *crc-services.com*) in France as a real example in FMCG industry. Their business model is that, for a given region, they propose a local service aiming at consolidating multi-supplier and multi-retailers flows to improve transport efficiency. No long-term LSP contract is needed; contrarily, suppliers/retailers pay the service per use and per pallet. The startup proposes a set of business protocols, called *charter*, instead of contract. The advantage is that, once the charter is standardized and respected by the companies, this kind of service can be run by any company anywhere, i.e., the *plug-and-play* principle. Thanks to this, the startup has set up five service centers in few years, see Fig. 6 for their network. Inspired by such initiative and the concept of PI and PSS, more innovations in business models for PI-hubs are expected.

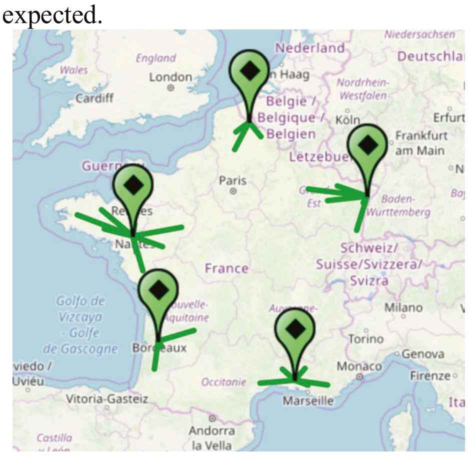

Fig. 6. The network of CRC Services in France (from *services.com* 2019).

3.3. Digital connectivity for interoperability

If digital connectivity can be seen as dematerialized PSS, its value should be highlighted in today's SC and logistics management, and especially for PI. Seamless communication and data exchange is crucial to interoperability in PI. In this vein, the interconnection of heterogenous information systems (databases as well as devices) becomes an issue; therefore, services of digital connectivity are put into forward.

Digital connectivity is massively relying on ICT or IoT technologies or techniques, for example wireless communication technology (LoRa, 5G, NB-IoT, etc.), online data platforms (cloud), API (application programming interface), industrial blockchain, industrial wearables, digital twin or Cyber-physical systems. More and more companies - sometimes called 5PL - are proposing high-tech services for logistics industry. The solutions that they come up with could be tangible (e.g., devices or sensors) or intangible (e.g., data or web services). Though not all of the solutions strictly fits the conventional definition of PSS, we may still develop digital connectivity services from the perspectives of PSS (after dematerialized). Obviously, smart PSS seems one of the most promising models [34]. As PI advocates large-scale cooperation and interoperability as well as decentralized real-time decision-making, the value created by smart PSS may lie in not only digital connectivity for communication, but also preliminary data analysis and processing for responsive decision making. The relevant topics can be very broad, including fog computing, ambient intelligence for logistics, smart API, or smart contract. The business models associated should also be further discussed.

3.4. Sharing economies

By its definition, PSS has evidently great opportunities in sharing economies. *Savelsbergh et al.* [33] indicate that there are two kinds of sharing economies in SC and logistics. The first is called *collaborative consumption* that can be simply described as a peer-to-peer (P2P) product or service sharing based on consumer-to-consumer (C2C) network, for example carsharing or crowdshipping (e.g., *piggybee.com*). While the second is called *collaborative business* that involves sharing logistics assets or services with competitors based on business-to- business (B2B) network. The latter is particularly of interest to PI concept. First, PI consists of horizontal collaboration in logistics [4]; and it is practically a B2B network for resource and service sharing. Second, the fact that collaboration in PI should be relying on protocols would help enhance seamless B2B interoperability and trust (same as TCP/IP in digital internet). However, collaborative protocols for PI need further investigation, taking into account logistics constraints and companies' business process that are very different from digital internet. In a broader sense, seamless interoperability enabled by PI will certainly encourage PSS-enabled sharing economies.

4. Conclusion

In this paper, we discuss the new opportunities and perspectives of PSS in Physical Internet, which is a breakthrough sustainable paradigm in supply chain and logistics management. We argue that PI may provide a new and fruitful research field for PSS; and in turn PSS will incite business models development in PI as well as implementation. Four primary topics are discussed to point out some future directions for research and application.

In the next future, PSS and PI together will probably drive us towards new organizational models in SC and logistics management, e.g., *Supply-chain-as-a-Service* or *Logistics-as-a-Service* model [38]. Generally speaking, these models are most likely relying on sharing economies (especially collaborative business) and *pay-per-use* model. Currently, there exists already some practical examples, e.g., in e-commerce sector the *Fulfillment by Amazon* or some startups like Active Ants (*activeants.nl*) and Cubyn (*cubyn.com*), or in traditional FMCG industry the aforementioned CRC Services. Facing the fast-growing amount of on-demand logistics services, we believe that more and more similar services and business models will appear. Consequently, the current practices in SC and logistics management will be fundamentally disrupted and challenged, which will open up new research topics of significance and importance to the area. Notably considering the boom and rapid development of high-tech technologies and techniques, it is predictable that future logistics will be more intelligent, open, decentralized, and autonomous, for example towards the scenario of self-organizing logistics system discussed in *Pan et al.* [39].

Acknowledgements

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