5. The physical internet as enabler of new business models enhancing greener transports and the circular economy

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1. INTRODUCTION

The physical internet (PI) approach to global logistics uses the digital internet as a metaphor for the physical world and aims at building an industry-wide standardized service architecture for logistics systems. The idea is that PI would merge the currently separate and fragmented logistics solutions into a unified system comparable to the digital internet – an approach that could be accomplished by standardizing containers, interfaces and protocols, for example. Thus, logistics networks would be opened up, resources could be shared, and higher efficiency achieved. However, despite the growing number of theoretical discussions and blueprints, PI does not yet have many practical applications. The Physical Internet Manifesto[1] declares PI as an 'instrument for tackling the grand logistics sustainability challenge', and suggests the following definition of PI: 'The physical internet is an open global logistics system founded on physical, digital, and operational interconnectivity through encapsulation, interfaces and protocols.'

PI is motivated by the claim that the current methods by which cargo is moved, stored, supplied, and used throughout the world are not sustainable environmentally, socially, or economically, and that this situation could be remedied by adopting PI.[2] This argument can be easily understood concerning

1 Benoit Montreuil, 'Physical Internet Manifesto' (Version 1.11.1: 2012-11-28, 2012), https://www.slideshare.net/physical_internet/physical-internet-manifesto-eng-version-1111-20121128, accessed 29 August 2018.

2 Ibid.

environmental unsustainability, because transport is one of the biggest greenhouse gas (GHG) originators and polluters. Transport is responsible for almost a quarter of the EU's GHG emissions and is the main cause of air pollution in cities.[3] Furthermore, there are trends in logistics that increase the pressures on current logistics systems For example, as e-commerce has vastly increased, the number of small packages has proliferated all around the world, causing problems in city logistics especially.[4] In addition, although the EU has promoted intermodal transport as an environmentally friendly option for 20 years,[5] its popularity has not increased very much. Road transport was responsible for about 73 per cent of GHG emissions in the EU transport sector in 2014.[6] *Social* unsustainability includes untenable working conditions in logistics, such as truck drivers spending weeks on the road, moving goods from door to door through continents.[7]

The *economic inefficiencies* of the current system include significant and increasing logistics costs. Trucks and containers are often half empty, with one-quarter (25.4 per cent) of journeys being performed by empty vehicles and the average utilization of load space being only 43 per cent at the EU-28 level in 2016.[8] Products are stored in numerous warehouses and distribution centres throughout the world, yet response times do not always meet the market requirements, leading to high storage costs, lost sales and inefficiencies.[9] The logistics industry has not normally been very innovative.[10] Transport service

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3 Commission, 'A European Strategy for Low-Emission Mobility' (Communication) COM(2016) 501 final.

4 Werner Delfmann, Sascha Albers and Martin Gehring, 'The impact of electronic commerce on logistics service providers' (2002) 32(3) *International Journal of Physical Distribution & Logistics Management* 203.

5 Vasco Reis, 'Analysis of mode choice variables in short distance intermodal freight transport using an agent-based-model' (2014) 61 *Transportation Research Part A: Policy and Practice* 100.

6 'EU Transport in figures, Statistical pocket book' (European Commission, 2016) https://ec.europa.eu/transport/sites/transport/files/pocketbook2016.pdf, accessed 30 December 2016.

7 Montreuil, 'Physical Internet Manifesto' (n 1).

8 Eurostat Statistics explained, 'Road freight transport by journey characteristics' (Data extracted in October 2017, 2017) http://ec.europa.eu/eurostat/statistics-explained/index.php/Road_freight_transport_by_journey_characteristics, accessed 15 March 2018; SETRIS, 'A Truly Integrated Transport System for Sustainable and Efficient Logistics' (SETRIS, Strengthening European Transport Research and Innovation Strategies, 2017) https://euagenda.eu/publications/a-truly-integrated-transport-system-for-sustainable-and-efficient-logistics, accessed 29 August 2018.

9 Montreuil, 'Physical Internet Manifesto' (n 1).

10 SETRIS (n 8); Henrik Sternberg and Andreas Norrman, 'The Physical Internet – review, analysis and future research agenda' (2017) 47(8) *International Journal of Physical Distribution & Logistics Management* 736.

providers and companies involved in the construction of transport infrastructure have limited R&D resources,[11] although such lack of radical innovations could also be attributed to a lack of transparency or open standards, protocols or infrastructure. Companies have been responsible for their own development, and that is why there has been no division of labour in investments, or justification of investments based on smart technology, for example.[12]

PI promises to make the logistical system economically, environmentally and socially more sustainable by modularization and the increased connectivity, transparency and sharing of resources. Even though Sternberg and Norrman point out that there are no practical applications of PI yet,[13] we must remember that there are trends and initiatives that have led towards more cooperation, transparency and information sharing in logistics, and that there are already at least some practical applications that greatly support sustainable development. Just to give some examples, many logistics service providers (LSPs) let their customers track their shipments and, in the most advanced systems, the state of goods in containers, too. Furthermore, Maersk has launched Remote Container Management (RCM), which allows its customers to monitor the conditions inside containers from the moment goods are locked inside, right up to delivery at their final destination.[14] The CO^3 (Collaboration Concepts for Co-modality) project also aims to increase the competitiveness and sustainability of European logistics by stimulating horizontal collaboration between European shippers.[15]

It has been said that collaboration – both horizontal and vertical – in the logistics industry is a means of supporting not only cost reduction, but also the industry's targets for sustainable development.[16] Some research has shown the benefits of cooperation and flexible attitudes. For example, Vanovermeire et al. showed in their case study of three companies that, by allowing changes in delivery dates and the splitting of large orders into smaller deliveries, it

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11 Tobias Wiesenthal, Ana Condeço-Melhorado and Guillaume Leduc, 'Innovation in the European transport sector: A review' (2015) 42 *Transport Policy* 86.

12 Benoit Montreuil, 'Toward a physical internet: meeting the global logistics sustainability grand challenge' (2011) 3 *Logistics Research* 71; Physical Internet Manifesto (2012), Montreuil, 'Physical Internet Manifesto' (n 1).

13 Sternberg and Norrman (n 10).

14 'Remote Container Management' https://www.maersk.com/solutions/shipping/remote-container-management, accessed 29 August 2018.

15 'Collaboration Concepts for Co-modality' http://www.co3-project.eu, accessed 29 August 2018.

16 Robert Mason, Chandra Lalwani and Roger Boughton, 'Combining vertical and horizontal collaboration for transport optimization' (2007) 12(3) *Supply Chain Management: An International Journal* 12(3) 187.

was possible to achieve about a 26 per cent decrease in transportation costs.[17] Moreover, TransFollow, a logistics tracking platform for paperless transport (the so-called e-CRM), was created by Dutch associations and is now owned by the International Road Transport Union (IRU).[18]

However, if we compare these initiatives to the PI concept, there is an important difference. Whereas they typically focus on using ICT to accomplish greater efficiency and transparency in the current processes, PI aims at profoundly changing the whole system, including infrastructure (containers, hubs, corridors, and so on), processes and business models. Based on the prior PI literature, Treiblmaier et al. listed the crucial PI components as follows: modular containers, vehicle usage optimization, transit centres/hubs, seamless secure and confidential data exchange, legal frameworks, cooperation models and business models. All of these components will need to be developed when proceeding towards PI.[19] With this in mind, we take a logistics ecosystem view of PI in this chapter. According to Tsvetkova and Gustafsson, an industrial ecosystem has no value chain as it is normally perceived, but rather a value network consisting of a number of value chains in various industries; and the connection of these value chains forms an industrial ecosystem. They (ibid.) claim that, by being part of an ecosystem, a company can gain greater value than it would gain through reliance on a conventional direct value chain, and that environmental and economic benefits can be realized only within a system consisting of business actors from normally disconnected industries. Such open or 'boundary-spanning' business models require high involvement of a wide variety of stakeholders, that is customers, suppliers, partners and authorities.[20]

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[17] Christine Vanovermeire and others, 'Horizontal logistics collaboration: decreasing costs through flexibility and an adequate cost allocation strategy' (2014) 17(4) *International Journal of Logistics Research and Applications* 339.

[18] 'IRU-TransFollow Partnership' https://www.iru.org/node/2584, accessed 29 August 2018.

[19] Horst Treiblmaier , Kristijan Mirkovski and Paul B. Lowry, 'Conceptualizing the physical Internet: Literature review, implications and directions for future research' (11th CSCMP Annual European Research Seminar, Vienna, Austria, May 12–May 13 2016)

https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2861409, accessed 29 August 2018.

[20] Anastasia Tsvetkova and Magnus Gustafsson, 'Business models for industrial ecosystems: a modular approach' (2012) 29–30 *Journal of Cleaner Production* 246.

2. LITERATURE AND INDUSTRY ACTIVITIES RELATED TO PI

The history of the PI concept began in the year 2006 when *The Economist* launched the concept on the cover of its theme issue on logistics practices. The issue discussed the moving of goods around the world with ever greater efficiency, and the information attached to them. This idea was further developed by Dr. Benoit Montreuil, a Canadian professor who generated a vision of PI that uses the digital internet as a metaphor for the physical world.[21] Montreuil has published multiple versions of the Physical Internet Manifesto on-line since 2009.

According to the Manifesto, PI aims at achieving universal interconnectivity by high-performance logistics centres, movers and systems, making it easy, fast, reliable and cheap to interconnect physical objects through modes and routes.[22] PI's conceptualization and realization have been further developed in Canadian, French and US-based research projects – for example in the OpenFret project focusing on the conceptualization of PI, and the PREDIT programme focusing on fast-moving goods logistics in France. The European Commission has also funded a lot of research on PI. For example, the Modulushca project which was submitted to the 7th Framework Programme received considerable funding from the European Commission.[23] This project aimed at achieving proofs of concept by implementing and testing key functions of interconnected logistics, and, on a technical level, it aimed at advancing modular logistics units, resource-efficient logistics and an information framework for interconnected logistics.[24]

Apart from these projects, PI-related research is still in its early stages, being scarce and fragmented, and with its ideas not having been much tested in practice. However, it is increasingly gaining transdisciplinary attention from researchers and practitioners.[25] Several research papers have already simulated the potential benefits of PI and some projects have already tested its basic concepts. For example, Sarraj et al. tested various transportation protocols and scenarios in the French fast-moving consumer goods sector, using a dataset from two major retail chains (Carrefour and Casino) and their 106 biggest common suppliers. They reported encouraging results for efficiency indicators

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21 Shenle Pan and others, 'Physical Internet and interconnected logistics services: research and applications' (2017) 55(9) *International Journal of Production Research* 2603.

22 Montreuil, 'Physical Internet Manifesto' (n 1).

23 Shenle Pan and others (n 21).

24 http://www.modulushca.eu, accessed 29 August 2018.

25 Shenle Pan and others (n 21).

such as CO_2 emissions, costs and lead times, and so on – results that increased the fill rate of transportation means by almost 17 per cent, and raised the share of rail transportation, leading to a 60 per cent reduction in CO_2 emissions, without compromising lead times or costs. They (ibid.) emphasized that PI constitutes a universal interconnection of logistics services, where goods travel in modular containers in interconnected open networks.[26] Similarly, when Fazili et al. simulated PI solutions, they found a reduction in driving distances and times, GHG emissions and the social costs of truck driving, but conversely found an increase in the number of container transfers within the PI logistics centres.[27] Therefore, it should be noted that the success of the PI logistic systems depends to a great extent on the efficiency of the PI transit centres, and also, in our opinion, on the infrastructure, standardized interfaces, and innovative service offerings and ecosystem business models.

Sternberg and Norrman were the first to present a review of the PI literature, discuss the concept critically, and outline a research agenda. They analysed 46 publications and found that, although a growing number of strategies, blueprints and specifications had been developed for PI, there was a lack of models that would illustrate how the move from current logistics business models to PI models could happen.[28]

The growing interest in PI in practice by global logistics companies and their biggest customers has led to the establishment of *The European Technology Platform on Logistics (ALICE)*[29] that made PI the principal European 2030–2050 vision for logistics and supply, and proposed a com-

[26] Rochdi Sarraj and others, 'Interconnected logistic networks and protocols: simulation-based efficiency assessment' (2014) 52(11) *International Journal of Production Research* 3185.

[27] Mehran Fazili and others, 'Physical Internet, conventional and hybrid logistic systems: a routing optimisation-based comparison using the Eastern Canada road network case study' (2017) 55(9) *International Journal of Production Research* 2703.

[28] Sternberg and Norrman (n 10).

[29] ALICE (Alliance for Logistics Innovation through Collaboration in Europe) is one of the European Technology Platforms (ETPs), which are industry-led forums recognized by the European Commission as key actors in driving innovation, knowledge transfer and European competitiveness. ETPs develop research and innovation agendas and roadmaps for action, and mobilize stakeholders to deliver priorities and share information across the EU. Today, there are four transport ETPs besides ALICE: 1) ACARE (Advisory Council for Aviation Research and Innovation in Europe), 2) ERRAC (The European Rail Research Advisory Council), 3) ERTRAC (European Road Transport Research Advisory Council) and 4) WATERBORNE (European Maritime Industries Advisory Research Forum). ETPs are independent, self-financing and act in a transparent manner. They are open to new members. (http://ec.europa.eu/research/innovation-union).

prehensive roadmap for its implementation and adoption.[30] The members of ALICE include big global manufacturers and shippers such as Procter & Gamble, Ford, Bayer, Bosch, Volvo and Daimler, LSPs such as Geodis and PosteItaliane, and ICT and consultancy firms such as IBM and Marlo, along with research institutes, logistics clusters, and innovation-funding organizations. ALICE aims at developing a comprehensive strategy for research, innovation and the market deployment of logistics and supply chain management innovation in Europe. Its mission is 'to contribute to a 30 per cent improvement of end-to-end logistics performance by 2030' (ALICE, 2013). This improvement could mean a cost reduction of EUR 300 billion for European industry.[31]

To achieve efficient logistics and supply chain operations, close collaboration between shippers and LSPs is necessary. PI is one of the key means identified by ALICE to achieve these performance goals. ALICE has recognized five different areas that need to be analysed and addressed in order to achieve its mission. Therefore, five Working Groups have been launched, one for each of these areas, to further analyse and define research and innovation strategies, roadmaps and priorities agreed by all stakeholders to achieve the vision and mission of ALICE. These areas are 1) Sustainable, Safe and Secure Supply Chains, 2) Corridors, Hubs and Synchromodality, 3) Information Systems for Interconnected Logistics, 4) Global Supply Network Coordination and Collaboration, and 5) Urban Logistics.[32] Keeping PI as a goal can prompt a misconception that PI is a binary state, either existing or not, even though the process leading to PI is progressive. According to ALICE, the purpose is also to achieve PI in all of the above-mentioned five theme areas step-by-step, and, at the end, the goal is to get PI wholly realized by 2050.

Referring to Meller et al.,[33] Treiblmaier et al. claimed that there are at least three critical challenges related to PI: (1) physical challenges, such as the

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[30] Shenle Pan and others (n 21); ETP-alice www.etp-logistics.eu, accessed 29 August 2018.

[31] Alliance for European Logistics, 'A Technology Roadmap for Logistics – Promoting a comprehensive and integrated European strategy to support and incentivize ICT platforms and green technologies for European transport and logistics operations' (Alliance for European Logistics, 2010) http://www.transport-ncps.net/wp-content/uploads/plikownia/TOOLbox/Documents-Repository/LOGISTICS/AEL%20-%20Alliance%20for%20European%20Logistics/AEL_Technology_Roa_Map_Oct_2010.pdf, accessed 31 August 2018.

[32] Along with these areas several important projects enhancing PI development are listed related to theme 1) Modulushca, Cofret, and Cassandra, theme 2) Supergreen and Tiger, theme 3) E-Freight, Integrity and Finest, theme 4) Smile and Success, and theme 5) Nextrust and CO3.

[33] Russell D. Meller, Kimberly P. Ellis and Bill Loftis, 'From horizontal collaboration to the Physical Internet: quantifying the effects on sustainability and profits when

design of containers, transit and hub facilities; (2) digital challenges, meaning interoperability between PI components; and (3) operational challenges, such as changes in business models and culture.[34] To overcome the challenges, they proposed that future research should look into how governments could affect changes in corporate culture and how global interoperability could be accomplished between the PI components. In addition to the standardization and modularization of physical objects, PI will need multi-level standardization and certification of protocols, handling and storage technologies, distribution and production centres, multimodal hubs, information systems, and so on.[35] Furthermore, it has been claimed that even modularization related to PI must be understood across different scales, from small to large containers and from long distance to last mile distribution.[36] In our opinion, the modularity of PI should also be understood at the business model and ecosystem levels.

To summarize PI's theoretical and practical development, the idea of PI is to transform the way in which objects are manufactured, moved, stored, supplied or used, in order to achieve greater efficiency and sustainability. Further, it is expected that PI will have the potential, by opening logistics networks and sharing resources, to streamline the global transport system in ways that will make it economically, environmentally and socially more efficient and sustainable than what is achievable by any individual company.[37]

Sternberg and Norrman pointed out that potential business models involving key actors who would promote the adoption of the PI concept are still poorly understood. They concluded that, because it is unclear why LSPs should become involved in PI, policy makers and practitioners should start to consider the practical development and adoption of the concept.[38] In our opinion, these arguments emphasize the advantages of taking a wider ecosystem approach to PI.

For efficient adoption of PI, different models based on a layered-structure approach have been suggested. Some of these models and a new simplified model are described next. We propose that, by using the modular structure presented in this chapter, it will be easier to understand which business models are viable and which actors could be involved in the PI ecosystem, and the

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shifting to interconnected logistics systems' in *Final Research Report of the CELDi Physical Internet Project* (Phase I, 1–29, (2012).

[34] Treiblmaier, Mirkovski and Lowry (n 19).

[35] Montreuil, 'Physical Internet Manifesto' (n 1).

[36] SETRIS (n 8).

[37] 'ALICE Recommendations to H2020 Work Programs 2016-2017' http://www.etp-logistics.eu/wp-content/uploads/2015/07/ALICE-Recomendations-HORIZON2020-WP-2016-2017-v141218_DEF-2.pdf, accessed 29 August 2018.

[38] Sternberg and Norrman (n 10).

reasons why, and thereby to tackle the challenges of PI and bring it a bit closer to realization.

3. LAYERED STRUCTURE OF PI

A layered PI structure has been seen as a prerequisite for an open-to-all system, with different numbers of layers being suggested, such as the four layers suggested in the Physical Internet Manifesto and Montreuil et al.[39] The four-layered model includes, first, a '*Realization Web*' consisting of centres for open production, personalization and modification of objects, and, second, a '*Distribution Web*' where encapsulated objects are placed and stored in open and shared warehouses across markets. The third layer consists of movers, hubs and transits moving encapsulated objects through an open multimodal '*Mobility Web*'. For the fourth layer, interconnected suppliers and subcontractors form a '*Supply Web*'. In addition to these four layers, interconnected users and service providers form a '*Service Web*'.

Furthermore, building PI more in emulation of the digital internet, Montreuil et al. presented a seven-layered model, basing their thinking on the Open System Interconnection (OSI) model originally presented by Zimmermann and used for the digital internet.[40] The standard OSI model was designed with the explicit objective of allowing openness to a variety of systems. The idea behind the OSI model was that, by following specific international standards, a system could be open to all other systems complying with the same standards.[41] Similarly, the Open Logistics Interconnection (OLI) model suggested by Montreuil et al. would enable the interconnection of logistics services within PI. Logistics networks are diverse and engage not only in moving goods, but also in exchanging information and money digitally. Ensuring universal connectivity in such a diverse setting requires standardized approaches, as is done in PI.[42] The OLI model proposes the following layers: (1) physical, (2) link, (3) network, (4) routing, (5) shipping, (6) encapsulation, and (7) Logistics Web.[43] The physical layer focuses on moving and operating the physical elements,

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39 Montreuil, 'Physical Internet Manifesto' (n 1); Benoit Montreuil and others, 'The Physical Internet and Business Model Innovation' (2012 a) 2 *Technology Innovation Management Review* 32.

40 Hubert Zimmermann, 'OSI Reference Model-The IS0 Model of Architecture for Open Systems Interconnection' (1980) 28(4) *IEEE Transaction on Communications* 425.

41 Benoit Montreuil, Eric Ballot and Frederic Fontane, 'An open logistics interconnection model for the physical internet' (2012 b) 45(6) IFAC Proceedings Volumes 327.

42 Ibid.; Montreuil and others (n 39).

43 Montreuil, Ballot and Fontane (n 41).

including containers, vehicles, carriers, conveyors, and so on. The link layer checks the consistency between physical operations and their digital mirror. The network layer focuses on the interconnectivity, integrity and interoperability of networks, thus providing the functional and procedural means for insuring that containers are routed within and across networks. The routing layer offers the functional and procedural means to take a set of containers from its source to its destination in an efficient and reliable manner. The shipping layer identifies the type of delivery (normal, express, and so on). It includes the procedures and protocols for monitoring, verifying, adjourning, terminating and diverting shipments. Shipping requests are received from the deployment layer and transport services from the transport layer. The encapsulation layer converts decisions about moving and storing products into decisions about moving and storing containers. The Logistics Web is the interface between PI and the users of logistics services.[44]

We take an ecosystem view of PI, as there are many industries connected to and networked with the development of PI. We weave together the previous discussion on layers, and simplify and summarize it by suggesting a model (see Figure 5.1 below) consisting of three layers or modules which we consider key to the PI structure. These three modules are:

(1) *the physical web module*, including a network of all activities related to the physical movement ecosystem: suppliers; manufacturing; handling; transport and distribution of products;
(2) *the information web module*, seamlessly connecting information to support the physical web module and the ecosystem business model module. This module covers information sharing for the other modules;
(3) *the ecosystem business model module,* based on cooperation, transparency and information sharing between the ecosystem partners, and providing a connection point and alignment for the information and physical web layers with a web of sustainable and efficient services.

These three modules together form the core for the sustainable movement of goods from the point of origin to the destination. It is important to note that these three modules encourage innovations that could reduce resource and material consumption and thereby promote systems for a circular economy (CE). For example, the physical web module in PI discusses the restructuring and innovating of new resource-efficient hubs, transport means and distribution channels such as dry ports for efficiently reducing emissions and promoting sustainable logistics solutions. Similarly, the use of new technologies for information sharing will promote collaborative efforts and culminate

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[44] Ibid.

in optimal solutions for the movement and delivery of products, resulting in more sustainable solutions. The ecosystem business model module weaves the physical web and information layers into services developed together with partners from different industries, for example, thus supporting the development of new innovative business model ecosystems. To summarize, we argue that the proposed three modules of PI are adequate for understanding the basic elements of PI, and aim at sustainable logistics solutions, thereby contributing towards the implementation of CE systems.

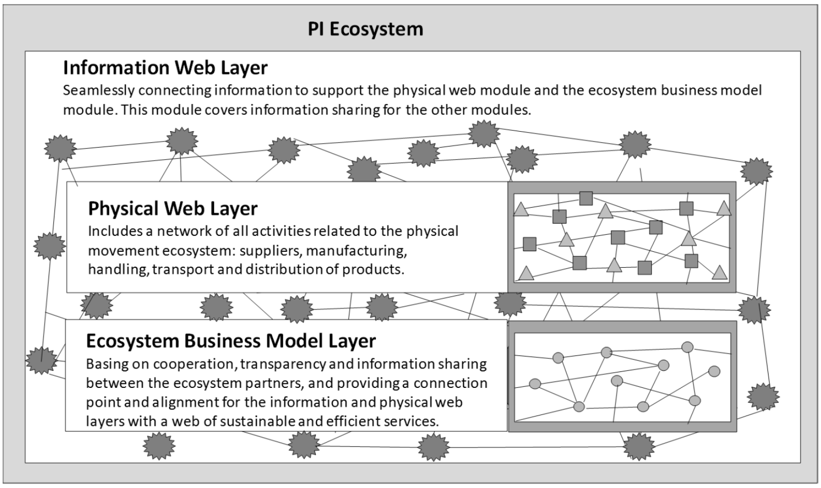

Figure 5.1 Three key layers/modules of the Physical Internet (PI) ecosystem

Next, we describe these three levels in more detail, focusing on how they support sustainable development and CE, and giving examples from the different layers. As the definition of PI expects that open global logistics systems are enabled through modularization, standard interfaces and protocols, these issues are also discussed, as they have slightly different meanings in each layer.

3.1 The Physical Web Layer

3.1.1 Current situation and ideas for improvement based on PI

The physical web layer includes a network of all activities related to the physical movement ecosystem: supply, manufacturing and the physical activities of product logistics (that is hubs, transport means and distribution). Compared to the digital internet, the users of PI need not think about the route of the parcels they send, but they can trust that the parcel will be securely delivered to the receiver through PI, just as their messages are delivered in the internet (ALICE webpage). Accordingly, PI is an open and global system of transport and logistics assets, hubs, resources and services that are operated by individual companies, but are fully visible and accessible to market players.[45] It is based on open markets for freight transportation, shared supply, transportation and distribution networks, modular containers, a vast community of users, and supplier certifications and ratings of logistics performance given by users.[46] In other words, all storage and distribution facilities belonging to PI, for example, regardless of which company they belong to, are open to any other company.[47]

Manufacturing is also an essential part of this physical web layer, and, in multinational corporations, is typically divided between different regions and countries. Global activities clearly require a well-functioning physical mobility system to be efficient. But even though the outsourcing of activities has long been the trend, discussion on nearshoring or reshoring (that is taking manufacturing 'back' closer to the market) has recently increased,[48] which impacts on sustainability in terms of less transport. Other potential for changing manufacturing locations includes the 3D printing of products and the assembly of modular products close to customers and only according to orders. These more flexible modes of manufacturing are also affecting physical movement, and vice versa. A well-organized logistics system is essential for flexible, sustainable and efficient manufacturing operations covering the circular flow of materials and resources.

Contrary to the networks in the digital world with highly standardized structures and elements, the logistics networks through which physical objects are moved, are still today quite fragmented and dedicated to specific companies or supply chains. A notable exception regarding standardization is the worldwide use of 20ft and 40ft intermodal containers, allowing the shipment of goods regardless of the operator and the transportation means.[49] The PI initiative

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45 SETRIS (n 8).

46 Montreuil, 'Physical Internet Manifesto' (n 1).

47 Driss Hakimi and others, 'Simulating a Physical Internet enabled mobility web: the case of mass distribution in France' (9th International Conference on Modeling, Optimization & SIMulation MOSIM'2012, Bordeaux, June 2012) https://hal.archives-ouvertes.fr/hal-00728584, accessed 30 August 2018.

48 Lisa M. Ellram, Wendy L.Tate and Kenneth J. Petersen, 'Offshoring and reshoring: an update on the manufacturing location decision' (2013) 49(2) *Journal of Supply Chain Management* 14; John V. Gray and others, 'Why in the world did they reshore? Examining small to medium-sized manufacturer decisions' (2017) 49–51 *Journal of Operations Management* 37.

49 Montreuil, Ballot and Fontane (n 41).

aims to respond to this challenge by reforming heterogeneous logistics networks into resource-efficient and environmentally sustainable systems (see for example Montreuil[50]).

European transport still relies heavily on road transport, although one of the key targets of the EU's White Paper on transport was that by 2030 at least 30 per cent of road freight over 300 km should have shifted to other modes, such as rail or waterborne transport, and that by 2050 the figure should have exceeded 50 per cent, facilitated by efficient and green freight corridors.[51] No substantial growth in modal shift has been achieved yet. At least 60 per cent of freight-related emissions are linked to journeys under 300 km, which needs special attention. Especially in urban deliveries, a lack of transparency and knowledge of freight traffic and its load factors prevents synergies from arising for example by pooling solutions to reduce traffic and congestion). Additionally, parcel delivery companies and so on seem to be reluctant to share their vehicles due to a fear of negatively affecting their image.[52]

In PI, the transport system will be integrated and based on an open and global system of transport and logistics assets, hubs, resources and services operated by individual companies. The system will be transparent and accessible to all market players, hence creating *a network of logistics networks.* Efficiency and sustainability drivers are among the key messages of PI. By opening up logistics networks to partners and members of the network, and sharing resources, high efficiency can be achieved.[53] This has been proven in some cases, as shown by Cheng et al. who presented a relevant example when studying the policies of parcel pick-ups for express courier services in dynamic environments.[54] Darvish et al. optimized the total cost of distribution, including production, inventory, demand and distribution decisions, and revealed that a PI-enabled open network would greatly reduce total logistics costs, especially storage and transportation costs.[55] Ballot et al. used a continuous approximation model to argue that costs would be divided by 1.5–2.5, and

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50 Montreuil, 'Physical Internet Manifesto' (n 1).

51 Commission, 'Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system' (White Paper) COM(2011) 144 final (White Paper 2011).

52 SETRIS (n 8).

53 Ibid.; 'ALICE Recommendations to H2020 Work Programs 2016-2017' (n 37).

54 Xian Cheng, Shaoyi Liao and Zhongsheng Hua, 'A policy of picking up parcels for express courier service in dynamic environments' (2017) 55(9) *International Journal of Production Research* 2470.

55 Maryam Darvish, Homero Larrain and Leandro C. Coelho, 'A dynamic multi-plant lot-sizing and distribution problem' (2016) 54(22) *International Journal of Production Research* 6707.

distances by 2–5, depending on the hypotheses, leading to a reduction of CO_2 emissions caused by logistics by four.[56]

Among the most important enabling concepts of PI are standardized, modular and smart containers, which enable a universal interconnectivity of logistics networks and services.[57] Modularization is one of the most important enablers of the consolidation and bundling of goods to an adequate extent and degree of efficiency.[58] Generally, product modularity has been seen as increasing supply chain efficiency and flexibility, and as a driver triggering changes in the roles of the supply chain actors.[59] In our opinion, the use of modular principles is not limited to the physical web layer of PI. Business models based on modular ecosystem thinking may achieve the flexibility to adapt to different contexts and local circumstances.[60]

3.1.2 Examples of new emerging physical web applications

The EU has aimed to increase rail transports for greater efficiency and to act as environmental drivers.[61] Another example that supports sustainable development in transport are dry ports, which are inland intermodal terminals connected by rail to a seaport and operating as a centre for the trans-shipment of sea cargo to inland destinations. It is possible to reduce the number of transportation links from/to seaports by efficiently using dry ports. Furthermore, this also increases seaport terminal capacity.[62] A dry port is an efficient way

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[56] Eric Ballot, Benoit Montreuil and Frederic Fontane, 'Topology of logistic networks and the potential of a physical internet' (International Conference on Industrial Engineering and Systems Management IESM 2011, Metz – France, 25-27 May 2011) 585–94.

[57] Benoit Montreuil, Russell D. Meller and Eric Ballot, 'Towards a physical internet: the impact on logistics facilities and material handling systems design and innovation' (International Material Handling Research Colloquium (IMHRC 2010), Milwaukee, États-Unis, 21–24 June 2010).

[58] SETRIS (n 8).

[59] Hans Voordijk, Bert Meijboom and Job de Haan, 'Modularity in supply chains: a multiple case study in the construction industry' (2006) 26(6) *International Journal of Operations & Production Management* 600; Young K. Ro, Jeffrey K. Liker and Sebastian K. Fixson, 'Modularity as a strategy for supply chain coordination: the case of U.S. Auto' (2007) 54(1) *IEEE Transactions On Engineering Management* 172; Sebastian Pashaei and Jan Olhager, 'Product architecture and supply chain design: a systematic review and research agenda' (2015) 20(1) *Supply Chain Management: An International Journal* 98.

[60] Tsvetkova and Gustafsson (n 20).

[61] COM(2011) 144 final (n 51).

[62] Violeta Roso, 'Evaluation of the dry port concept from an environmental perspective: A note' (2007) 12(7) *Transportation Research Part D: Transport and Environment* 523; Violeta Roso, Johan Woxenius and Kenth Lumsden, 'The dry port

to promote intermodal rail transport and prevent congestion in metropolitan areas, since one train can substitute some 35 lorries and reduce CO2 emissions (see for example Roso[63]). The dry ports share with traditional ports many of the functions enabling seamless transport and movement of goods.[64]

E-commerce is growing at a double-digit rate in all European countries and is changing transport demand to small-size shipments that form a challenge for the efficient and sustainable management of logistics, especially for the big e-commerce companies. But traditional retailers are also facing the challenge of running two different distribution channels – traditional and on-line. These trends will influence transport systems in cities, where the number of shopping trips will be reduced, while personalized parcel deliveries will simultaneously increase. That is why there is a need to organise overall efficient management and use of transport systems. Several new business and service models are being piloted for last-mile deliveries, including crowd-sourced home deliveries, the use of bikes, automated delivery vehicles, city terminals and delivery boxes, and even helicopter-type drones.

3.1.3 Discussion on challenges of implementation

The report by the SETRIS project, 'A Truly Integrated Transport System for Sustainable and Efficient Logistics' (2017), discusses challenges concerning the physical web layer. First, currently there is a lack of modular and standardized containers for inland and air transport. Second, there are many regulations that slow down innovation, while dissimilar standards, regulations and procedures in EU Member States prevent smooth cross-border transport operations. Third, there is a lack of trans-shipment technologies for the fast and low-cost handling of freight in loading and unloading operations, and for fulfilling the needs of efficient operation in networks.[65]

If we compare the situation in the USA and Europe, coast-to-coast rail transport in the USA involves no borders, one language, one rail gauge and the same regulations, whereas in Europe the same distance can involve many borders, languages, rail gauges and regulations. Reliability and flexibility are among the major barriers affecting modal shift.[66] However, the future growth of dry ports will provide potential to improve the sustainable movement of goods across the EU.

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concept: connecting container seaports with the hinterland' (2009) 17(5) *Journal of Transport Geography* 338.

[63] Roso (n 62).

[64] Anu Bask and others, 'Development of seaport-dry port dyads: two cases from Northern Europe' (2014) 39 *Journal of Transport Geography* 85.

[65] SETRIS (n 8).

[66] Ibid.

To work properly, PI will need standards relating to location, equipment and the capacities of hubs and corridors. Taking into account the current business practices and diversity of industry, the implementation of EU-wide systems will be a challenge. It will call for international research and development in order to operationalize PI and develop technologies that will serve it.[67]

3.2 The Information Web Layer

3.2.1 Current situation and examples of new emerging information web applications

DaSilva and Trkman are among those who have described how the advantages of the digital internet have spread into many industries, improving efficiency and decreasing transaction costs.[68] The rapid development of ICTs will have many impacts on logistics, too. For example, the Internet-of-Things (IoT), big data, artificial intelligence (AI) and blockchain technologies will impact the information web layer.[69] Haller et al. define the IoT as a world where physical objects are seamlessly integrated into the information network, and where these objects can become active participants in business processes.[70] IoT allows for the real-time tracking and tracing, and monitoring of the movement of goods. Such operations could result in the optimum sharing of resources between collaborating partners, thereby improving sustainability and transparency in supply chain operations.[71] Furthermore, linking multiple IoT technologies with intermodal transportation could help in optimizing routing decisions and decreasing fuel consumption, thereby resulting in more sustainable transportation.[72]

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67 'ALICE Recommendations to H2020 Work Programs 2016–2017' (n 37).

68 Carlos M. DaSilva and Peter Trkman, 'Business model: what it is and what it is not' (2014) 47 *Long Range Planning* 379.

69 'ALICE Recommendations to H2020 Work Programs 2016–2017' (n 37).

70 Stephan Haller, Stamatis Karnouskos and Christoph Schroth, 'The internet of things in an enterprise context' in John Domingue and Paolo Traverso (eds), *First Future Internet Symposium - FIS 2008* (Springer Verlag 2009).

71 Mohamed Ben-Daya, Elkafi Hassini and Zied Bahroun, 'Internet of things and supply chain management: A literature review' [2017] *International Journal of Production Research* 1.

72 Zhibo Pang and others, 'Value-centric design of the internet-of-things solution for food supply chain: value creation, sensor portfolio and information fusion' (2015) 17(2) *Information Systems Frontiers* 289; T. Wang, Y.F. Zhang and D.X. Zang, 'Real-time visibility and traceability framework for discrete manufacturing shopfloor' (Proceedings of the 22nd International Conference on Industrial Engineering and Engineering Management, Singapore 2015) 763.

Similarly, big data will also influence decisions on planning, inventory and logistics. For example, applying algorithms and programming to big data could provide useful insights into future predictions and their impacts on logistics operations.[73]

As an example, while taking advantage of new technologies such as IoT, big data and AI, Rolls-Royce is collaborating with Google to develop intelligent awareness systems, that will help make autonomous ships a reality. The agreement allows Rolls-Royce to use Google's Cloud Machine Learning Engine to train the company's AI-based object classification system for detecting, identifying and tracking the objects a vessel can encounter at sea. The intelligent awareness system is able to benefit maritime businesses by making vessels safer, and easier and more efficient to operate, and also by providing crew with an enhanced understanding of their vessel's surroundings. A well-trained machine learning model can perform predictive analytics faster and better than a human. The aim is also to test whether speech recognition and synthesis are viable solutions for human-machine interfaces in marine applications.[74]

These examples show that the successful evolution and implementation of PI will require new technologies and ways of sharing information among the various actors in the logistics network.

3.2.2 Discussion on challenges of implementation

Despite the vast opportunities, there are still many challenges for the information layer. A SETRIS report describes the challenges facing the information web layer. First, the report argues that there is a lack of ICTs to rapidly connect to, and disconnect from, and supply networks at both the business level and the technical ICT level. Currently, ICT systems are usually complex and customized, and their information interfaces are not suited for efficient transport and logistics operations. Parties do not want to join platforms offered by other parties, or do not want to pay for using them. Some companies may also feel that their business model will be threatened by standardization. Second, there is still a lack of trust concerning the sharing of information services and systems, although information sharing across the logistics chain is critical to ensure a truly integrated transport system.

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73 Gang Wang and others, 'Big data analytics in logistics and supply chain management: certain investigations for research and applications' (2016) 176 *International Journal of Production Economics* 98.

74 'Rolls-Royce joins forces with Google Cloud to help make autonomous ships a reality' (2017), https://www.rolls-royce.com/media/our-stories/press-releases/2017/03-10-2017-rr-joins-forces-with-google-cloud-to-help-make-autonomous-ships-a-reality.aspx, accessed 27 June 2018.

In other words, although there is a lot of information (big data) and the technological means to use it (IoT, AI, blockchain), current business practices do not allow the sharing of data. Moreover, the standards for data collection or reporting systems, or for data quality monitoring for commercially and socially important information (about emissions, load factors, congestion levels, and so on) still do not allow comparisons to be made between value chains or modes of transport – comparisons that would make informed decisions about transport solutions possible.[75] Furthermore, IoT has brought many data management and security issues into focus,[76] in addition to the governance of information networks. At the firm level, too, alignment of ICT with the elements and requirements of PI will require effort.[77]

3.3 The Ecosystem Business Model Layer

3.3.1 Current situation and ideas for improvement based on PI

A business model describes how a company operates and how it creates value.[78] Achtenhagen et al. claim that lately there has been a change in the business model discussion from ‘what business models are’ to ‘what business models are for’.[79] Further, although scholars consider the business model as a firm-level construct, some have argued for its systemic nature (cf.[80]). Accordingly, Zott and Amit argue that a firm’s business model system, consisting of activities, is dependent not only on the focal company, but also on

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75 SETRIS (n 8).

76 Luigi Atzori, Antonio Iera and Giacomo Morabito, ‘The internet of things: A survey’ (2010) 54 *Computer Networks* 2787.

77 Montreuil and others, ‘The Physical Internet and Business Model Innovation’ (n 39).

78 Alexander Osterwalder, Yves Pigneur and Christopher L. Tucci, ‘Clarifying business models: origins, present and future of the concept’ (2005) 16(1) *Communications for AIS* 1; Henrikki Tikkanen and others, ‘Managerial cognition, action, and the business model of the firm’ (2005) 43,76 *Management Decision* 789; Risto Rajala and Mika Westerlund, ‘Capability perspective of business model innovation: an analysis in the software industry’ (2008) 2(1) *International Journal of Business Innovation and Research* 71; Ramon Casadesus-Masanell and Joan E. Ricart, ‘From strategy to business model and onto tactics’ (2010) 43 *Long Range Planning* 195; David J. Teece, ‘Business models, business strategy and innovation’ (2010) 43(2/3) *Long Range Planning* 172.

79 Leona Achtenhagen, Leif Melin and Lucia Naldi, ‘Dynamics of business models – strategizing, critical capabilities and activities for sustained value creation’ (2013) 46(6) *Long Range Planning* 427.

80 Rajala and Westerlund (n 78); Mika Westerlund, Seppo Leminen and Mervi Rajahonka, ‘Designing business models for the internet of things’ (2014) 4(7) *Technology Innovation Management Review* 5.

the surrounding network.[81] Therefore, the company's business model can be claimed to link with its network and business ecosystem. There is a need for a deeper network view of business models.[82] Network and ecosystem views are important, because involving stakeholders in a 'win-win' relationship is essential for designing viable business models.[83] Also, Tsvetkova and Gustafsson claim that, by being part of an ecosystem, a company can gain greater value than normally, and that environmental and economic benefits can be realized only by the extensive involvement of a wide variety of stakeholders, that is customers, suppliers, partners and authorities, in the ecosystem.[84] Furthermore, they (ibid.) claim that, in relation to ecosystems, modular thinking is useful, because achieving flexibility and adaptability is easier with it.

The evolution towards PI will enable new business models, but at the same time will also require the development of new business models.[85] Business model innovation enhanced by PI has been addressed, for example, by Montreuil et al.. They claim that PI will be a key driver of business model innovation; it will redefine business models, supply chain configurations and value creation patterns. They also claim that, because in PI, standard containers are easily transported by various transport means (for example, planes, trains, trucks, private cars) through distributed, open multimodal transportation networks, companies will be able to shift their focus from operational issues to numerous opportunities for developing novel services and business models. Logistical chains become flexible and reconfigurable in real time.[86]

3.3.2 Examples of emerging ecosystem business models

Montreuil et al. argued that, in the context of PI, there are two categories of firms, namely the PI-Enablers and the PI-Enabled. The *PI-Enablers* provide infrastructural tools for PI, such as containers, vehicles, services and software. They include, for example, infrastructure providers, information brokers, node or hub operators, carriers, last mile operators, or facilitators such as insurers,

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81 Christoph Zott and Raphael Amit, 'Business model design: an activity system perspective' (2010) 43(2/3) *Long Range Planning* 216.

82 Steven Muegge, 'Platforms, communities, and business ecosystems: lessons learned about technology entrepreneurship in an interconnected world' (2013) 3(2) *Technology Innovation Management Review* 5.

83 Eva Bucherer and Dieter Uckelmann, 'Business models for the internet of things' in Dieter Uckelmann, Mark Harrison and Florian Michahelles (eds) *Architecting the Internet of Things* (Springer, Berlin, 2011); Westerlund, Leminen and Rajahonka (n 80).

84 Tsvetkova and Gustafsson (n 20).

85 SETRIS (n 8).

86 Montreuil and others, 'The Physical Internet and Business Model Innovation' (n 39).

customs agents, and so on. On the other hand, the *PI-Enabled* firms exploit the value creation generated by PI. Montreuil et al. also argued that PI increases the opportunities for creating tailored models, thus enriching customer experience and driving high-value creation for businesses. By increasing efficiency, mobility and flexibility, PI will provide opportunities for transforming currently unprofitable or unreachable markets and ideas into attractive business opportunities.

There are several comparable earlier examples of industry-wide disruptions from different contexts. DaSilva and Trkman give an example of the ground-breaking business model of Ryanair, which took advantage of the existing technology, while *on one hand* eliminating intermediaries in ticket sales, and *on the other hand* taking the role of an intermediary in hotel bookings and car rentals.[87] Moreover, Fine gives an example of how modularity can affect business models and the whole industry structure. In the 1980s, as IBM was developing the first personal computers, a crucial structural shift from a vertical/integral industry structure to a horizontal/modular structure occurred, and thus separate sub-industries for microprocessors and operating systems, software, and network services emerged.[88]

Our hypothesis is that, if PI eventuates, it will promote the emergence of several new business opportunities and business models in the logistics sector. The emergence of a new PI ecosystem, vertical disintegration and increased specialization, due to the division of labour, the sharing of resources and the reorganization of offered services, will lead to a more efficient usage of resources. Although new standards and coordination of the ecosystem will be needed, they will ultimately yield measurable performance indicators, and consequently it will become easier for service providers to differentiate themselves as ‘green’, offering environmentally sustainable services that support forward and reverse flows of products.

Already today, there are actors whose goal is to work according to PI principles. One example mentioned by Pan et al. is Flexe.com, a company that aims to be the ‘AirBnB’ of storage space, and which is already present in over 20 states in the USA. The utilization of under-used resources is a key issue in many of the new services, such as AirBnB and Uber, which organize their services on the basis of free apartments or cars.[89]

The collaboration between Maersk and Alibaba on container booking is another effort supporting the realization of PI ecosystems and is indicative

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87 DaSilva and Trkman (n 68).

88 Charles H. Fine, ‘Clockspeed-based strategies for supply chain design’ (2000) 9(3) *Production and Operations Management* 213.

89 Shenle Pan and others (n 21).

of the emergence of new types of cooperative business models between e-commerce platforms and logistics firms. Such cooperative models are set to overhaul the movement of goods by offering cargo owners online access to book space for goods on container vessels.[90] The aim is to reduce the paper trail in the logistics network and provide a level playing field for small- and medium-sized enterprises in China to get online services such as customs clearance and logistics. Further, the horizontal alliance between Alibaba and Maersk is set to improve overall sustainability by reducing the usage of natural resources and removing intermediaries, making it easier for service providers to offer sustainable services.

Yet another example focuses on the technologies that are making global supply chains more efficient and transparent. In 2016, IBM and Maersk started to collaborate on building new solutions based on blockchain and cloud-based technologies. They aim, for example, to create more transparency by empowering multiple trading partners to collaborate and establish a single shared view of a transaction. Exploiting blockchain technology, they aim to digitalize supply chains by developing a global trade digitization platform built on open standards and designed for use by the entire global shipping ecosystem. Thus, the new joint venture company aims to commercialize end-to-end supply chain visibility, enabling all actors to securely and seamlessly exchange information about shipments in real time, and paperless trade through the digitization and automation of paperwork filings. Manufacturers, customers, shipping lines, freight forwarders, port and terminal operators and customs authorities can all benefit from the new technologies. However, there is a caveat. The overall effects of such horizontal alliances between firms on the realization of PI still needs to be scrutinized.[91]

3.3.3 Discussion on challenges of implementing PI

How will the adoption of PI affect the logistics industry? In their review of the PI literature, Sternberg and Norrman examined PI based on four factors: the organizational readiness to adopt PI (development of technological blue-

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[90] Brenda Goh, 'Maersk, Alibaba team up to offer online booking of ship places' (Reuters, 4 January 2017) https://www.reuters.com/article/us-alibaba-maersk/maersk-alibaba-team-up-to-offer-online-booking-of-ship-places-idUSKBN14O0S7, accessed 27 June 2018.

[91] Maersk and IBM to form joint venture applying blockchain to improve global trade and digitise supply chains (2018) https://www.maersk.com/press/press-release-archive/maersk-and-ibm-to-form-joint-venture, accessed 27 June 2018; Michael White, 'Digitizing global trade with Maersk and IBM' (Blockchain Unleashed: IBM Blockchain Blog, 16 January 2018) https://www.ibm.com/blogs/blockchain/2018/01/digitizing-global-trade-maersk-ibm/, accessed 27 June 2018.

prints); external pressures (the promised effects of PI); the perceived benefits (new business models enabled by PI); and adoption. They also observed that there is scarce research on business models and the adoption of PI, and that, so far, PI literature has not dealt much with the operationalization of business models or the future of existing business models. Further, they pointed out that, unless supply chain actors opt in, PI will not become a reality, but remain a series of technological blueprints. They argued that shippers and LSPs will probably defend their existing business models and their ability to maintain control. Therefore, some important questions need to be addressed in future research. For example, which incentives might convince LSPs to give up control of their transport networks and risk losing their market positions, or to enter a system of real-time auctioning at the lowest price.[92]

A number of barriers slowing down or hindering the realization of PI have been addressed in the report published by the SETRIS project. First among the barriers is *market dynamics*. Because logistics has been a sector characterized by low innovation investments, the existing business environment (with its small margins and high fragmentation) makes it difficult to implement new technologies and processes, or even to encourage investments, collaboration or data sharing. Second, there are only a few examples of business models implementing horizontal collaboration in the industry. Therefore, the development of new revenue/cost sharing models will be needed in order to make it easier for logistics stakeholders to engage in horizontal collaboration. The revenue and cost sharing models currently used do not support attempts to encourage individual actors to cooperate, even though they may be more efficient overall. Companies may not be willing to share resources in the supply chain, since individual resources form their competitive advantage.

Similarly, Treiblmaier et al. argue that to achieve a fully developed PI, many factors need to be taken into account simultaneously, ranging from concrete physical objects to abstract concepts such as legislation and business models.[93] It will be challenging to develop new business models forwarding the societal and industrial objectives of PI.[94] Therefore, we believe that an ecosystem view of PI will be the most useful.

92 Sternberg and Norrman (n 10).
93 Treiblmaier, Mirkovski and Lowry (n 19).
94 'ALICE Recommendations to H2020 Work Programs 2016–2017' (n 37).

4. DISCUSSION AND CONCLUSION – ARE WE HEADING TOWARDS PI BUSINESS MODELS?

PI has the potential to transform supply chains and transportation flows. It contains a promise of seamless, flexible and robust connections between the corridors of different modes of transport. However, for PI to become a reality, the PI concept has to be operationalized and concretized. There will be a demand for new or renovated infrastructure (that is hubs, corridors and ICT), but PI will also require innovation of the technological, architectural and organizational concepts.[95]

Meanwhile, there is a societal demand for better utilization of existing infrastructure, rather than building the new. A sharing economy and social networks will enable the utilization of under-used resources by means of new business models such as ‘Uber for freights’. This societal trend may also decrease the mental barriers to sharing resources at the industry level.[96]

PI will facilitate many new services and business models. The creation of large integrated ecosystems based on PI will open markets for specialized and focused services, providing the PI network with essential services such as big data-based analysis of information on real-time traffic situations, or understanding consumer preferences for last-mile deliveries. As we move into more networked and standardized modes of operation, the competitiveness of network players will increasingly derive from ecosystem business models, rather than from individual business models or services.[97]

To conclude, we expect that when or if PI eventuates, it will promote:

(1) the emergence of several new business opportunities and business models in the logistics sector;
(2) the more efficient usage of resources;
(3) standards yielding measurable performance indicators;
(4) the differentiation of service providers as ‘green’ providers, offering environmentally sustainable services; and
(5) the emergence of ‘green’ business ecosystems.

We may also come to agree with Pan et al.[98] and expect that ongoing ICT innovations (such as IoT or blockchain) can strengthen infrastructure in the different layers even further.

95 Ibid.
96 SETRIS (n 8).
97 Tsvetkova and Gustafsson (n 20).
98 Shenle Pan and others (n 21).

From an environmental point of view, PI is promising because it implies the efficient use of resources, and consequently a substantial reduction in the carbon footprint of logistics systems, reducing especially truck traffic on the roads. Another major benefit of PI is that it seems likely to reduce the social costs associated with truck driving, due to optimization of routes, real time tracking, vehicle automation and the linking of intermodal transport systems.

However, there are challenges that need to be overcome before PI can become a reality. These challenges are not just technological, but also – and more significantly – economic and social.[99] Further, PI will demand a modular approach and standardization of processes, not just physical objects and hubs.[100] One of the important questions is which incentives will convince LSPs to opt-in to PI.[101] In the PI literature, there has been some discussion about incentives. For example, a report by SETRIS lists various incentives for freight transport and logistics stakeholders to advance towards a truly integrated transport system. Economic gains are important incentives for business stakeholders to adopt green practices, as has been observed in earlier research, too.[102]

According to the ecosystem view, a company involved in an ecosystem may manage the complexity of the ecosystem with a modular approach.[103] However, as anybody can join a PI ecosystem, the ecosystem will need curators and coordinators so that the emerging innovations will develop the system in a proper direction. In other words, the ecosystem will need transparency and openness, but also coordination and data protection. Horizontal collaboration may even require the intervention of a neutral third party – a so-called network orchestrator or 'trustee' – to maximize the gains of the community.[104] All contracts dealing with the sharing of revenues and costs, and also insurances, need to be re-considered and rewritten. In addition, political will and public funding will most probably be needed. It has been claimed that collaboration, process re-engineering and business models will be important themes when pursuing a seamless, synchromodal system that supports sustainable development in forward and reverse product flows, including CE. Furthermore, deeper harmo-

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[99] Yan Cimon, 'Implementing the physical internet real-world interface: beyond business models, the devil is in the details' (Proceedings of 1st International Physical Internet Conference, Québec City, Canada (2014)); Sternberg and Norrman (n 10).

[100] Ibid.

[101] Sternberg and Norrman (n 10).

[102] Anu Bask and others, 'Environmental sustainability in shipper-LSP relationships' (2018) 172 *Journal of Cleaner Production* 2986.

[103] Tsvetkova and Gustafsson (n 20).

[104] 'Collaboration Concepts for Co-modality' (n 15).

nization of regulation is needed to advance evolution towards a truly integrated transport system.[105]

[105] SETRIS (n 8).