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Internet of Things (IoT) applications in the Physical Internet (PI) framework Can IoT be an accelerator for the PI roadmap?

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Abstract

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Can IoT be an accelerator for the PI roadmap?

Research promoted by Prof. Dr. Cathy Macharis

The Physical Internet is defined as "an open global logistics system founded on physical, digital and operational interconnectivity through encapsulation, interfaces and protocols". This logistics paradigm shift could remodel the whole transport sector by allowing real-time decisions, re-routing, instant communication among stakeholders, transparent management and efficiency improvement. Benoit Montreuil demonstrates that "the way physical objects are currently transported, handled, stored, realized, supplied, and used throughout the world is unsustainable economically, environmentally, and socially", and suggests how to use the digital metaphor to create a Physical Internet (PI) to face this challenge, lowering transportation costs and the environmental footprint of logistics.

Physical Internet is aiming at revolutionizing logistics by improving its efficiency and lowering its social costs and to achieve this goal the tech industry is needed and IoT can be an accelerator in this process. All the components of the logistics flow are becoming *smarter* every day, being equipped with technology that can provide important information for the management of the Supply Chain. RFID technology in logistics, as well as many other IoT applications, can help boost the PI roadmap, enabling all the different stakeholders to work together towards a more sustainable Supply Chain Management.

This thesis investigates the research that has already been done on Internet of Things and Physical Internet, assessing the state of the art of both domains and looking for possible links. Furthermore, it aims at showing how IoT technology can be an accelerator for the PI roadmap. The core of the study is how the relationship between IoT and PI can grow deeper, facilitating the paradigm shift towards the PI. Given the importance of finding an answer to the huge challenge of improving the current unsustainable state of the logistics network, this thesis gives an insight on one specific aspect related to the possibilities of using IoT technologies to help implementing the PI roadmap.

After performing a thorough literature review and confronting the results with the answers from the interviews, it is absolutely clear that IoT technology is deeply connected with the PI agenda, and that this technology can actually be an enabler. The R&D departments of IoT companies and big tech companies like Oracle, are already able to present solutions that could help accelerating the PI implementation. A physical infrastructure of sensors connected to a software architecture that communicates to all stakeholders and automatically performs data extraction that can provide insightful information both for fleet management and supply chain management is available and ready to use. Nevertheless, all the stakeholders expressed the fact that logistics companies often see innovation as a cost and a complication, and do not perceive the improvement and the added value. This shows that the main challenge for the PI implementation is not technological - as it has already been demonstrated that the technology is available - but cultural.
Drawing a final conclusion on the purpose of this thesis, IoT technologies can accelerate the implementation of the PI roadmap but they are just one link in the global chain.

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1 Introduction

1.1 Objective

This thesis provides a clear assessment of the current situation of the transport sector, the current stage of implementation of the Physical Internet (PI) roadmap and whether Internet of Things (IoT) technologies can accelerate in reaching the goal of implementing the PI. The PI is “an open global logistics system founded on physical, digital and operational interconnectivity through encapsulation, interfaces and protocols” (Montreuil, Meller, & Ballot, 2012) that could remodel the logistics and transport sector by making it smarter and more sustainable both economically and environmentally. This is extremely relevant since the current situation has been described as unsustainable. PI represents a paradigm shift across the whole transportation sector and is one of the options to renew the system, creating a modern and efficient network of logistics.

Furthermore, this thesis investigates the research that has already been done on Internet of Things - “objects that are able to interact, communicate and work together” (Atzori, Iera, & Morabito, 2010) - and Physical Internet, assessing the state of the art of both domains and looking for possible links. I show how both academic- and industry-driven research in the domain of IoT can be an accelerator for the PI roadmap. Smart objects and IoT applications have already found their space in the logistics and transport industry, what I study is how this relationship can grow deeper, facilitating the paradigm shift towards the PI. Also, I check the trends in the transport sector and the IoT industry and assess whether current stakeholders and tech companies are working on applications that may help speeding up the PI implementation. This thesis is relevant, because it provides an updated overview of the logistics sector, specifically regarding the latest trends that are related to the PI. Furthermore, it provides an insight as to what kind of IoT technologies can be relevant for the PI gathering information directly at the source by interviewing relevant stakeholders of the IoT and logistics sector. By providing this kind of information, this thesis presents the IoT applications that are already available for the logistics sector to use.

1.2 Type of study, scope and limitations

This thesis is structured in two main parts and, being an exploratory work, it presents an extensive preliminary research that is then be confronted with Qualitative data gathered through selected interviews. The first part is a literature review, focused on studying the theoretical work that has been done in the fields of IoT and PI through secondary sources. Both topics have been widely investigated and I explore the existing scientific literature to present the state of the art on both topics. The main goal of the review is to assess the already existing and possible future links between IoT and PI.

The second part of this paper will be a qualitative study that will present the data gathered by making interviews to extremely competent and selected stakeholders of the logistics and IoT industry, during which I will try to understand the industry’s interest in investing resources to work together with PI networks on applications that would foster the implementation of the PI roadmap.

To reach an in-depth analysis of the links between both topics, especially the ones related to assessing what the industry is doing to help the PI goal, I plan to start with an unstructured interview design to bring the relevant issues to the surface that will be followed by a set of specific questions designed to gather qualitative information on the current state of the industry and possible future developments. By combining two different data collection methods - unstructured interviews and questionnaires - rigor will be added to the research.

As already stated, the main focus of this work is an assessment of the current situation and a qualitative take on possible solutions. This thesis will not focus on elaborating mathematical models to evaluate possible scenarios, the models and tables that will be contained in this thesis will only be used to analyse the work that has already been done and as references.

2 Literature Review

2.1 Background information

2.1.1 Internet of Things

Despite its rising popularity and the huge interest that revolves around it, there is still some controversy over the definition of "Internet of Things" (IoT). Generally, it is accepted that the IoT involves the presence of "objects that are able to interact, communicate and work together" (Atzori, Iera, & Morabito, 2010). The confusion over its definition can be attributed to the fast technological developments and the different approaches that have been taken toward this issue. The term itself may be the reason for the different interpretations; *Internet* refers to an idea of Network and virtual space, while *Things* focuses on physical objects (Atzori et al., 2010).

The first approaches to IoT have, indeed, been *Thing*-oriented. The ***Auto-ID Labs*** - "a world-wide network of academic research laboratories in the field of networked Radio-Frequency IDentification (RFID) and emerging sensing technologies" - was working on creating "industry-driven global standards" to sponsor RFID technology (Atzori et al., 2010).

While Internet-oriented approaches have been focusing on working with IP technology (Atzori et al., 2010), ***CASAGRAS Consortium*** managed to create a definition that integrates both the *Internet*- and *Thing*-oriented vision, proposing IoT "as (i) a global infrastructure which connects both virtual and physical generic objects and (ii) highlights the importance of including existing and evolving Internet and network developments in this vision. In this sense, IoT becomes the natural enabling architecture for the deployment of independent federated services and applications, characterized by a high degree of autonomous data capture, event transfer, network connectivity and interoperability." (Atzori et al., 2010).

To provide a broader view on IoT and its structure, one should understand the architecture upon which this technology is constructed.

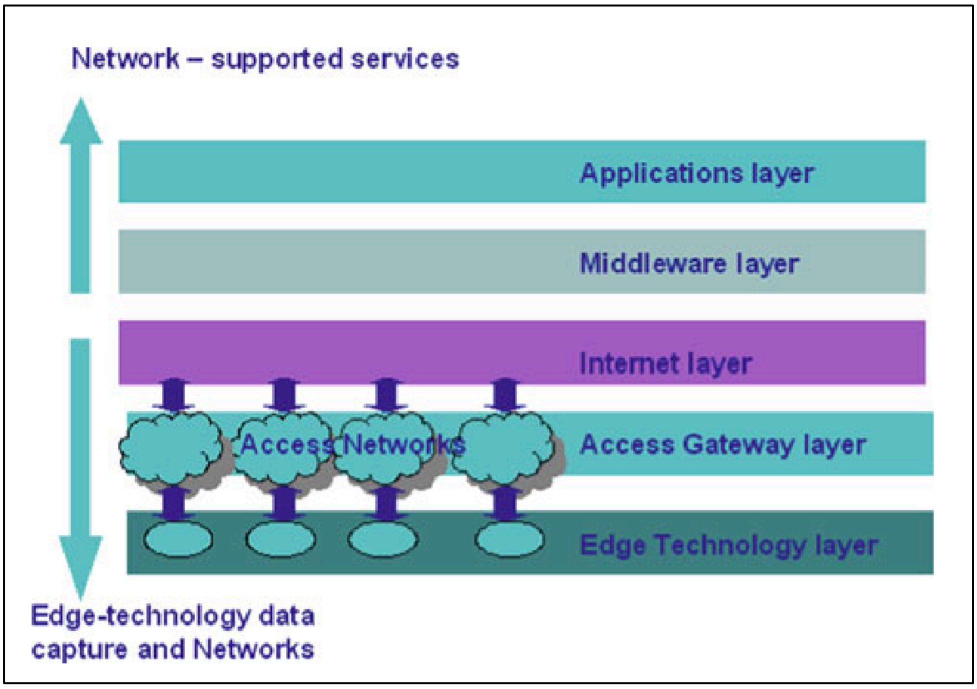


Fig.1 IoT - Layers and architecture (Bandyopadhyay & Sen, 2011)

Bandyopadhyay & Sen describe a 5-layer architecture that is mainly composed by two blocks divided by the middle layer - the Internet layer - which allows communication between the separated bottom and top layers. The bottom layer (Edge Technology) is composed by physical objects like sensors, RFID technology which are actually located in the field and provide information. The Access Gateway layer performs the first data management by routing information. The Middleware layer is crucial in actually performing a detailled management of data by filtering, aggregating and analysing information. The Application layer is the one that actually gives back the organized information to end users of different sectors and can be personalized through different data visualization tools (Bandyopadhyay & Sen, 2011).

Investigating further opportunities introduced with IoT, one interesting use is made possible by "wireless sensor networks" (WSN), which are sensor equipped devices than can communicate with RFID technology to improve the information flow of specific objects by matching information against specific KPIs such as location, movements, temperature and status. This can clearly give a contribution in the logistics sector and has been already implemented in "cold chain logistics" where the temperature of the transported goods plays a crucial role and is an important insight for the stakeholders.
WSN applications clearly don't stop with logistics, an interesting case history is presented by General Electrics. The company installs sensors in its engines in order to gather knowledge on the conditions of its products and save money with preventive maintenance. The same has been done by American Airlines who is able to reduce and monitor risks by gathering huge amount of data on the status of its airplanes during all different stages of a flight (Lee & Lee, 2015).

The huge amount of data that is gathered through smart objects, sensors and other IoT applications needs a back-end structure that enables the storage and processing of data. This is relevant both for automatic interactions between objects but is even more so for human decisions making and interpretation of data. Cloud computing, be it Infrastructure as a Service (IaaS) or Software as a Service (SaaS), is the perfect structure to allow real time decision making and data visualization (Lee & Lee, 2015).

The interest around IoT also revolves around its huge collaboration potential with Big Data and Business Intelligence. Companies have started using Big Data to design smarter products for consumers, to analyse business opportunities and to increase the effectiveness of marketing. One example of smarter products created with IoT is the new Oral-B Pro 5000 by Procter & Gamble, a toothbrush able to personalize the oral care routine of its users. The sensors within the toothbrush are able to record the habit of its users during the use and enable a better oral care, also increasing the average amount of time spent brushing ones teeth (Lee & Lee, 2015).

Among the countless possible future applications of IoT, Chunling's Paper "Application of RFID Technology for Logistics on Internet of Things" shows one of the ways in which the IoT could impact Supply Chain Management and Logistics through RFID technology. This paper is only one of the many studies that are showing the possible and interesting links between IoT, logistics, Physical Internet (PI) and Supply Chain Management (SCM).

2.1.2 The Physical Internet

Benoit Montreuil (2011) demonstrates that "the way physical objects are currently transported, handled, stored, realized, supplied, and used throughout the world is unsustainable economically, environmentally, and socially"(Montreuil, 2011), and suggests how to use a digital metaphor to create a Physical Internet (PI) to face this challenge, lowering transportation costs and the environmental footprint of logistics. While decades ago the digital world used a physical world metaphor to find a way to connect micro-computers - building the information *highway* -, the digital metaphor revolves around the idea that the network of physical goods should be inspired by the digital internet interconnection, that allows "the transmission of formatted data packets in a standard way permitting them to transit through heterogeneous equipment" (Montreuil, 2011). Building upon this metaphor, the Physical Internet - "an open global logistics system founded on physical, digital and operational interconnectivity through encapsulation, interfaces and protocols" (Montreuil, Meller, & Ballot, 2012) - could remodel the logistics and transport sector by allowing real-time decisions, re-routing, instant communication among stakeholders, transparent management and efficiency improvement.

The Physical Internet requires three main elements in order to be implemented. These elements are listed in Fig. 2 (Montreuil, Meller, & Ballot, 2010) and are π-containers, π-nodes and π-movers.

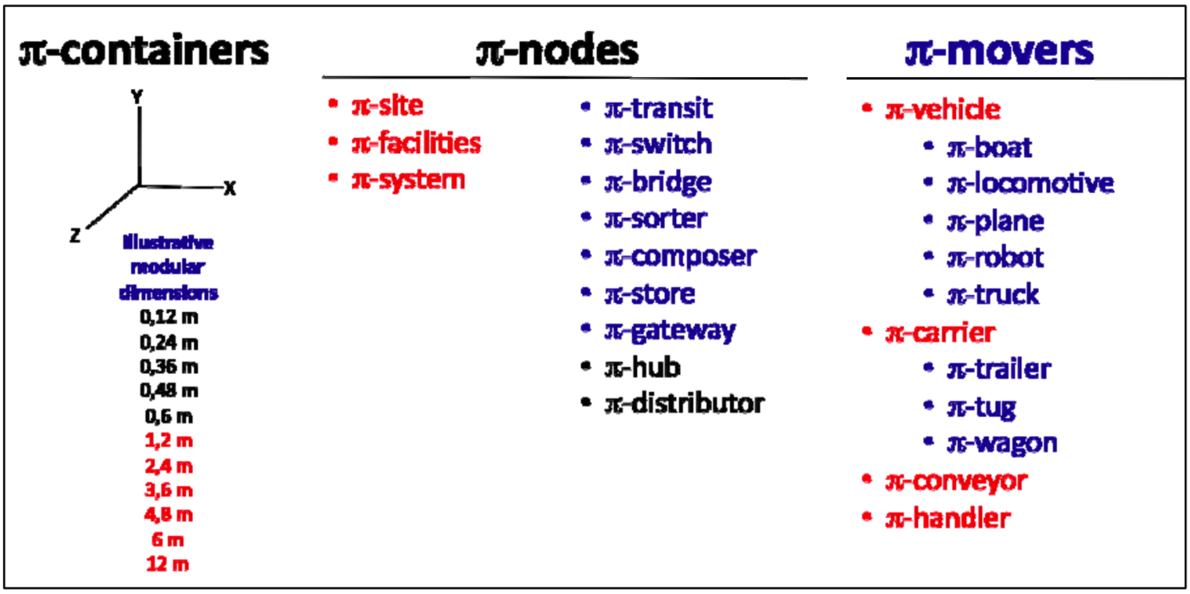


Fig. 2 Three Physical Internet Elements (Montreuil et al., 2010)

As shown by Fig.2, containers for the Physical internet have modular dimensions. Nodes are the facilities that create the Physical internet gateways while movers take care of the transport of the containers to the different nodes, actually connecting the network of the PI. (Montreuil et al., 2010).

The prefix π is used because it corresponds to the Greek letter pi, which corresponds to the abbreviation of the Physical internet (Montreuil et al., 2010).

Going back to the concept of the PI metaphor, containers are like internet packages, regardless of what they contain, packages move information within the internet network. In the same way, the PI, which only handles specifically designed π-containers, doesn't involve physical goods. The only transported units are containers, regardless of their content. For the PI, containers must obey to a global standard and have to be designed in order to be as efficient as possible both for handling and storage, as well for other aspects like locking, loading, unloading etc. (Montreuil et al., 2010). Each container needs to be identifiable, RFID technology can gear the π-container with tags that are expected to provide information such as involved stakeholders, dimensions, capacity, functionalities etc. (Montreuil et al., 2010).

π-movers include transporters, conveyors and handlers, and within the PI framework these are responsible of handling the π-containers. Transporters are vehicles - like trucks, trains, boats, planes, lifts or robots - and carriers - trailers, carts, barges or wagons, that need to be pushed or pulled by vehicles (Montreuil et al., 2010).

The nodes within the PI can be described as stations, connected to different activities related to the supply chain, where the containers are managed. In these locations it is possible to change the transportation mode of the containers, this means that decisions can be taken in real time in order to make the logistic network more efficient. There are specific indicators - "speed, service level adherence, handled dimensions of π-containers, overall capacity, modal interface and accepted duration of stay" (Montreuil et al., 2010) - to assess a node and therefore decide on the most suitable one for a specific need. As seen in Fig 2., π-nodes are further divided in many different sub-categories, depending on location and activities.

In another study, Montreuil defined the PI through other characteristics. Beside further stressing the need for a global standard of modular containers and an efficient inter connectivity, Montreuil also underlines the importance of using smart objects in order to exploit the full potential of technology which could lead to virtuous results. Like making truck transportation more efficient or shortening the average mileage per driver. Furthermore, the PI suggest a multi-level framework that is able to withstand a network no matter its size. This system connects the single intra-centre inter-processor to worldwide inter-continental network through 5 different layers, each one containing the smaller network allowing efficient operability no matter what the scale of the network (Montreuil, 2011).

1. Intra-center inter-processor networks;
2. Intra-facility inter-center networks;
3. Intra-city inter-facility networks;
4. Intra-state inter-city networks;
5. Intra-country inter-state networks;
6. Intra-continental inter-country networks;
7. Worldwide inter-continental networks.

Fig. 3 the multi-level framework of the PI (Montreuil, 2011)

Another characteristic of the PI focuses on the logistics network. Currently the logistics network is built upon privately owned supply chain networks, this leads to the fact that most facilities are used by a handful of enterprises - making it hard for the facilities to express full potential - while the same companies just use a small number of facilities, therefore not taking advantage of more possibilities.

One of the most ambitious goals of the PI is to be able to take advantage of an “open global supply network” (Montreuil, 2011) which has specific characteristics related to its accessibility and capacity. This network is beneficial under many aspects to enterprises.

Fig. 4 makes a comparison between a private network, a shared network and an open network. In the figure below, each cell represents a region. In an ideally designed open network scenario, suppliers and manufacturers can use different DC in every region, adjusting their stock in order to respond to the demand. By taking advantage of a high number of distribution centres, lead time can be reduced almost to zero, in case the suppliers directly deploy stock in open DCs, shifting the products towards the consumers. This scenario would also allow for an overall lower number of DC facilities. In a scenario where enterprises and retailers are able to share open DCs, it is likely that the current number of facilities would be redundant and therefore reduced (Montreuil, 2011). This clearly leads to a higher efficiency, a lower number of facilities would be used to their full potential, allowing better strategical decision-making for each company’s supply chain management. Fig. 4 shows that by lowering the number of “Firm dedicated DCs” from the current private supply network to a shared supply web, companies can take advantage of more facilities therefore having more and better options in choosing where to deliver stock. Going even further, an open supply web with high density of open DCs, reduces firm dedicated DCs to zero, while bringing the overall number of DCs used from 16 - in the case study with four different companies - to more than 60. This would bring benefits both to suppliers but also to consumers, by reducing lead time and avoiding backlogs.

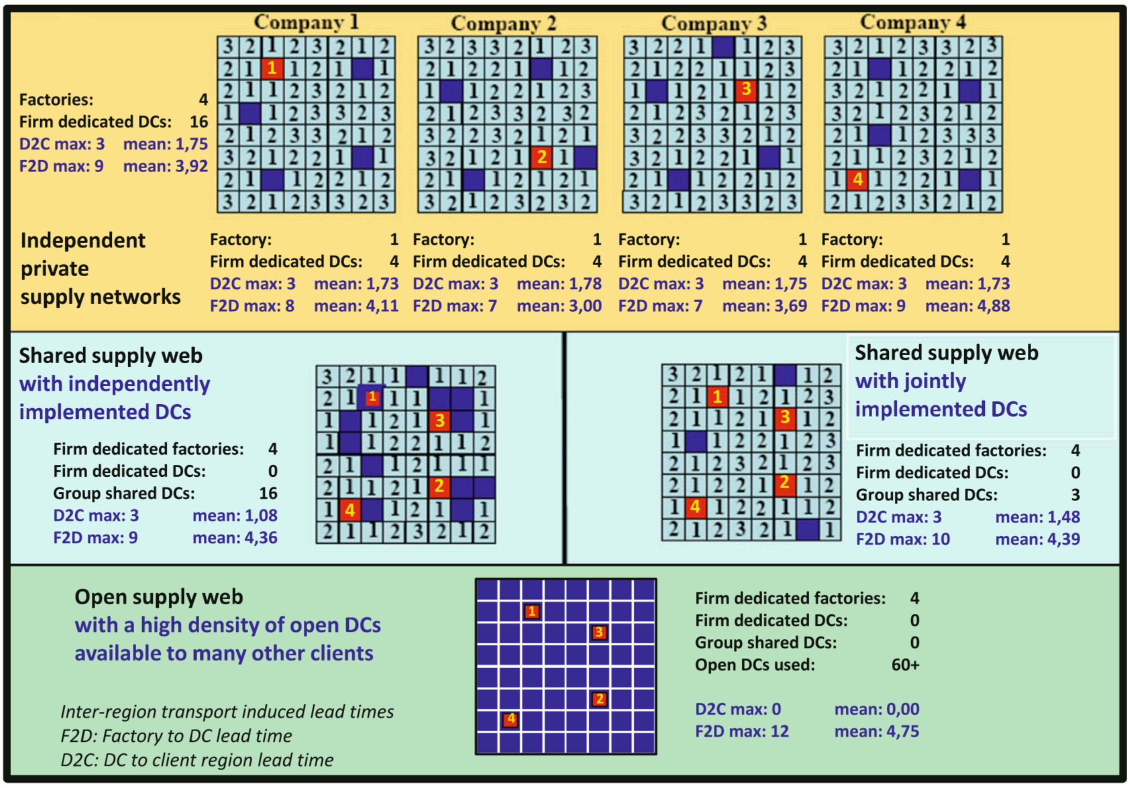


Fig. 4 Comparison between private, shared and open supply network (Montreuil, 2011)

Packaging design also needs a paradigm shift. The content of the modular containers of the PI needs to be efficiently filled with a smart packaging, this means that enterprises need to adapt to a standard and minimize the load, engineering solutions that compress the goods as much as possible and delivering only the needed materials, using locally available products when possible. Stressing further on this issue, actual transportation of goods should be reduced to the minimum, fostering decentralized production through open knowledge of product realization. This would increase the number of third-party production, which would again help the realization of a global and open supply chain (Montreuil, 2011).

The implementation of the PI roadmap clearly needs a big effort by all the stakeholders involved also regarding transparency and information sharing. Nowadays, stakeholders keep information to themselves, protecting their competitive advantage. This attitude of information keeping and secrecy doesn't allow for information sharing which usually creates and environment that fosters constant improvement and rational decision making. In a PI scenario, all the stakeholders that are responsible for one part of the logistic web, would publicly post their performances in order to allow rational decision making on which location to choose (Montreuil, 2011). Performances would be evaluated against Key Performance Indicators (KPI) - designed and agreed upon by all the stakeholders - that would represent an accepted standard. This can at first seem a risky move by the stakeholders, publicly posting eventual flaws within one's organization, but would on the long run foster innovation, sharing of best practices and an overall improvement of the whole system.

2.2 The Problem: The current stage of implementation of the Physical Internet

2.2.1 Assessment of the current stage of implementation of the Physical Internet

The PI roadmap is fronted with many challenges in order to be implemented, and it is extremely important to show how technology can help accelerating this process. The integration of IoT technologies in the PI can enable the paradigm shift, removing one of the many obstacles that are currently obstructing the way. This thesis gives an insight on this issue and helps finding concrete answers as to what kind of technologies will be the key ones in the integration between IoT and PI.

In order for the Physical internet to be implemented, some conditions need to be fulfilled. In a study by Benoit Montreuil, Jean-François Rougès, Yan Cimon, and Diane Poulin, the Physical internet is said to be structured on "four layers", the first one being the realization web that is structured upon Open π-factories that produce goods in an "open" way, a distribution web which is made out of Open π-stores and π-distributors that take care of storage and distribution. If the first two layers are in place, Open π-hubs, π-transit zones and π-Ports create the mobility web, that ensures the open mobility of objects. These three layers allow the Physical Internet logistic web which allows for the design and creation of many different business models and opportunities (Montreuil, Rougès, Cimon, & Poulin, 2012).

While case histories of authentic open π-factories are not found in scientific literature, it is possible to witness a rise in Physical Internet-based manufacturers thanks to technological advancements in the field of IoT, RFID systems and smart infrastructure (Ray Y. Zhong, Chen Xu, 2015). These PI-based manufacturers still have proprietary knowledge on production and produce goods for their own business or as third-party production plants and are therefore not to be considered as π-factories, but the ways these facilities operate can at least enable future developments towards open factories. If all the processes in a production plant are managed through smart objects and infrastructure, the facilities will be able to work in a PI environment and are therefore a first step in the right direction.

As we have already seen, warehouses and distribution centres are still privately owned; therefore, there is still a long way to go in order to reach the implementation of an "open global logistics web" (Pan et al., 2015). Nevertheless, the case history presented by Montreuil (2011) shows that there is a slight shift towards a shared network, with companies engaging strategic partnerships to improve their logistics. At the same time, mergers and acquisitions (M&A) allow to rationalise and take advantage of the strategic assets - among which WH and DCs - of holding companies.

Further conditions associated to the implementation of the Physical Internet Roadmap are dependent on the use of standard containers that "are easily transported through different transport means (e.g. planes, trucks..)" (Montreuil, Rougès, et al., 2012). One possible approach to tackle this issue is presented by Christian Landschu, Florian Ehrentraut, Dirk Jodin in their paper "Containers for the Physical Internet: requirements and engineering design related to FMCG logistics", in which they present their approach on the engineering of a modular box prototype introducing the MODULUSHCA-box "M-box" (Landschützer, Ehrentraut, & Jodin, 2015) which is based upon characteristics listed by Ballot et al. that are key for the implementation of the Physical internet:

- "Unique international identification to ensure traceability, in the manner of the BIC code in the maritime sector"
- "Physical protection of the content"
- "Anonymization of the content"
- "Standardized size"
- "Standardized mechanical strength which then enables them to be handled and stacked"
- "The possibility of handling and locking between containers using a standardized system, a suitable development of the twist-lock" (Ballot E, Montreuil B, Meller RD (2014) The Physical Internet— the network of logistics networks)

Furthermore, there are three layers formalized by the inventors of the PI regarding containers. These are related to size, design and Loading (Landschützer et al., 2015). In a PI environment, containers can come in three different sirzes: large ("cross section of approximately 2.4 m by 2.4 m with a variable length"), medium ("size around 1 m3") and small ("size approximately of 0.1 m3") (Landschützer et al., 2015). Today containers can be divided in two main categories, handling containers and transportation containers. The inventors of PI theorized that transportation containers won't probably change in their dimension - more likely they will adapt to specific standards in the long run - while handling containers will most probably be reduced to modular containers and unit loads (Landschützer et al., 2015). This means that from the sizing point of view, the current situation of transportation containers doesn't need too much of an update in order for the PI to be implemented, while the same cannot be said for handling containers and boxes. Currently, given the different brands and products, there are thousands of "different shapes and sizes of carton boxes, which leads to inefficient space utilization at a pallet level and therefore also at truck" and container level (Landschützer et al., 2015). Following the study by Landschützer et al., we can see how in the current situation, the transport of an item involves carton boxes - or cases -, pallets and finally trailers. The V-Model (Landschützer et al., 2015) gives us a perspective of a future (2030 roadmap) in which an item will be put in an M-BOX that will replace the cases, while pallets will be replaced by unit loads. This will lead to a better fill rate of the trailers and will therefore be more efficient.
It is clear that at the current state, still a lot needs to be done in order to have a standard compliant to the needs of the PI.

2.2.2 ICT Trends in the freight sector

While the majority of technologies related to the supply chain management has been developed in the 1990s and early 2000, recent developments have introduced new technologies and

new opportunities (Harris, Wang, & Wang, 2015). In this paragraph I will list the main trends that are shaping the development of new ICT solutions in the transport sector.
Cloud computing represents one of the main trends in ICT and has created many opportunities for companies, allowing them to avoid making big investments in infrastructure by hosting their systems directly to third parties. Using Software as a Service (SaaS) solutions, companies can focus on their business while taking advantage of the web solution that are made available on demand on pc, smart phones and tablets (Harris et al., 2015). This is specifically beneficial to SMEs who can exploit these new technologies because of the lower costs and therefore keeping the pace with bigger enterprises. An example of Cloud-based solution for the multimodal transport, is the Electronic Logistics Marketplace (ELM), that links the different stakeholders through a web application allowing them to exchange important information.

IoT solutions are currently on the rise and might represent the physical infrastructure that will allow real time and automated communication through machine-to-machine and human-to-machine interaction, while gathering huge amount of data that can be translated into insightful knowledge. IoT devices will be discussed later in chapter 3.2.1.

The internet has encouraged direct communication between final customers and the different stakeholders of the supply chain network, be it suppliers or distributors. Web 3.0 represents an opportunity for companies that can now gather data about current and potential customers through infrastructure that analyses and combines data while at the same time allowing real and efficient communication. Social networks represent a platform that can really match the different needs of the customers and creates a communication channel between hauler and user. At the same time private social networks can create a more efficient intra-company communication allowing internal stakeholders to quickly address specific problems, creating value for operational management (Harris et al., 2015). The logistics sector is currently taking advantage of Web 3.0 and social networks, by engaging in direct communication with end users and improving internal and inter-company communication. An interesting example is set by the UPS Mobile App - for android and iOS - which allows for "schedule-planning and making changes to shipments" (UPS website, https://bit.ly/2HKwf10) while giving alerts and information regarding a specific shipment. The App also allows to:

- "Decide where to have packages delivered
- Authorize a driver to leave a package without a signature
- Track packages without tracking numbers" (UPS website, https://bit.ly/2HKwf10)

This kind of solutions takes advantage of the modern web infrastructure and increases the efficiency of end user shipments by lowering failed or wrong deliveries, creating a communication network that directly connects shippers and customers.

Augmented reality (AR), a technology that allows interaction between the physical world with virtual images (Harris et al., 2015), is raising interest especially in relation to port and warehouse management, where solutions like "KiSoft" allow error-free picking instructions and real time and constant tracking of the goods (Harris et al., 2015). Thanks to this technology, ports or warehouse operators can get information on the content of a containers by simply looking at a code through technologically enabled glasses or can get instant virtual instructions on how to operate with specific goods.

All the aforementioned technologies create a data stream with huge amount of information that needs to be collected and analysed. These "Big Data" streams represent a huge opportunity to have efficient Decision Support systems (DSS) that allow real-time, knowledge-based decision making. Huge chunks of information can turn into insightful knowledge thanks to the use of machine learning algorithms and open source platforms like Hadoop, and therefore be integrated in the current

DSS giving competitive advantage to its users, like increasing fill-rates, reducing useless or empty trips and even informing on strikes or further unexpected variables that might create disturbances to transport (Harris et al., 2015).

2.2.3 The Stakeholders

At this point it is already clear that a large number of actors are involved in the global logistics networks, both from the private and public sector. In order for the PI roadmap to be implemented, all the different stakeholders need to be actively involved in the process, bringing each one's contribution to the project. Under this perspective, it is important to define all the different stakeholders.

The Oxford English Dictionary defines Stakeholders as "any person or group that has an interest or concern in something" (Oxford English Dictionary).

The Urban Transport System (UTS) (Ward, 2001) gives the opportunity to analyse the main stakeholders involved at Urban level.

An UTS is designed by Engineers and Planners who usually work with the Public Administration (PA) and at least one part of elected government. This first image already highlights the main actors of the PA - institutional officials that work in offices related to transport and logistics - and politicians - or political parties - who work on transport related issues and may or may not have specific interests. As for the business sector, Ward's (2001) list is as follows: "Chamber of Commerce, trade and business associations, motoring organizations" while on the opposite side we can find independent neighbouring organizations and non-governmental organizations (NGO) (Ward, 2001). Beside the aforementioned typical stakeholders, there is also the possibility of having open forums that discuss urban transport that may be open to any citizen and smaller organizations.

While including Commuters, community leaders and regulatory agencies, a study by Steudle et al. (2013) also gives us a list of all the stakeholders involved in the freight. The list suggests six main categories, namely "actors related to the freight private-sector, Economic development agencies, Port Authorities and Marine Terminal Operators, Local Government, Transportation agencies and Other Stakeholders" (Steudle, Board, & National Academies of Sciences and Medicine, 2013). Among the private sector stakeholders, Beneficial Cargo Owner (BCO) - "the importer of record, who physically takes possession of cargo at destination. And does not act as a third party in the movement of such goods." (Steudle et al., 2013) - work closely with Logisticians to plan and arrange the transportation of goods. Motor Carriers and Railroads are the main partners in the inland transport sectors, Trucks being "the single largest customer of U.S. freight-rail industry" (Steudle et al., 2013). Industrial real Estate developers are mainly responsible for the construction of facilities that allow the transportation of goods within a region, they own Warehouses, distribution centres and fulfilment locations (Steudle et al., 2013).

Because of the great impact of the transportation sector on national GDPs, Economic Development Agencies work closely both with governments trying to foster economic growth and with companies, helping them expanding their business (Steudle et al., 2013).

Freight Stakeholders

Private-Sector Freight Stakeholders
BCOs
Logisticians
Motor carriers
Railroads
Industrial real estate developers
Chambers of commerce and other business associations

Economic Development Agencies

Port Authorities and Marine Terminal Operators (MTOs)

Local Governments

Transportation Agencies
FHWA, state DOTs, MPOs

Other Stakeholders
Environmental and community groups, general public

Fig. 5 Freight Stakeholders Box (Steudle et al., 2013)

Ports and Airports clearly have a big role in the transport sector, since movement of containers and goods often involves their facilities and “Ports and airports are often some of the greatest generators of truck and rail traffic in a region” (Steudle et al., 2013).
While local governments’ involvement in freight has already been analysed by Ward (2001), Steudle et al. (2013) see the Transportation Agencies as important stakeholders in the process, since they have the ability to integrate operations and lead the highway capacity process.

Given the high number of actors participating on different levels of the transport network, it is clear how ambitious the PI roadmap is. Finding a way to engage all the different stakeholders and creating a common plan appears to be a gigantic mission, also because of an inefficient system of information exchange, often caused by the same stakeholders.

The paradigm shift of the PI needs to be strongly supported by political institutions, both at EU level and regional or local level, with frameworks like the aforementioned “Modulushca” by the European Commission (EC) while the general public and community groups have to pressure private companies to embrace the beneficial change of the PI implementation.

2.2.4 Environmental and economic implications of the current situation

A study by Montreuil, shows the huge implications of the current transport system through two case studies of developed countries like France and the USA.
From a greenhouse gas emission perspective, it is clear that the current situation is unsustainable with more than 3.7 T ton-miles generated with mixed transportation methods in the USA (Montreuil, 2011). While trends show that the situation is getting worse, France has seen its transport-related greenhouse gas emissions grow by 23% on annual base from 1990 to 2006, adding up to 14% of total greenhouse gas emissions in the country (Montreuil, 2011).
This environmental inefficiency has also huge economic implications, the USA department of transportation published reports that show how transportation adds up to 10% of US GDP, excluding costs incurred by the manufacturing industry and distribution, meaning that the annual costs adds up to many billions of dollars (Montreuil, 2011).

Another study by (Sternberg, Hagen, Paganelli, & Lumsden, 2010) indicated that the carbon footprint of the freight sector adds up do the 14% of global greenhouse gas emissions.

There are different reasons that can be seen as root causes of these inefficiencies. Despite the huge costs connected to transportation, fill rates of containers, trucks and wagons are surprisingly low. Statistics show that the average fill rate in the USA at departure amounts 60%, not counting the inefficient packaging solutions designed by manufacturers that often contain mostly air (Montreuil, 2011). Furthermore containers are not managed in an efficient way, studies made in the USA and the UK show how containers often return empty or have to travel many extra miles in order to find goods to transport back, at the same time, due to inefficient communication, containers loose goods on-route while travelling through different delivery points (Montreuil, 2011).
This data finds confirmation in Sternberg et al. (2010) who impute useless and empty trips to inefficient planning.

	Unsustainability symptoms	Economical	Environmental	Societal
1	We are shipping air and packaging	●	●	
2	Empty travel is the norm rather than the exception	●	●	
3	Truckers have become the modern cowboys	●		●
4	Products mostly sit idle, stored where unneeded, yet so often unavailable fast where needed	●		●
5	Production and storage facilities are poorly used	●	●	
6	So many products are never sold, never used	●	●	●
7	Products do not reach those who need them the most	●		●
8	Products unnecessarily move, crisscrossing the world	●	●	
9	Fast & reliable intermodal transport is still a dream or a joke	●	●	●
10	Getting products in and out of cities is a nightmare	●	●	●
11	Networks are neither secure nor robust	●		●
12	Smart automation & technology are hard to justify	●		●
13	Innovation is strangled	●	●	●

Fig. 6 Symptoms of unsustainability of the current situation (Montreuil, 2011)

Fig. 6 shows other relevant aspects that currently negatively influence the economic, environmental and social situation. Beside the aforementioned root causes, other relevant inefficiencies are related to transportation methods, storage, warehousing and distribution (Montreuil, 2011).

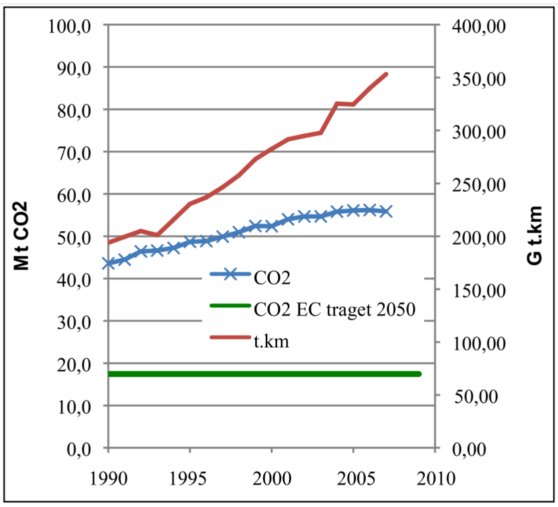


Fig. 7 EU CO2 target for 2050 (Montreuil, Meller, et al., 2012)

From an environmental point of view, logistics is widely recognized as one of the main causes of pollution and greenhouse gas emissions worldwide. Fig 7. Shows how the trend is clearly going in the wrong direction and not meeting the EU CO2 target for 2050 (Montreuil, Meller, et al., 2012).

2.2.5 Possible benefits of Physical Internet implementation

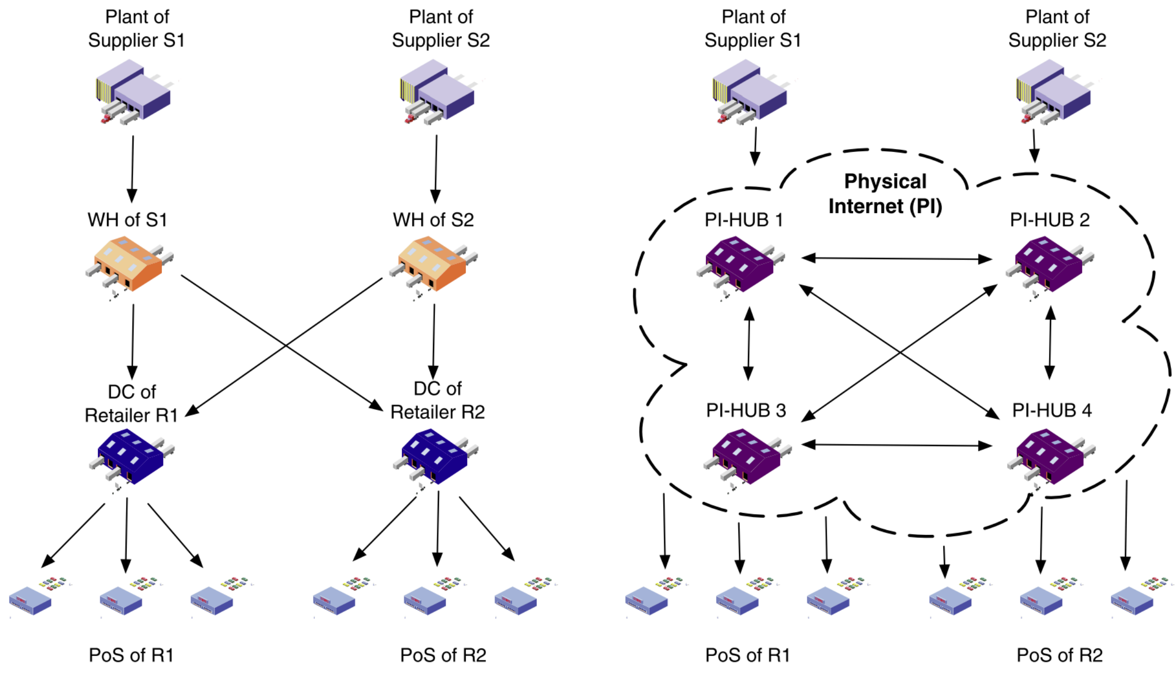
Physical Internet is widely connected with the goal of reaching a "green logistics" network, idea first theorized by Björklund, (2003) that encompasses the general "effort of reducing the environmental impact of the logistics operations" (Sternberg et al., 2010). While green efforts are often undertaken by companies for corporate social responsibilities and PR reasons, many studies demonstrate how more sustainable choices also lead to more cost-efficient solutions (Sternberg et al., 2010).

Another crucial aspect for the PI implementation depends on the transportation route. While intermodal transport has been looked at with increased interest in recent years, point to point transport is still dominating the logistic trends. Truck drivers are currently driving extremely long miles for various days in order to deliver their trailer to a destination. This is both inefficient and also extremely demanding for the drivers. In a PI scenario, the driver, or even better the driver-duo, would only be transporting goods for a few hours' drive, unloading the trailer in a π-transit, then picking up another trailer that needs to be delivered back to their destination of origin. This scenario could be implemented by carriers "taking charge of inter-node segments", enabling the "synchronized transfer of containers between segments and a platform enabling an open transport market" (Montreuil, 2011). Fig. 8 shows the example analysed by Montreuil of a transport from Quebec to Los Angeles. It is clear how beneficial the proposed system is both for the drivers as well for the efficiency of transportation.

Fig. 8 Example of PI distributed transport (Montreuil, 2011)

From a cost and efficiency point of view, inventory management and distribution have a huge impact on the supply chain management because of their strategic role as KPIs.

The current model sees a privately owned, hierarchical structure that connects plants with retails. In the example in Fig. 9, we can see that with the traditional system, plant owners send their products to a privately-owned Warehouse (WH) which then forwards the goods to a regional distribution centre (DC) owned by the retailers who then decide where to send the goods. Even if the location of Warehouses and Distribution Centres has been carefully studied and has been placed in the best possible location, it is clear that the current system doesn't create a lot of space for smart an efficient transportation. The limitations of relying on the privately-owned networks are crystal-clear, since the range of options comes down to the quantity of WH and DC available. The current model only allows for strategic decisions such as when to send goods and in what quantity, which are usually managed with an inventory control model.
Fig 9b. foreshadows the same scenario under a PI perspective. Thanks to the suggested open logistic web and open available WHs and DCs - or PI Hubs-, suppliers have many different options of where to send goods and can push their goods towards the demand in a more efficient way, outsourcing part of the inventory. At the same time, retailers can reduce lead time and stock by sourcing from all the open available DCs, this way creating an interconnected network (Pan, Nigrelli, Ballot, Sarraj, & Yang, 2015). Given the new possibilities made available by an open network, Pan, et al., (2015), propose new inventory management systems based on criteria other than the classic fixed scheme, and the results show that PI can actually reduce inventory level and total logistic costs while improving the service level to clients.
Venkadatri et al. further analyse the total cost, inventory cost, transportation cost, number of truck trips and average delivery time of the PI against the same KPIs in the traditional current model. Breaking down the reduction of the avarage total cost, it is clear that while transportation cost remain similar to the current situation, we can see a 93.9% reduction in average inventory cost and an overall rise in fill rates. This is mainly due to the aforementioned PI distribution network that allows for better consolidation possibilities which also significantly translates into quicker deliveries (Venkatadri, Krishna, & Ülkü, 2016).



a. Classical hierarchical multi-echelon distribution network b. Open distribution network through Physical Internet

Fig. 9 Traditional distribution vs PI distribution network (Pan, et al., 2015)

One of the main goals of the PI implementation is aimed at facing the current unsustainability of the transport sector.

Compared to Fig. 6, Fig. 10 shows how PI can tackle each one of the aspects that are currently a threat to the sustainability of the transportation sector. It demands a huge common effort of thousands of enterprises and it is clearly an extremely ambitious vision, but it is also clear that not one single point is beyond technological reach. Each step that is required could be implemented and is available today or at least possible to achieve.

Unsustainability symptoms		Physical Internet Characteristics												
		1	2	3	4	5	6	7	8	9	10	11	12	13
		Objects encapsulated in world standard modular containers	Universal interconnectivity	Container handling and storage systems	Smart networked containers embedding smart objects	Distributed multi-segment intermodal transport	Unified multi-tier conceptual framework	Open global supply web	Product design for containerization	Product materialization near to point of use	Open performance monitoring and capability certification	Webbed reliability and resilience of networks	Business model innovation	Open infrastructural innovation
1	We are shipping air and packaging	●							●					
2	Empty travel is the norm rather than the exception		●			●								
3	Truckers have become the modern cowboys			●		●								
4	Products mostly sit idle, stored where unneeded, yet so often unavailable fast where needed	●			●			●						
5	Production and storage facilities are poorly used	●	●	●				●	●	●				
6	So many products are never sold, never used							●		●		●	●	
7	Products do not reach those who need them the most		●			●	●	●		●		●		
8	Products unnecessarily move, crisscrossing the world		●		●	●					●			●
9	Fast & reliable intermodal transport is still a dream or a joke	●	●	●	●	●	●				●			●
10	Getting products in and out of cities is a nightmare	●	●		●	●	●	●		●		●		
11	Networks are neither secure nor robust	●	●		●	●		●			●	●		
12	Smart automation & technology are hard to justify	●	●	●	●		●				●		●	●
13	Innovation is strangled	●	●	●	●		●						●	●

Fig. 10 PI answers to the unsustainability challenge (Montreuil, 2011)

3 Empirical Search

3.1 Barriers to the adoption of IoT and other ICT solutions in the transport sector

The ICT business is currently facing a "golden era", with new technologies disrupting different markets and creating new opportunities, finding their place in today's business eco-system (Harris et al., 2015). While technology keeps upgrading, application in current business models isn't always simple.
Harris et al. (2015) present three main obstacles - or "barriers" - that pose a threat to ICT adoption in the multimodal transport, specifically user-related barriers, policy-related barriers and technology related barriers, as shown if Fig.11 (Harris et al., 2015).

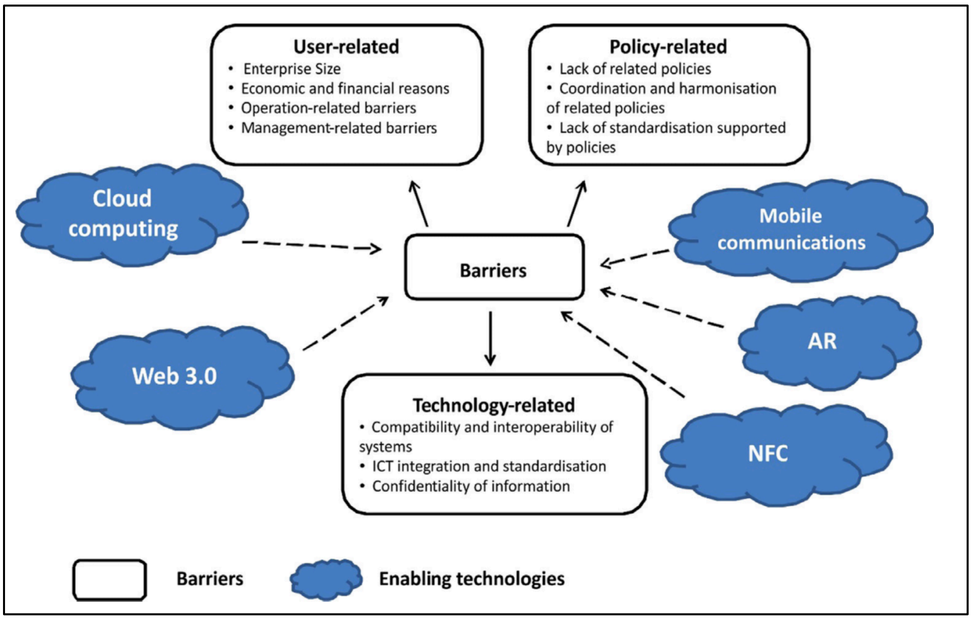


Fig. 11 Barriers to ICT adoption (Harris et al., 2015)

User related barriers have economic, operational and managerial root causes that mostly affect small and medium enterprises (SMEs) (Harris et al., 2015). Due to lack of financial resources and competences, SMEs can find it challenging to buy, implement and maintain ICT solutions that might allow them to comply with best practices, as done by big corporation that often have the talent and resources to develop *ad hoc* solutions that integrate with all their internal systems. Furthermore, as illustrated by Evangelista and Sweeney (2006), "high investment costs and high running costs rank as the top two factors inhibiting ICT adoption" in the Italian transport and logistics market, which has specific characteristics like a competitive ecosystem with low operating margins. Operational and managerial barriers are again mainly affecting SMEs that don't have the culture to develop new solutions due to low employee turnover and reluctance to change, as well as little knowledge about ICT solutions (Harris et al., 2015).
The multimodal transport network involves many different stakeholders; technology related barriers underline the difficulties of integrating new ICT solutions within the existing infrastructure and the interaction among the players, who often have different systems that do not work together and do not like to share information. This could be tackled with homogeneous ICT standards, but the multimodal network chain revolves around so many actors that it is extremely difficult to create an efficient cooperation, while at the same time, the rapid obsolesces of technology doesn't encourage stakeholders to undertake expensive and time consuming ICT implementations (Harris et al., 2015).

Multimodal transport generally requires goods to travel through different countries that might have different regulations related to customs, security, transport mode and other issues. This poses a policy barrier that should be overcome by harmonizing regulations, at least at EU level, while promoting policies that foster ICT implementation in the transport sector (Harris et al., 2015).

3.2 The proposed solution: IoT as accelerator for the PI roadmap implementation

3.2.1 IoT applications in the Physical Internet framework

Physical Internet is aiming at revolutionizing logistics by improving its efficiency and lowering its social costs and to achieve this goal the tech industry is needed and IoT can be an accelerator in this process. All the components of the logistics flow are becoming *smarter* every day, being equipped with technologies that can "provide important information for the management of the Supply Chain" (Atzori et al., 2010). RFID technology in logistics, as well as many other IoT applications, can help boost the PI roadmap, enabling all the different stakeholders to work together towards a more sustainable Supply Chain Management (Sun, 2012a).
ALICE's (2014) (Alliance for Logistics Innovation through Collaboration in Europe) publication "Information Systems for Interconnected Logistics", shows how, among the gaps that need to be filled in order to implement the Physical Internet, the ICT challenge represents one of the first steps, and should ideally be met by 2020. IoT has a role in this agenda, as it can provide the opportunity "to track items, dynamically manage assets, goods and environments in real time, increasing reliability, reducing risks and increasing security. IoT technologies also simplify the interactions between objects, allowing self-organisation and improving the logistics flow" (Alliance for Logistics Innovation through Collaboration in Europe (ALICE), 2014).
IoT can also help in the automation process, allowing machine decision making without human involvement (Zhou, Chong, & Ngai, 2015).
One of the technologies linked to IoT that has already been investigated is the before mentioned RFID. This technology resembles the bar code technology but doesn't require visibility to communicate with a database or to exchange data (Sun, 2012b). Since one of the main concepts of the PI is the possibility to quickly re-route or adapt a schedule to be as efficient as possible, RFID technology could enable such change through its Tag, interrogator and back end system components, by transmitting "the identity, location, status of an object wirelessly using radio waves in the form of a unique serial number" (Sun, 2012b). This means stakeholders can monitor the goods in real time, hence adapting the logistics to specific needs. This technology doesn't just allow to supervise the goods, but also to analyse the gathered information in order to forecast possible accidents, therefore allowing communication within complex logistic networks to lower chances of incidents, delays etc. (Sun, 2012b). The information exchange is crucial within any supply chain management, RFID can therefore play a crucial role in creating more efficient systems allowing real time information exchange.

One possible evolution of the RFID Technology is presented by Jones (2011), who introduces the idea of Near Field communication (NFC) - a hybrid solution that integrates RFID technology with GPS tracking that "enables wireless data transfer using smart phones" (Harris et al., 2015). Harris et al. (2015) present an example for the use of NFC in a typical context, showing how technological evolution can speed up processes in the logistic sector; a driver who needs to unload the goods could directly scan his smart phone using an app to signal his arrival, receiving instant instructions on where to unload and further instructions on the next activity. This kind of application could help with "faster customs clearance, tracking goods at any point in time, and instructions for dealing with hazardous goods." (Harris et al., 2015).

A limit of RFID technology is that it allows for data and information exchange only if the necessary infrastructure is present, like RFID readers. IoT is paving the way for new advanced solution related to the transport of containers. Smart devices geared with photoelectric sensors are allowing for unprecedented monitoring and real time information, while also automatically performing strategic tasks on their own. These objects are able to increase container security and monitoring thanks to these sensors that can give feedback on the luminosity within the container, giving important information on whether the container has been opened or breached, while assessing the impact of the containers through accelerometers and combining this information with GPS sensors that can constantly track the goods. At the same time, these devices are able to automatically send out SMS messages or emails accessing GSM networks, should some anomalies occur (Harris et al., 2015).
The whole data that is collected and transmitted by these objects is available to "all the stakeholders of the transport network", both private parties and public authorities, which helps to speed up all the process while increasing security and transparency (Harris et al., 2015). This kind of systems could help accelerating the PI roadmap by allowing an increasingly efficient multi-modal transport network that would enable real-time decision making, re-routing and automated data transfer and information exchange between π-containers and π-hubs and open distribution networks.
IBM has already taken the lead and provides and insightful case history with the development and production of its container tracking system called "tamper-resistant embedded controllers (TRECS)" through collaboration with Maerks. An advanced back-end, a wireless system and smart sensors give a real time view of the cargo to the shippers thanks to short- and long range networks that allow for timely decision making, supporting the multi-modal shift and empowering stakeholders to move away from the predestined logistic route by enabling changes before a cargo arrives at its destination (Harris et al., 2015).

As already discussed, PI also has the aim of increasing fill rates of containers in order to have a more efficient and sustainable open logistic web. In this framework, IoT technology finds a strategic partner in the Web 3.0 which, thanks to its languages and infrastructure, allows intelligent decision making by giving access to the information provided by smart devices and creating a visible stream of data. Evolution in this field could greatly address the problem of "empty trips" by identifying the ID and location of empty cargos therefore enabling stakeholders to take advantage of this information to take real time decisions to increase the fill-rates of the containers (Harris et al., 2015).

IoT can also represent the physical infrastructure to the evolution of Decision Support Systems (DSS), by delivering Big data - "a collection of data sets so large and complex that it is difficult to handle using on-hand database management tools or traditional processing approaches" (Ray Y. Zhong, Chen Xu, 2015) - that can be then analysed through machine learning algorithms and statistic modelling, delivering relevant insights supporting the decision making in the transport sector. Academic literature provides examples, like the "dynamic model, with a real-time-oriented control approach to allow the expansion of load consolidation, the reduction of empty vehicle trips, and handling of dynamic disturbances for freight forwarder transportation networks" proposed by Bock (2010) or other information systems (IS) that can manage intermodal transport networks through the use of Big Data containers (Harris et al., 2015).

Another example in which IoT works together with the most advanced ICT innovations like "cloud computing semantic web" is the Intelligent Cargo, or iCargo (iCargo, 2011), a project by the European Commission that foreshadows the possibility of goods being autonomously aware of their context and location while connected to other systems (Harris et al., 2015). This project is embedded within the Smart Logistic System (SLS) (Stefansson et al., 2007) and has the goal of "storing data and information at the goods level, allowing data and information to follow the goods on their way to their final destination" (Sternberg et al., 2010). The iCargo doesn't simply aim at monitoring goods and making smart decision throughout the delivery process, but actually serves the greater purpose of the PI roadmap - having an environmentally friendly logistics system. An experiment by (Sternberg et al., 2010) was led by creating an intelligent cargo geared with an Open-SIS Ericsson infrastructure and RFID tags and readers in a virtual reality road network. The results showed an increase in the efficiency of the transportation that was possible because of quick responses to unexpected events thanks to "route planning, road consolidation improved fill rates" (Sternberg et al., 2010). The iCargo allows to have greater control over the whole transport process, allowing an increase in environmental and financial sustainability (Sternberg et al., 2010).

IoT components can also contribute in creating new solutions at manufacturing level, by facilitating most of the operations at shop floor level and thus creating a PI-based intelligent shop floor. In a scenario presented by (Ray Y. Zhong, Chen Xu, 2015) we can see how IoT, RFID technology and Big Data analytics can co-work to produce value at shop floor level.
Attacking and RFID tag to a pallet converts it into a smart manufacturing object (SMO). Internal and external logistic operators can therefore gather all the necessary information on products both regarding the in-buffer and the out-buffer by simply having an RFID reader that automatically communicates with the SMOs and gives instructions to the operators.
All activities are monitored through a network that gathers data which is transmitted to a central data warehouse through Wi-Fi, Bluetooth or other solutions. In order to transform data into information, a specific architecture needs to be implemented.
A data-structure needs to be decided, in order to decide on data presentation and interpretation, due to the complex operations that occur at shop floor. Once RFID Data is collected into a data warehouse, the raw data set needs to be cleansed, classified, compressed, stored. Data can now be analysed through patterns, standardization and representation. Now the management has access to information that enables knowledge-based predictions, data-driven decision making and logistics knowledge repository.

These examples show how IoT technologies can actually help and accelerate the implementation of the PI roadmap. It is clear that technology alone cannot tackle the global challenge of sustainable logistics, but it creates the structure for the achievement of this goal and can help speed up the process. A PI logistics network will only be possible if all the stakeholders commit to this idea and work in order to improve the current system. Technology - and IoT in particular - can accelerate the process both by enabling the paradigm shift through smart solutions and by removing barriers to de adoption of PI solutions. Technology can facilitate the implementation of the PI from a technical point of view, reducing the problem to the sheer will of all the involved actors.

4 Methodology

4.1 Data collection method

This thesis aims at assessing whether IoT can be an accelerator in the implementation of the PI roadmap. In order to being able to provide an insight on this issue, data will be collected in two ways. In order to gather extensive information a thorough literature review has been performed, this allows to gain knowledge and to assess the studies that have been already performed regarding this topic. Since this work is a qualitative study, my contribution - beside providing a real state of the art overview on the current studies - will be given through in-depth interviews.
Qualitative studies are gaining more and more popularity among researchers, since their capability of providing deep views on specific issues (Sandelowski, 2000).

Given the chosen topic, a quantitative study would be hardly providing specific insight, given the fact that only a number of academic and professionals are currently investigating and working on IoT applications in the PI framework.

4.2 Data analysis

As suggested by the literature, qualitative studies have an inductive approach and the analysis usually starts with a set of complex texts that might be the transcript of unstructured interview, like in this case, or field notes and documents (Life, 1994).
The first step of the analysis starts with a first thorough read of the notes and by listening the recorded interviews at least two or three times while writing down thoughts and impressions on a separate notebook.
This phase helps stimulating creative and critical thinking and to have a first general idea on the collected information.
A second phase involves a selection of the most relevant information gathered through the interviews. There will be two main criteria for the selection of text fragments, the information is currently demonstrable, or the information refers to a personal view regarding possible future evolutions of IoT applications within the PI framework.
Following the selection of the text, fragments will be coded following the grounded theory method, in order to be able to compare the different information gathered by different stakeholders and check for coherence, similarities and differences (Life, 1994).
After all these phases, a theory will be developed that will try to answer to the purpose of the study itself, namely if the IoT can actually accelerate the implementation for the PI roadmap and what stakeholders are actually doing in order to reach this goal.

4.3 The Survey

4.3.1 Sample

Following the work of S. Dworkin (2012), for this qualitative research structured on in-depth interviews, I decided to gather a sample made out of three people.
The selected people represent stakeholders of the IoT industry whose work revolves around logistics. The sample therefore embeds a pool of experts who are extremely well prepared and informed regarding current trends in the logistics sector, especially related to new technologies, IoT and PI (Dworkin, 2012).

4.3.2 Definition of the questionnaire

Before defining the set of questions that will create the skeleton for the unstructured interviews, it is once again important to define what kind of information is needed to fulfil the purpose of the study and how that information will be used (Marshall, 1998).
The main focus of this work has been to give an in-depth literature review regarding the current state of the art of IoT Technologies and PI and to give a final answer to the question whether IoT can help implement the PI roadmap.
In order to provide a contribution, this study will investigate further by gathering information from experts.
Before asking the questions, information regarding this work, its scope and general knowledge about the PI will be provided to the interviewed stakeholders. Following the provided information, the interview will begin, and the following questions will be asked:

- The PI is aiming at creating a common and open logistics web that might allow for a cheaper and more sustainable transport of goods. As already demonstrated by literature, IoT technologies might have a role in implementing the PI roadmap. Given the provided information, is there the will of IoT companies and the logistics sector to actually implement the PI roadmap?
- Are IoT companies currently working on technology solutions that might accelerate the goal of reaching the PI goal?
- IoT technologies already demonstrated having potential to address some of the issues related to PI, especially related to gathering and distributing information regarding the production and transport of goods to all the stakeholders involved. Literature shows how smart objects and IoT might be one part of the physical infrastructure for the information flow of the logistics web. Given the current technological advancement in the field of IoT, what solutions are the most probable to be available in the short and medium term? What are the trends in the IoT sector?
- (Continuing from the previous question) What value can these solutions bring to the PI and the logistics sector in general?
- What is the time horizon for the next IoT technologies related to the logistics sector?
- What will the future of IoT look like and how will it change the logistics infrastructure?

Mashall's (1998) work illustrates how to structure such open-ended questions in order to gain the most insight from the interviews.
First of all, Marshall distinguishes between four kinds of information types that are gathered with different kind of questions, namely knowledge, beliefs, behaviours and attributes (Marshall, 1998). Knowledge related questions investigate what respondents know for a fact and believe to be true (Marshall, 1998); in this work the interviewed sample will provide information on IoT and PI to the best of its knowledge given the sample's work experience and expertise. Furthermore, the design of the questions will try to investigate the sample's beliefs and opinions. This is especially important given the depth of insight the sample has regarding the IoT industry and will therefore provide not only the personal views on trends and technologies but also opinions regarding the future and possible evolutions.
The questions will also investigate the sample's behaviour - how and to what extent they are contributing - and attributes - what role the respondents have from a formal point of view.
The questions will be open-ended, in order to allow the interviewed stakeholders to provide complete and structured answers while stimulating their free thought, provide further details and recall insightful information.

5 Results

5.1.1 Interviews

Before reporting the interviews, I introduce the interviewed stakeholders provide information about their specific expertise regarding IoT and logistics.

- Paolo Prandini - IoT Business Solution Lead (Supply Chain) @ Oracle.
  Business Solution Lead with 22+ years in the industry. Helps Prospects, Customers and Partners solving their Business problems from Technology to Business Intelligence to Applications and ease their path to the Cloud. Innovation Lead with special focus on Internet of Things and Blockchain and corresponding applications in Supply Chain. Internet of Things EMEA Community Domain Lead.
- Mariarita Costanza - Founder and CTO @ Macnil (Zucchetti Group).

Her main competencies are IoT, Smart Cities, Automotive and Digital Mobile Marketing. Digital Innovation expert, she founded the first company in Puglia that focuses on IoT, Fleet Management and Digital Mobile Marketing. Mariarita Costanza also created and App on sustainable mobility for Smart Cities: InfoSmartCity. She has been listed as one of the 15 most influential women in the digital world for Italy.

- Fares Beainy - Electromobility Strategy @ Volvo.
  Electromobility expert with focus on developing and managing strategies through collection of market drivers and technology trends to support Volvo products, components and depth of engagement development.

Before analyzing and interpreting the results of the conversations, I will report the transcriptions of the interviews:

- *Q1: The PI is aiming at creating a common and open logistics web that might allow for a cheaper and more sustainable transport of goods. As already demonstrated by literature, IoT technologies might have a role in implementing the PI roadmap. Given the provided information, is there the will of IoT companies and the logistics sector to actually implement the PI roadmap?*

Paolo Prandini: "So far companies are still looking for the next big thing. Some say it will be Blockchain, some say it will be IoT some that the merge of two will change the world. However, when it's back to the amount of money needed to fuel innovation, most companies still setup their best undecided face and wait."

Mariarita Costanza: "Physical Internet represents an extreme innovation in terms of applicability of the internet metaphor applied to the logistics sector. In order to deliver the right message and to avoid misunderstandings with the user (like a logistics provider) who might see it as a complication, it is important to clearly explain the concrete advantages of this innovation. Talking about IoT, which is the core business of our company, there already is a lot of literature on the subject but unfortunately there aren't enough concrete projects that could allow to perceive the benefits of an IoT system in the different sectors of application. To answer your question, IoT companies like ours, which live for innovation and research, want to invest, but we are just one stakeholder, we create systems for others to use. The logistics providers will invest accordingly to our capacity of explaining the advantages of PI to them."

Fares Beainy: "I would put this one more on the logistics sector than on the IoT companies. It could be a push by IoT companies, or a pull by the logistics sector. I think the IoT companies are willing to invest in this framework, but the framework implementation rely on the willingness of the logistics sector. Normally, IoT companies exist to make profit, so they will be willing to invest as long as it is a good business through widespread global implementation of the framework.
Anyway, basic IoT technologies has been proven and are employed in many areas from smart homes, wearables, smart grids, connected cars, connected health, etc. Physical Internet is just another application that would adapt existing IoT technologies."

- *Q2: Are IoT companies currently working on technology solutions that might accelerate the goal of reaching the PI goal?*

Paolo Prandini: "Yes. Actually, the IoT platform did not trigger an excited response from the market. IoT is perceived as difficult, low ROI and undetermined value. That was the beginning of a new model that gave birth to IoT Applications. IoT is not about the sensors, IoT is about the data and the value that comes from it. Many misunderstood the Industry 4.0 message and IoT message altogether. They concentrated in getting the data out (sensors and dashboard / reporting) rather than thinking about data processing and predictive analytics. At the time of answer, Microsoft still has an IoT Platform to enhance with Big Data, Machine Learning and Analytics as a side dish. SAP is struggling to integrate Plat-One acquisition in its new Leonardo Platform, complete with Apps and Oracle has IoT Apps out of the box with Machine Learning and AI included in the subscription at a very convenient price model."

Mariarita Costanza: "One of the main goals of IoT is increasing the efficiency of any system. Focusing on logistics, we have been working on fleet management for years and our R&D department is working on improving our systems; the market provides the feedback and it depends on the customer experience of our clients and on our ability of optimizing their processes through our solutions. Thanks to this interview, we are going to put some resources into an assessment of how the PI model can apply to our systems. This is our approach, and this is how we like to do innovation."

Fares Beainy: "Yes, I believe that IoT companies already have solutions that might accelerate the goal of reaching the PI goal and I think current IoT technologies could be easily adapted to fit PI applications."

- *Q3: IoT technologies already demonstrated having potential to address some of the issues related to PI, especially related to gathering and distributing information regarding the production and transport of goods to all the stakeholders involved. Literature shows how smart objects and IoT might be one part of the physical infrastructure for the information flow of the logistics web. Given the current technological advancement in the field of IoT, what solutions are the most probable to be available in the short and medium term? What are the trends in the IoT sector?*

Paolo Prandini: "Again, the aim here is not about the sensors. There are plenty of them in the market. The aim is to provide an end to end analytical layer that performs data gathering from IoT sensors, Analysis and acts based on a network of rules. Smart objects need to be made "smarter". They need to incorporate ability to connect to all IoT cloud providers so that the initial IoT substrate, connectivity, is exploited in an easy way. After that it's all about data processing, machine learning and AI-like rules, to help machines take decisions without or with limited Human intervention."

Mariarita Costanza: "The logistics sector is a good example to show how IoT solutions can add value: on one side we have the need for systems that allow the planning, management and flow optimization - throughout the supply chain and within intermodal nodes - on the other side we have the need of traceability of the goods in real time throughout the whole supply chain, also thanks to the evolution of the legal framework.
IoT solutions can support the improvement of logistics by increasing the degree of visibility and control over the supply chain. The most important solutions are going to be the ones that will enable the control of the integrity of the goods (for example systems that ensure and certify lack of breaches), and the ones that will identify and monitor goods remotely through RFID, GPS technologies and sensors that monitor specific parameters and variables on the condition of the assets. All these technologies are already tested and available. Our company provides exactly this kind of service to logistics companies."

Fares Beainy: "PI is a global logistics system based on the interconnection of logistics networks by a standardised set of collaboration protocols, modular containers and smart interfaces. Short term: would be the employment of current IoT technologies to specific case scenarios, regionally, or on specific global routes/carriers.
Long term: develop standard protocols and optimize IoT systems for PI toward efficiency and scalability."

- *Q4: (Continuing from the previous question) What value can these solutions bring to the PI and the logistics sector in general?*

Paolo Prandini: "The value expected from IoT solutions, beside the costs of sensors, is the business insight they can give to business processes and the business automation that derives from using IoT as a middleware of things. However, although software is there and with an excellent range of functionalities (at least Oracle!) there is still something to be done: IoT solutions shouldn't be painful to adopt. IoT solutions should offer a pre-tailored application / industry bias to help fast implementation and ROI and should be sold as 'packages' including both hardware and software. The IT industry has identified this pain and has addressed it by creating cooperation with Partners and System Integrators but we're far from offering a 'Turn Keys' IoT Enablement Package, with all the ingredients included, Software, Machine Learning, Hardware."

Mariarita Costanza: "IoT creates a number of different opportunities for the logistics sector. In order to simplify, we can separate the benefits in two main areas: on one side there are solutions designed for fleet management that allow for the support and automation of activities like real time monitoring of failures and manumissions on the fleet as well as the location of the vehicles through localization; on the other side there are solutions designed for the supply chain management in terms of traceability of the goods and management of the logistics activities through the complex logistic nodes, while ensuring traceability and operational security. We think that IoT solutions add value and can be applied throughout the whole supply chain."

Fares Beainy: "PI is not feasible without IoT, or at least it would not reach its potential. IoT would provide PI the connectivity, unique identifier to all involved assets (containers, ships, trucks, facilities…), and the ability to transfer data over a network without requiring human to human interface to human to computer interface."

- *Q5: What is the time horizon for the next IoT technologies related to the logistics sector?*

Paolo Prandini: "I think we'll see more in the next years (2 to 5) and all depends on how Blockchain will be adopted by logistic sector. That will open to IoT spreading as 'Blockchain of Things'."

Mariarita Costanza: "There has been a lot of buzz round IoT in the past years, but we still don't have concrete and visible models of IoT systems. This is not due to a slow progress in R&D, rather innovation is so fast that it doesn't allow for an easy and fast understanding by the market. This leads to the assumption that innovation actually complicates processes. I believe that the time horizon depends on our ability to communicate the advantages and benefits of innovation. Innovation has to be perceived as an evolution and not as something that goes against tradition. This also means that the systems have to be easy to use for the end user."

Fares Beainy: "I don't think we have discrete time horizon. But rather a continuous spectrum of undefined, unpredictable events that will continue to integrate IoT technologies into the logistics sector, until a PI framework is developed and implemented. It all depends on the logistics sector push for standardization of protocols, and development of the framework."

- *Q6: What will the future of IoT look like and how will it change the logistics infrastructure?*

Paolo Prandini: "Let's imagine such utopic future: Time Travel to 2030. Do you remember 2018? At that time, we didn't know anything about the contents of our shipped packages, we were not recycling the cargos, we had a lot of empty cargos coming back empty from destinations and with a large consumption of CO2. Then a change happened. The WTO decided that something had to be done with packaging, tracking, frauds, CO2 Emissions, overall optimizations. That was done. Now with IoT we track real time almost everything and thanks to that we have data exchange between operators and a network of cargo ready to help to optimize and avoid spare trips, empty trips, less than truck load trips. In a nutshell IoT and blockchain created the commons of network logistics a sort of socialist network where peer to peer is applied to logistics and transportation. The optimization has been enormous and in 2025 with the upcoming of autonomous trucks connected 24/7 with service and logistics control towers we allowed companies to transport at the best of their capacity. Moreover, no job has been lost, although many have to be converted to new profession. A swarm of robots that needs mechanical assistance has been built and behind that humans to control and provide service. Logistics networks are everybody's roads and paths, being @ sea, @ train, @wheels, in the air, all is interconnected and working without missing a beat. Frauds were gone by 2025 with the adoption of Blockchain. We use crypto lognet money so that we have ability to track transactions and check against bad behaviors as well as documents, advanced shipping notes, receipts, exceptions. IoT also helps to know about the fate of a cargo content before it's delivered and once arrived at destination, Blockchain is invoked to create immediate payments. This has eliminated impostors and criminally connected companies as they used fake money in the past. All is supervised with massive usage of machine learning and artificial intelligence. Even though this might seem as if humans might lose control, it is not. We are 100% in control. Now more than ever."

Mariarita Costanza: "It is now clear that IoT technology represents a concrete and effective support for the logistics infrastructure; the more nodes in the IoT web - which means gathering more information - the more efficient will the whole structure become. This will bring advantages for the user in terms of performance (delivery time, transportation cost, quality of the transported goods…).
It is important to focus on the user; the market has to perceive the benefits if we want IoT to be successful and become an enabling technology."

Fares Beainy: "More and more devices will be connected. Today, at least in the US and many developed countries, almost everything is connected. Even fridges, egg trays are now connected to the cloud. It will just keep increasing. In extreme cases, microchip implants into human bodies will become popular. Such development will definitely spill into the logistics sector and accelerate the possible adoption the PI framework."

6 Discussion

Having gained the insights of extremely competent professionals who work directly in the mobility, technology or logistics sector, it is now possible to draw some conclusions comparing their answers to the set of questions, trying to find some patterns in the answers of the different stakeholders. Formulating the conclusion, I will first focus on trying to analyse each question separately, gaining an insight on the specific issues. Finally, I will try to summarize the whole knowledge gathered trough the interviews into a generic conclusion that will try to answer to the main question: Can IoT be an accelerator for the PI roadmap?

Regarding Q1, it is clear that right now there is not a definite answer as to if there's a will by the industry to invest in IoT technologies to implement the PI. Paolo Prandini clearly states that there is a budget issue, because companies don't perceive the value of IoT technology but only see the cost of implementation. Companies are still on a "hold" position, trying to assess whether and when to make a move in this direction. Furthermore, Mr. Prandini said that many companies, at least in Italy, still do not see a great difference between industrial automation and data driven process transformation. Therefore, also taking into account the vision of Fares Beainy, it's still unclear whether the disruption will be driven by IoT companies, that might still evaluate the risk of developing solution that won't meet the market's demand, or by the logistic sector, that has to decide whether to actually adopt standards and evolve into a PI framework, based also on an IoT infrastructure. Nevertheless, Mariarita Costanza, as a real IoT stakeholder, provided an extremely interesting insight. IoT companies, like Macnil, are constantly innovating and looking for new solutions but the impact they can have on the market is still not enough. They have to be extremely well prepared and deliver amazing solutions in order to convince the market of the benefits, but the decision still lies on logistics providers and big companies that have to join the challenge and invest in this kind of solutions.

As for Q2, all the interviewed stakeholders agree that companies are investing in IoT solutions that might be supporting the PI roadmap. This has to be seen as a positive message, especially because the interviewed stakeholders are actually part of the business itself. This means that their insight is backed up by business knowledge. This view demonstrates that the adoption of IoT technology in the logistic sector - more specifically for the PI roadmap - won't be related to the availability of solutions but will depend on cultural and business-related barriers that might prevent the paradigm shift. An even more promising sign is given by the fact that Macnil - company represented by Mariarita Costanza - will actually study the PI framework in order to understand whether they can implement some of the solutions within their systems. This once again shows that not only are IoT companies willing to invest and actually developing solutions, but they are actually dragging the whole industry through innovation.

Q3 is a first attempt to gather a concrete answer on what the future of IoT will be and what solutions will be available in the short and medium term. While Fares Beainy states that current technologies are already enough to work on short term goals, Paolo Prandini shows how the infrastructure is actually already available, what is missing are integrated solutions - sold as a "package" - that can actually drive the market and therefore foster money in the sector, allowing for new technologies and solutions to reach the market. The interesting aspect of Paolo Prandini's answer, is that it underlines once again that the focus shouldn't be on the technological infrastructure of IoT. IoT solutions are available and might add value immediately. The point is that IoT cannot be a stand-alone technology because by itself it won't bring great value to PI, logistics sector or any other business. IoT needs data gathering layer, a data processing layer, an analytical layer and data visualization layer. This is an extremely important answer because it demonstrated once again that there has to be a common effort from the market, developing integrated solutions that can actually bring great value for the sector and for the PI implementation. Once again Mariarita Costanza provided a concrete example of what kind of IoT solutions represent the most important ones. The most popular solutions, which are already available for the market to use, will be the ones that will allow for the real time monitoring of the status of the goods thanks to RFID and GPS technologies.

Mariarita Costanza helps us understanding what concrete value IoT solutions can bring to the logistics sector. She explains that the value of IoT will impact two major areas; one focuses on systems related to the fleet management - which are an extremely important part of the whole logistics web - the other one focuses on how IoT technologies can positively affect the supply chain management.
In a first informal phone call with Paolo Prandini, he gave an interesting insight on the value of IoT technology, if supported by an integrated system, to business automation. IoT gives "voice" to things, this means that it acts as a "guardian" for the delivered goods, giving information on the status of the objects. As an example, if sensors register a strong turbulence or a crash, while transporting extremely fragile goods, it can immediately communicate with an ERP, asking for an immediate new shipment. At the same time, thanks to IoT and geo-fencing, systems can track goods and send messages to all the stakeholders regarding the location of the goods, also automatically creating invoices based on the country in which the goods are. This also helps building up trust among the involved parties. Paolo Prandini sees an even greater value in the combination between IoT and Blockchain technology, going towards a "Blockchain of things" era that will put all the information gathered by IoT and analysed by the layer above, into an open ledger that will pave the way for a system of records, smart contracts and in general to a more transparent communication among stakeholders. While supporting this thesis, Fares Beainy also stresses an important point, because, while underlining the added value of IoT for the PI roadmap, he states an even more fundamental issue, namely that PI won't actually be possible without the help of IoT technology, or at least won't reach its full potential. This answers actually makes clear that the value added by IoT is fundamental.

Q5 tries to gain a temporal insight on IoT technologies, specifically related to PI and the supply chain sector. While Mr Beainy and Mariarita Costanza don't provide a specific timeframe because of the constant development and the possible variables that might accelerate or slow down the process, Mr. Prandini gives a clear time frame. The next 2-5 years will be decisive, and the developments in the area of IoT, Machine Learning, AI and Blockchain - specifically regarding integrated solutions combining the above-mentioned technologies - have to happen within this timeframe. During the first informal phone-call, he actually stressed deeply on this time frame. "We are already late", he said, "and the next 2-5 years will be extremely important, also because technology can actually help the environment, creating the infrastructure for a *"greener"* supply chain - which is also one of the PI's goals. If we won't manage to deliver in this timeframe, it will be a problem”. This statement gives a deeper meaning to the timeframe for technology development and PI roadmap implementation, addressing one of the main issues: sustainability.

The last question, continuing with a time-frame related topic, tries to address the whole issue looking into the future. The interviewed stakeholders are being asked to imagine the next steps of IoT technology related to PI and the logistics sector.
All the interviewed stakeholders see the future as more and more interconnected, also thanks to the use of IoT technologies. Connectivity will increase more and more, bringing new developments in the logistics sector and creating the infrastructure that will help the implementation of PI. Goods will be tracked constantly, providing information and data that will be exchanged among all stakeholders, allowing for transparent and efficient flow of goods and money, also thanks to Blockchain technology that, connected with IoT devices, will allow for automated information and payments. The IoT infrastructure will also provide the necessary data for freight optimisation, reducing to zero empty trips or less than truck load trips. Generally speaking, IoT also plays a role in the development of self-driving trucks that will allow for efficient freight, automated re-routing and will increase the transport capacity to its maximum.
Everything will be integrated with AI, Machine learning and big data analytics, which will create the layer above the IoT infrastructure and will be extremely beneficial for the PI implementation.

7 Conclusion

Drawing a conclusion, based on the results obtained through the extensive literature review and the information gathered by the interviewed stakeholders, It is clear that not only can IoT technology help accelerating the implementation of the PI roadmap, but it is fundamental for its implementation. IoT technology is already available and can be part of the infrastructure that is needed for a common, open logistics network. Of course, IoT alone is not enough for the PI implementation, for both technological, economic and cultural reasons, but it is clear that it can help, accelerate and make possible the ambitious goal set by the PI roadmap.
All the interviewed stakeholders underline that there are no technological barriers, many possible solutions are already available in the market. The barriers are often cultural and economic; companies perceive innovation as a cost and not as an added value and are afraid to be the first to move or to invest in systems that won’t show short-terms returns. Businesses focus on financial quarters or semesters and are afraid to take decisions that don’t have a clear and immediate ROI. From both Paolo Prandini and Mariarita Costanza’s words it appears that the large-scale implementation of IoT technology in the supply chain and logistics sectors is still far away, since there aren’t apparently enough concrete projects. The “push” from the tech companies is not enough, the market is moving too slowly and won’t react in time to the important and strategic challenges that we are facing. PI is an ambitious goal, but it is crucial for the future of the planet, not only for the logistics sector.
The e-commerce economy is constantly growing, and this clearly puts an even bigger pressure on the logistics operators that are going to be extremely important stakeholders for the PI implementation. This evolution in the consumer behaviour increased the volumes of goods being transported each day around the world, thus also the climatic side-effects of transportation. Thanks to the information gathered through the literature review and the interviews, we now have the proof that technology is ready, what needs to be worked on is the infrastructure and the culture.
The PI challenge is extremely important and crucial for the future of the planet and needs to be addressed as soon as possible. IoT is ready to play its part for this grand challenge.

8 Further studies and possible limitations

The aim of this thesis has been to assess the current stage of implementation of the PI and, by studying the technological landscape, provide an insight as to what kind IoT Technologies might prove essential to the implementation of the PI roadmap.
No mathematical modelling has been developed to provide quantitative insights and, furthermore, no legislative frameworks have been analysed.
Legal frameworks could represent an obstacle for the use of IoT technologies within the logistic sector; for example, tracking containers also means indirectly tracking the drivers. In Italy unions are currently addressing this issues with regard to food delivery apps (e.g. Deliveroo, etc.) and to Amazon and Amazon Prime deliveries.
Furthermore, the ATEX normative (https://ec.europa.eu/growth/sectors/mechanical-engineering/atex_en) is a legal framework that regulates, among other issues, what kind of objects can be transported in airplanes, specifically this legal framework regulates the use of electronic devices during flights, be it for commercial flights or freight. Smart objects have batteries that represent a risk because of explosion hazard, and they also communicate via different methods that might interfere with the airplane communication system, therefore the use of IoT sensors in planes might be controversial and might need a new legislative framework. In my thesis, such issues have not been analysed since my focus has been to assess whether IoT technology can add value to the logistic sector, specifically for the PI implementation. Not to assess whether the current legal framework can pose a threat for IoT use within the PI framework. A further study might analyse national, European and Worldwide legislation in order to provide an insight as to what legal requirements are needed in order to use IoT technology for logistic purposes.

9 Bibliography

Alliance for Logistics Innovation through Collaboration in Europe (ALICE). (2014). Information Systems for Interconnected Logistics Roadmap. *Alice*, (December).

Atzori, L., Iera, A., & Morabito, G. (2010). The Internet of Things: A survey. *Elsevier*, 19. Retrieved from https://www.researchgate.net/profile/Luigi_Atzori2/publication/222571757_The_Internet_of_Things_A_Survey/links/546b36df0cf2f5eb180914e5/The-Internet-of-Things-A-Survey.pdf

Bandyopadhyay, D., & Sen, J. (2011). Internet of Things: Applications and Challenges in Technology and Standardization. *Wireless Personal Communications*, *58*(1), 49–69. https://doi.org/10.1007/s11277-011-0288-5

Dworkin, S. L. (2012). Sample Size Policy for Qualitative Studies Using In-Depth Interviews. *Archives of Sexual Behavior*, *41*(6), 1319–1320. https://doi.org/10.1007/s10508-012-0016-6

Harris, I., Wang, Y., & Wang, H. (2015). ICT in multimodal transport and technological trends: Unleashing potential for the future. *International Journal of Production Economics*, *159*, 88–103. https://doi.org/10.1016/j.ijpe.2014.09.005

Landschützer, C., Ehrentraut, F., & Jodin, D. (2015). Containers for the Physical Internet: requirements and engineering design related to FMCG logistics. *Logistics Research*, *8*(1), 8. https://doi.org/10.1007/s12159-015-0126-3

Lee, I., & Lee, K. (2015). The Internet of Things (IoT): Applications, investments, and challenges for enterprises. *Business Horizons*, *58*, 431–440. https://doi.org/10.1016/j.bushor.2015.03.008

Life, R. S. (1994). Qualitative data analysis Aims and objectives. *Reingeneering*. Retrieved from http://reengineering2011.webs.com/documents/Social_research CH_4-1.PDF

Marshall, M. G. (1998). Constructing a questionnaire. Retrieved from http://oregon.4h.oregonstate.edu/sites/default/files/about/research/questionnaire_design.pdf

Montreuil, B. (2011). Toward a Physical Internet: meeting the global logistics sustainability grand challenge. *Logistics Research*, *3*(2–3), 71–87 (16). https://doi.org/10.1007/s12159-011-0045-x

Montreuil, B., Meller, R. D., & Ballot, E. (2010). Towards a Physical Internet: The impact on logistics facilities and material handlic systems design and innovation. Retrieved from https://pdfs.semanticscholar.org/a907/08526f1c787bdafbcebf8492583b7ef668d4.pdf

Montreuil, B., Meller, R. D., & Ballot, E. (2012). Physical Internet Foundations Bureaux de Montréal : Bureaux de Québec. *CIRRELT*, 10. Retrieved from https://www.cirrelt.ca/DocumentsTravail/CIRRELT-FSA-2012-56.pdf

Montreuil, B., Rougès, J.-F., Cimon, Y., & Poulin, D. (2012). The Physical Internet and Business Model Innovation. *Technology Innovation Management Review*. Retrieved from http://www.timreview.ca/sites/default/files/article_PDF/Montreuil_et_al_TIMReview_June2012.pdf

Pan, S., Nigrelli, M., Ballot, E., Sarraj, R., & Yang, Y. (2015). Perspectives of inventory control models in the Physical Internet: A simulation study. *Computers & Industrial Engineering*, *84*, 122–132. https://doi.org/10.1016/j.cie.2014.11.027

Ray Y. Zhong, Chen Xu, C. C. & G. Q. H. (2015). Big Data Analytics for Physical Internet-based intelligent manufacturing shop floors. *International Journal of Production Research*, 13. Retrieved from https://www.researchgate.net/profile/Ray_Zhong/publication/281649322_Big_Data_Analytics_for_Physical_Internet-based_intelligent_manufacturing_shop_floors/links/55f81ce608aeafc8ac0a4a9f.pdf

Sandelowski, M. (2000). Focus on Research Methods Whatever Happened to Qualitative Description? *Research in Nursing & Health*, *23*, 334–340. Retrieved from http://www.wou.edu/~mcgladm/Quantitative Methods/optional stuff/qualitative description.pdf

Sternberg, H., Hagen, A., Paganelli, P., & Lumsden, K. (2010). Intelligent cargo - enabling future's sustainable and accountable transportation system. *World Journal of Science, Technology and Sustainable Development*, *7*(3), 253–262. https://doi.org/10.1108/20425945201000016

Steudle, K. T., Board, T. R., & National Academies of Sciences and Medicine, E. (2013). *Integrating Freight Considerations into the Highway Capacity Planning Process: Practitioner's Guide*. (I. Cambridge Systematics, Ed.). Washington, DC: The National Academies Press. https://doi.org/10.17226/22459

Sun, C. (2012a). Application of RFID Technology for Logistics on Internet of Things. *AASRI Procedia*, *1*, 106–111. https://doi.org/10.1016/j.aasri.2012.06.019

Sun, C. (2012b). Application of RFID Technology for Logistics on Internet of Things. *AASRI Procedia*, *1*, 106–111 (5). https://doi.org/10.1016/j.aasri.2012.06.019

Venkatadri, U., Krishna, K. S., & Ülkü, M. A. (2016). On Physical Internet Logistics: Modeling the Impact of Consolidation on Transportation and Inventory Costs. *IEEE Transactions on Automation Science and Engineering*, *13*(4), 1517–1527. https://doi.org/10.1109/TASE.2016.2590823

Ward, D. (2001). Stakeholder involvement in transport planning: Participation and power. *Impact Assessment and Project Appraisal*, *19*(2), 119–130. https://doi.org/10.3152/147154601781767131

Zhou, L., Chong, A. Y. L., & Ngai, E. W. T. (2015). Supply chain management in the era of the internet of things. *International Journal of Production Economics*, *159*, 1–3. https://doi.org/10.1016/J.IJPE.2014.11.014