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1 Introduction

The aim of this report is to provide an overview of logistics changes in Danube ports triggered by the Physical Internet concept. At the beginning of the report, an introduction to the concept of Physical Internet will be provided, including a definition of the concept and its impact on logistics in general as well as on ports. Afterwards the implementation of the Physical Internet in Danube ports will be discussed based on the results of a survey conducted in Austrian Danube ports. Recommendations for other Danube inland ports will be derived from the results of the survey. Also the implications for Human Resources in Danube ports will be discussed. At the end of the reports, best practice examples will be presented followed by a conclusion of the whole report.

2 Background

2.1 Introduction to the concept of the Physical Internet

Since transport is expected to triple by 2050, Europe needs to adequately accommodate transport flows on the different available transport modes (OECD/ITF 2017). A big part of Europe lacks inland waterways and in most cases goods are transport by rail or truck. In fact, in Europe around 75% of goods are transported by truck, followed by rail (~17%) and inland waterways (~6%).[1] As a consequence, European transport chains often lack sufficient capacity because infrastructure has already reached its maximum capacity. This is also in accordance with the current traffic jam situation in Europe: in Belgium for example 51 hours are wasted in traffic jams and 41 hours in the Netherlands.[2] The topic of sustainability and therefore the optimal use of existing transport resources is increasingly important for freight transport to guarantee sustainable, efficient and cheap transport for the future. This is also recognized by the European Commission, which aims to shift freight transport to sustainable transport modes such as inland waterways or rail (European Commission 2011). To facilitate this desired modal shift, different transport concepts have evolved during the last years and set the path for sustainable freight transport in Europe:

The usage of different transport modes to bundle the strengths of each transport mode is the idea of multimodality. Intermodality facilities the use of different transport modes by shipping products in the same transport unit and therefore lower the handling costs. To use the transport mode best suitable for the different transport routes (depending e.g. on the product) is the idea of co-modality. Synchromodality combines the best aspects of the previous concepts – standardized transport units over all transport modes, bundle strengths of different transport modes, avoid unimodal transport- by adding real-time data to guarantee the most efficient transport. [3] The concept of synchromodality can also be seen as a first steps towards the Physical Internet, which was first introduced by the Canadian professor Benoit Montreuil. The development steps and the main characteristics of the different transport concepts towards the Physical Internet are also summarized in Figure 1. As illustrated, the

[1] URL: https://ec.europa.eu/eurostat/statistics-explained/index.php/Freight_transport_statistics_-_modal_split [05.09.2018]
[2] URL: http://inrix.com/press-releases/scorecard-report-united-kingdom/ [05.09.2018]
[3] based on project report "SynChain" (2015) – for further information please contact Sarah.Pfoser@fh-steyr.at

different concepts aim to use existing transport resources more efficiently in order to avoid inefficiencies which may lead to negative environmental impacts and higher costs.

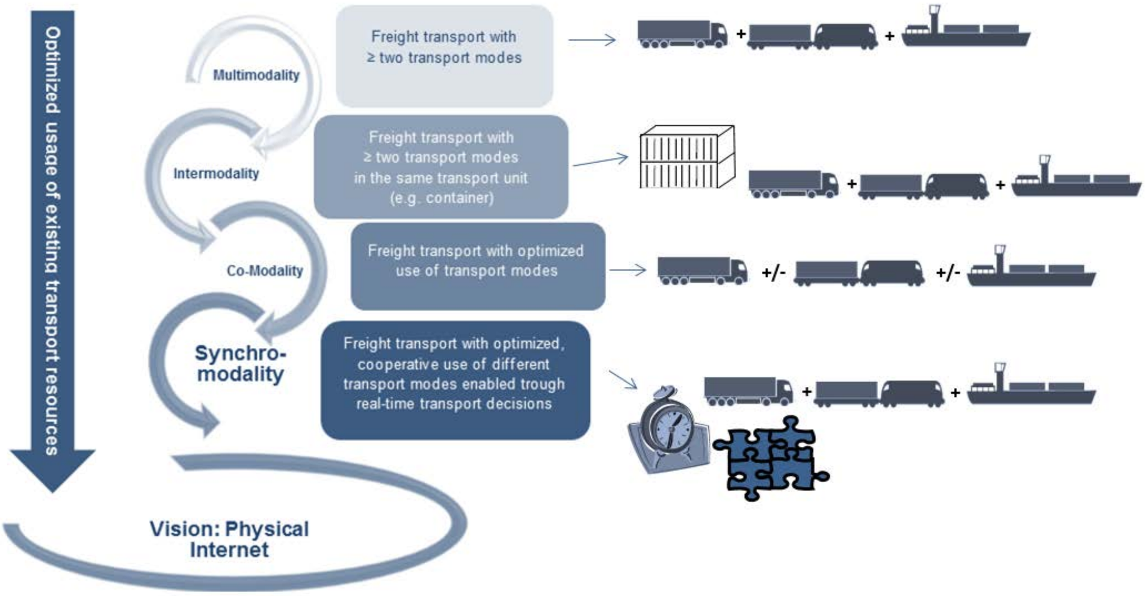


Figure 1- innovative transport concepts[4]

„The Physical Internet is an open global logistics system founded on physical, digital and operational interconnectivity through encapsulation, interfaces and protocols. It enables an efficient, sustainable, adaptable and resilient Logistic Web" (Montreuil et al. 2012)
The main idea of the Physical Internet is that shipments (e.g. a parcel) are transported anonymously and that the shipment is organized on its own through a constant data exchange between involved stakeholders. The concept can be compared with the approach of sending an email: when sending an email, the sender does not know which providers or servers are used while the email is sent to the recipient. The sender relies on the Internet, which securely sends the email to the intended recipient (REWWay 2016).

2.2 Drivers and Barriers for the Physical Internet

In the following the main drivers and barriers for the Physical Internet are described:

Drivers:
Various drivers can be identified which encourage the development of the Physical Internet: Currently, means of transport such as trucks are not fully loaded in most cases and also packing material accounts for a lot of space in current transport. Thus, means of transport could be loaded more efficiently and empty runs should be reduced. Also the working conditions in the transport sector could be increased. For example truck drivers are on the road for a long time and can't spend a lot of time at home. This leads to tensions in their family and social life but also affects their health.

[4] own illustration, based on project report "SynChain" (2015) – for further information please contact Sarah.Pfoser@fh-steyr.at

In addition, products are often not stored at the places where they are consumed leading to high inventory costs (at the wrong places) and long delivery times. As a consequence production and storage facilities are currently not efficiently used. In addition, a high percentage of produced products is not used/consumed at all (e.g. in the food industry). Due to globalization products can be ordered from almost every country which leads to an increasing transport distance. Thus, efficient transshipment and a combination of different transport modes (multimodal transport) is required to coordinate these transport flows. Currently multimodal transport still needs a lot of coordination and is connected with handling costs for transshipments. In addition, trends such as urbanization and the increasing importance of sustainability have to be respected in multimodal transport.
At the moment existing transport networks still lack security and robustness which makes collaboration between different stakeholders of the supply chain even more difficult because of the lack of trust in collaboration (REWWay 2016).

Potential barriers:
The Physical Internet is still a new area of operation for most companies and therefore connected with uncertainty. Therefore, a mind shift is necessary to encourage the integration of the Physical Internet in companies. One main aspect of the Physical Internet is the idea of sharing – sharing assets such as trucks and warehouses which means less property and as a consequence less control for one company. Sharing information about customers, shipping routes and markets which can be seen as most valuable assets of a company in some cases should also be shared in the Physical Internet. It is not surprising that a lot of companies have the fear to lose their market advantage and are not very open minded for this concept.
Another fact is that the idea is to have a network instead of one-to-one agreements between few actors in the supply chain. Furthermore at the moment products and containers are not standard/modular which makes transshipment complicated and bundling effects are difficult to realize. In summary, especially the needed mind shift and therefore building of mutual trust is needed in many cases to guarantee the success of the physical internet (REWWay 2016).

2.3 Fundaments of the Physical Internet

The Canadian professor Benoit Montreuil can be seen as the pioneer in the field of the Physical Internet. He names the main elements which form the foundation of the Physical Internet. In the following these thirteen elements can be summarized as follows (Montreuil 2011):
Standardized containers, parcels, warehouses and turnover points need to be installed to guarantee a barrier-free and seamless transport in the Physical Internet. By installing a standardized infrastructure also processes such as transshipment can be standardized in a broader sense and may minimize the risk of discrepancies. These standardized transport units and processes lead to a reliable and resilient smart network in which the units (e.g. a parcel or a warehouse) communicate almost independently. This smart network should be open for all supply chain stakeholders and on a global level. In total, this makes simplification and standardization possible, since transport units choose the best transport route on their own and interact with other transport units and stations. This makes a human interaction almost unnecessary (e.g. planning transhipments from one transport mode to another).

These fundaments are also shown in Figure 2. As already mentioned in the beginning of the report, sustainability has become a very important topic in nowadays society and thus is also affecting freight transport. The environmental pollution caused by production and transport processes worldwide should be reduced in order to meet our own demands for long-term sustainability. Above all, the social aspect concerns the difficult working conditions in the course of fulfilling logistical tasks. The Physical Internet creates a scenario in which the three perspectives of sustainability (social, economy, ecology) are respected and improved. In the next layer the importance of standardized physical objects is described. Standardized containers can be moved, stored etc. in the Physical Internet. All these processes are realized and linked in a logistics web – similar to the Internet. Based on a global universal interconnectivity all elements are connected and are able to communicate (e.g. a parcel can communicate independently with infrastructure and transport modes). By using standardized protocols and interfaces processes can also be standardized and can be organized more efficiently e.g. in terms of time and costs. However, the concept of the Physical Internet is still very new and not well known by all stakeholders. Thus, innovations in technology, business models and infrastructure are necessary to implement all the necessary preconditions for a functioning Physical Internet (Montreuil et al. 2012).

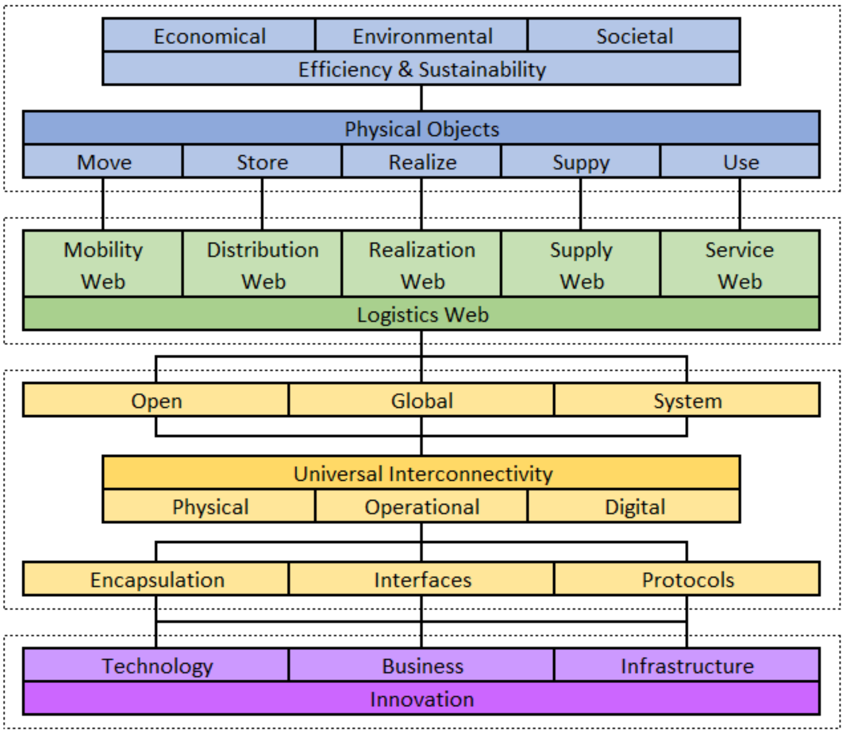


Figure 2 - Fundaments of the Physical Internet (Montreuil et al. 2012)

The connection between the different stakeholders, the infrastructure and the different transport modes is essential for the Physical Internet and leads to a comprehensive interconnectivity in freight transport. Sharing all relevant information and to guarantee that the data is up to date in a real-time manner is crucial for the concept of the Physical Internet. Furthermore, innovations in connection with new business models are necessary to define the collaboration between the different stakeholders involved (Montreuil 2011).

2.4 Role of ports in the Physical Internet

Ports play a crucial role as regulators of freight flows in supply chains (Rodrigue et al. 2010). Especially seaports are key parts in international supply chains, facilitating international trade of goods and thus challenging hinterland transportation (Montwiłł 2014). This can also be lead back to the increasing capacity of container vessels arriving in European seaports. In fact, the capacity of container vessels has more than doubled since 1996 (van Hassel et al. 2016). Seaports are confronted with peaks and bottlenecks which are also transferred to inland ports as they play an important role in the hinterland transport of seaports (Brümmerstedt et al. 2017). By applying the concept of synchromodality – as a first step towards the Physical Internet - peaks and bottlenecks in ports may be tackled by an efficient use of existing capacities (Brümmerstedt et al. 2017). In research, the main focus has been on increasing the efficiency of logistics processes in seaports rather than in inland ports. However, the importance of inland ports as crucial hinterland connections is increasingly respected in recent years. Especially inland ports located in the hinterland of seaports are increasingly respected in research (Wiegmans et al. 2015). In the past years, inland ports have evolved to broad logistics zones offering traditional port functions such as transshipment but also other logistical services such as container-repair services (Notteboom and Rodrigue 2007). Increasing transport volumes from seaports cause challenges in inland ports in terms of limited capacity and quality of logistical services (Visser et al. 2007). On European level, inland ports in – especially in Eastern Europe – lack adequate infrastructure to hamper the efficient handling of cargo (Witte et al. 2014; European Commission 2013). In order to guarantee the competitiveness of inland ports, logistical processes have to be organized more efficiently (Caris et al. 2014). The concepts of synchromodality and the Physical Internet represent measures which could counteract the current bottlenecks in inland ports by organizing transport flows more efficiently (Tavasszy et al. 2015).

Trends such as Industry 4.0, smart production or self-driving trucks are buzzwords which are currently well known in the transport industry. Thus, these trends are also affecting the port industry. The Port 4.0 can be seen as the next evolution in shipping. The port 4.0 represents the fifth development step in the development steps of ports. According to Lee and Lam (2016) the five stages of the port development are structured as follows:

- Level 1: pure cargo port
- Level 2: logistics port including warehouse services
- Level 3: SCM port with bilateral information flows
- Level 4: globalized SCM Port
- Level 5: customer-centric port platform

Depending on the size of the port, inland ports are now usually at Level 3, where systems and processes are coordinated with each other as part of digitization. In addition, a mutual exchange of information between customers and the port administration already takes place at this stage. At Level 4, the extent of the exchange of information with port infrastructure users and with hauliers is even more advanced, but the focus of the port is mainly on its own optimization and profitability. The fifth stage, which is expected to develop in the near future, puts the interests of the community in the foreground in order to make the port part of a seamless transport chain. The optimum satisfaction of the customer's wishes and the achievement of a total optimum are the main drivers on this level.

As can be seen in Figure 3 the economic value creation (y-axis) is expected to increase from one level to the other. However, also the complexity (x-axis) in ports and port processes increases on the different levels. Due to an increasing number of market players, the market on which a port operates is becoming larger. Simultaneously competitive pressure is also increasing. Due to an increased number of stakeholders also the complexity of day-to-day processes increases. The handling of higher volumes requires the support of the authorities in order to be able to comply with geographical and local restrictions. Complex supply chains also require higher security standards and better protection of the entire network. Since port activities are linked with negative external effects on the environment, the aspect of sustainability has to be respected in the different development levels. Due to complex supply chains, disruptions such as strikes or accidents have a higher impact on operations. Thus, ports should become resilient systems, able to efficiently react to disruptions (Gutenbrunner 2018).

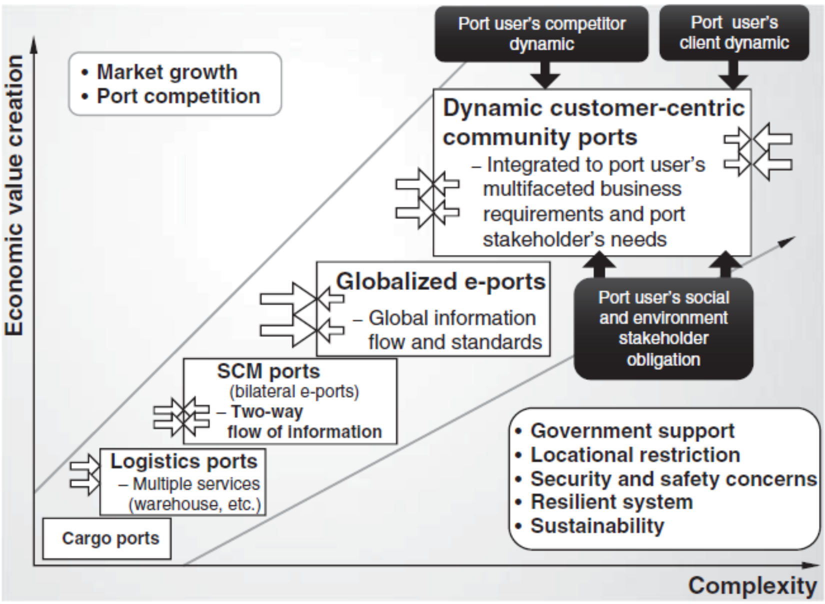


Figure 3 - Development process of ports (Lee and Lam 2016)

2.5 Inland Ports and the Physical Internet

In order to realize the vision of the Physical Internet in inland navigation on the long-term infrastructural and technical measures are necessary. In addition, transport has to be organized in a different way (e.g. no transport modes are defined by shipper). Inland ports, as modern multimodal logistics hubs, can be seen as information and aggregation hubs in a transport network. Due to the longer transport times of inland navigation compared to other transport modes such as road, inland waterway transports should be planned very well to avoid delays. Due to this preconditions, mainly raw materials and bulk cargo, cargo for which time is not a critical factor in most cases compared to last-mile logistics for example, are transported on inland waterways. The Danube has a beneficial location in Europe, connecting 10 countries and thus economic areas of importance. In addition, the connection

via the Rhine-Main corridor to five other European countries emphasize on the importance of the Danube as a transport axis on national and international level.
The trend of digitalization can be seen as an opportunity for inland ports to position themselves as important information and logistical hubs in the European freight transport sector. This can also lead the way to implement the concepts of synchromodality and the Physical Internet in inland ports. The following aspects may be seen as critical success factors in order to implement the Physical Internet in inland ports and thus also for Danube inland ports:

- Adequate infrastructure for seamless and efficient transshipment
- Efficient hinterland connections for inland ports
- Real-time communication between all inland ports and other relevant transshipment sites
- Time and cost truth of transport processes and communication to customers and other relevant stakeholders
- Seamless integration of inland navigation in national and international transport
- International expansion and maintenance of transport infrastructure
- Political promotion of ship transport by inland waterway
- Standardized technical equipment and networking of port infrastructure, superstructure, traffic routes, carriers and means of transport

3 Implementing the Concept of Physical Internet in Danube ports

This chapter contains the results of a survey conducted in Austrian ports in terms of a Master Thesis is presented, to discuss the potential integration of the Physical Internet in Danube inland ports. Expert interviews were conducted in three Austrian ports and in five companies located at Austrian ports, which can be identified as port users. An interview guideline was developed, based on the main success factors required to implement the concept of the Physical Internet in Austrian Danube ports. Since the concept of synchromodality can be named as the first step towards the Physical Internet, the main success factors of synchromodality were used as a basis for the developed interview guideline. This chapter is structured as followed: first the critical success factors for the concept of synchromodality – and thus also the Physical Internet – are described. Afterwards, the main results of the expert interviews are presented. At the end of the chapter, a conclusion includes some learnings for other Danube inland ports.

3.1 Critical Success Factors for Synchromodality in Danube inland ports

The successful implementation of synchromodality depends on the following seven critical success factors (Pfoser et al. 2016; Putz et al. 2015): (1) awareness/mental shift, (2) network/cooperation/trust, (3) ICT/ITS technologies, (4) physical infrastructure, (5) sophisticated planning, (6) legal/political framework and (7) pricing/cost/service (Pfoser et al., 2016). Only the first four out of these seven critical success factors were included in detail in the conducted study. The critical success factors legal/political framework, sophisticated planning and pricing/cost/service are neglected within the study since legal/political framework refers to external conditions which cannot be directly influenced by stakeholders involved in this study (port authorities and companies). Sophisticated planning can be seen as an element of the critical success factor ICT, facilitating a proper function and optimized decisions (Le et al. 2017). The success factor pricing/cost/service is regarded as an enabler for network/cooperation/trust in our study because it can be seen as a determinant for achieving network/cooperation/trust (Ramaekers et al. 2017). In the following table the four success factors included in the study are described in more detail.

Success Factor	Description
Awareness/Mental shift	The stakeholders' expectations and perceptions of sustainable transport and innovative transport concepts represent a fundamental requirement to realize a modal shift (Pleszko 2012; Putz et al. 2018). Since some basic changes in the current organization of transport, such as the a-modal booking of transport services (no transport mode is defined by the shipper) is required in the concept of synchromodality, a mental shift is needed (Tavasszy et al. 2015).
Network/Cooperation/Trust	A synchromodal network and thus also the Physical Internet is a complex sociotechnical system since various stakeholders with different relationships are included (Kurapati et al. 2017). Data sharing, privacy and data ownership are very important topics which have to be respected in such sociotechnical systems (Singh et al. 2016). Thus, One cooperation and trust between the stakeholders involved is a crucial element of the Physcial Internet (Pfoser et al. 2016).
ICT/ITS technologies	Real-time data are essential to respond accordingly to unexpected situations (e.g. strike) in a synchromodal transport network (Singh and van Sinderen 2015). ICT and ITS technologies are able to use the provided real-time data to optimize the transport planning. This may include tracking and tracing of containers, monitoring environment data as well as information and communication sharing between different stakeholders involved in the synchromodal network (Guo et al. 2017).
•Physical Infrastructure.	One main prerequisite in the synchromodal transport network is that capable transport infrastructures exist to carry out transport services and that the use of different transport modes – multimodal transport – is possible. Stationary resources (i.e. roads, rails or inland waterways and transshipment nodes such as inland ports) are connected with moving resources (i.e. trucks, trains, barges, etc.) (Behdani et al. 2016)

Table 1 - Critical success factors for synchromodality/Physical Internet in Danube inland ports

3.2 Status Quo of the Physical Internet in Austria

In the following table, the results from expert interviews conducted in Austria are summarized based on the same structure as in the previous chapter.

3.2.1 Awareness/Mental Shift

In this category interviewees were asked whether they are aware of the concepts Physical Internet or synchromodality. Five interviewees had no information about synchromodality or the Physical Internet. They were explained in detail the concept of the Physical Internet, which conditions must be fulfilled and why the logistics should be further developed economically, socially and sustainably. Of those three who were already about the concept Physical Internet, two were from inland ports. Above all, the interview partners mentioned on the subject of Physical Internet that all processes, from production logistics or the transport sector, are linked with each other and that there is complete transparency along the value-added stages. Concerns about networking have been mentioned by interviewees regarding data protection and economic competition. It was difficult for the interviewees to imagine that in a network with open infrastructures and shared information, companies are still operating cost-efficient.

In the context of transporting standardized containers, respondents indicated that the Danube is used only for the transport of empty containers and that only 10% to 15% of the container volume could be handled by the waterways. The rail links north to the ARA ports (ARA is an abbreviation for the three seaports of Antwerp, Rotterdam and Amsterdam) and south to Koper and Trieste are of great importance to both port operators and companies in connection with the Danube (Gutenbrunner 2018).

In summary, innovative transport concepts such as synchromodality and the Physical Internet do not play a major role in practice in Austrian Danube ports. All interviewees, regardless of whether they had previous knowledge or not, were very interested and would like to learn more and follow news about the trends of the Physical Internet. The willingness to deal with innovative transport concepts is given by all interviewees, from which a positive attitude to digital developments can be seen. In practice, however, few links to physical flows of goods and current business activities can be found (Gutenbrunner 2018).

3.2.2 Network/Cooperation/Trust

The question concerning the cooperative use of infrastructures was difficult to answer for most of the interviewees. Most interviewees though that this would mean to lease their current infrastructure. One interviewee mentioned, that if infrastructure was open and used on a shared basis, a new business model would have to be established. However, interviewees agreed that sharing infrastructure would make more sense than sharing technical equipment such as cranes. In terms of infrastructure, all companies and inland ports in Austria are well equipped. Transports on the three modes road, rail and waterway can be performed by all ports included in the study, either with their own facilities or in conjunction with partner companies. However, the trend towards cooperative use of infrastructure and sharing own facilities with other market players has raised concerns about current business models. It may be said that interviewees are interested in market opportunities and new business models that may arise in the course of implementing the Physical Internet. But most interviewees follow a wait-and-see attitude (Gutenbrunner 2018).

In order for logistics concepts such as the Physical Internet and synchromodality to become reality, the legal and political framework must be adapted. When asking interviewees about necessary policy changes, an adaption of the competition policy was mentioned by almost all interviewees. It is feared that in the course of collaboration and data exchange, know-how and competitive advantages of companies will be lost. In addition, data protection – also outside business boundaries - have been mentioned. With regard to the political landscape, it was also indicated that necessary adaptations are unlikely to be initiated by politics, but that new business models will develop beforehand, which will then require the adaptation of the political landscape. For the majority of interviewees it became clear that with current competition rules it is not possible to act as a stand-alone company within a fully networked system as envisioned in the Physical Internet (Gutenbrunner 2018).

3.2.3 ICT/ITS technologies

Only two interviewees mentioned that their company has a digitalization strategy. The landscape of IT systems is very heterogeneous among the surveyed stakeholders. Especially for warehouse management and transport organization it has been mentioned that a separate software is used. Besides the implemented system, most interviewees mentioned that they have fixed interfaces to their most important business partners, so that data can be shared and exchanged automatically. In all operating companies, transport data are recorded and used for evaluations. Three interviewees also reported that data is automatically passed on to defined customers or business partners, making processes very transparent. Only few interviewees mentioned that data are analysed in terms of Big Data analysis. Data are only used for example for controlling purposes or other administrative purposes in most cases. During the interviews, interviewees mentioned that data protection is very important when exchanging standardized data. Thus, attention has to be paid to which information is passed on. In fact, IT security is recognized as very important by all interviewees. There is a consensus that information and sensitive data must be protected. The majority of respondents have very strict security policies to ensure IT security. Thus, in the Physical Internet, which is based on seamless networking and data exchange, IT security is an essential part that has to be guaranteed for all stakeholders involved. An interesting result is that no information is shared between the different ports included in this study (Gutenbrunner 2018).

With regard to the IT systems used, there are, on the one hand, very modern and up-to-date systems, and on the other hand also outdated systems which may hamper networking with other companies. Apart from that, data is collected, recorded and used by all stakeholders surveyed. IT security is taken very seriously! When implementing the Physical Internet, interviewees agree that in the future, more attention have to be paid to IT security. The implementation of interfaces that enable data exchange between old and new IT systems is essential for the Physical Internet, so that all stakeholders are included in the system. In addition, safety standards must ensure that the data is protected within the Physical Internet (Gutenbrunner 2018).

3.2.4 Physical Infrastructure

Within the category 'infrastructural measures' interview partners were asked about their current infra- and superstructure as well as planned investments. All three inland ports included in this research are trimodal hubs and are thus accessible via road, rail and inland waterways. In addition, the inland ports included in the study provide storage facilities and other value added services.
All but three interviewees mentioned that they are planning to invest either in storage facilities or in transport infrastructure in the near future. One interviewee mentioned that there is a strategy for extensions of infrastructure but the implementation is depending on the market situation. Three companies plan to invest in the development of rail transport infrastructure by building new tracks or improving existing tracks. The majority of respondents confirmed that the focus is on efficient handling of trucks and trains. The willingness of most interviewees to invest in infrastructures shows that the development of the necessary infrastructures for the Physical Internet will not be an obstacle to the establishment of a digital logistics network (Gutenbrunner 2018).

3.3 Recommendations for Danube Inland Ports

As can be seen in the last chapter, in Austria only few interview partners (three out of eight) are aware of the concept of the Physical Internet of synchromodality. We may assume that this situation is similar in other ports in the Danube region. However, inland ports in Germany such as Duisport may be more familiar with the concept of synchromodality and the Physical Internet. However, this result indicate that measures to raise awareness for the Physical Internet such as workshops would be a suitable approach to facilitate the realization of the concept in inland ports. This would also respect one of the main success factors for implanting the concept: Awareness/Mental Shift.

In terms of collaboration, it is interesting that stakeholders seem to hesitate sharing their information with other stakeholders but are willing to do so if suitable business models are applied. Thus, business models which are also respecting the collaboration between international stakeholders along the Danube could be identified as potential facilitators for the Physical Internet.

Since only a few interviewees mentioned that they defined a digitalization strategy, it may be possible to define a common digitalization strategy for inland ports along the Danube. This may facilitate the implementation of the Physical Internet, by implementing well considered measures to improve the overall digital infrastructure of all Danube inland ports. In addition, a shared platform should be installed which can be used by all inland ports involved to include national data from heterogeneous programs.

Concerning physical infrastructure, it was apparent that interview partners emphasize the importance of adequate hinterland connections and warehousing facilities. By focusing on investments in adequate hinterland connections on an international level it may be guaranteed that Danube inland ports are attractive transshipment points in the European transport system. Consequently, enough cargo is transshipped in ports making inland waterway transport more attractive.

Since the survey was only conducted in Austria, results from other inland ports located on the Danube may be interesting to identify similarities and differences.

3.4 Effect of PI on Human Resources in ports

Due to the implementation of innovative transport concepts such as the Physical Internet which may be connected with a lot of new technologies, current jobs at the port may change and also new jobs may develop. Based on Saxe and Jahn (2017) the following job profiles could be possible in ports in the future:

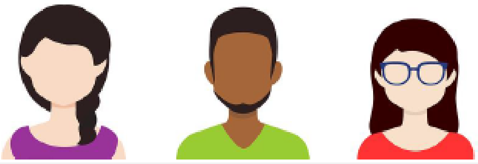
- Data scientist: responsible for analyzing the data gathered in ports in order to improve the ports efficiency.
- Shore-control-center operator: responsible for monitoring autonomous vessels and checking vessel's position and performance.
- Land based crew: monitor and maintain autonomous vessels from the port
- Multimodal traffic controller: optimizing the transport flows in ports by analyzing historic and real-time data.
- Port energy manager: monitoring the power consumption and production in ports and matching power supply and demand
- Officer in the Port Authority's nautical command center: responsible for the safety of vessels in port area. Besides information from radar systems also information from vehicle-to-vehicle/infrastructure communication is used to ensure safety in the port area.
- Port infrastructure manager: monitoring the mobile and stationary port infrastructure by using drones for on-sight investigations.

Even though these job profiles were elaborated for seaports, it is also possible that job profiles may change in inland ports as well. In fact, during a workshop organized within Activity 4.3 Human Resources Development of the DAPhNE project the changing working conditions for port employees in the future were discussed.
Among others, the topic of diversity (age, gender, ...) was discussed in the context of ports. Results suggest that new trends and developments not only influence the technology concepts, but also the human factor in ports. Discussions during a workshop session showed that social diversity in the working environment of people in the workplace is currently playing an important role and will continue to play a major role in the future. The following topics were discussed most frequently and can be named as major factors influencing the future of port employees also in the context of the Physical Internet:

- Education and training is an essential element in all areas → Education level must change (Qualifications will become more important in the future)
- Lifelong learning is important to be able to work with new technologies
- Working conditions change: more flexibility due to increasing technical infrastructure!

In addition, a potential new job profile was developed during the workshop (see Figure 4). The maintenance manager was described as a job position which is mainly influenced by the trend of digitalization. He/She is responsible for monitoring the performance of the port and the infrastructure. Due to a high level of digitalization, infrastructure is all connected to a system which can be monitored by using a table for example. Thus, the maintenance manger does not have to be at the port but can monitor the performance of all equipment and infrastructure in general 24/7 via a remote device (e.g. tablet, smartphone).

Human Resources in ports in the year 2040



FACTS

Name, age, gender, origin, job, family status, residence, commuter,...

Job: Maintenance Manager

- Male/Female
- Older (35 - 40 years)
- Married or divorced
- commuter
- Work-life balance important
- Fully networked (smartphone, tablet, etc.)
- Salary: Country dependent (about 75% of the CEO's salary) - but may change over time

BIOGRAPHY

Educational background, professional background, description of professional activity (e.g. working hours)

- Technical / commercial training (understanding of total cost of ownership / lifecycle of products)
- Flexible working hours (even home office possible), as fully networked and work with Virtual Reality glasses possible (remote diagnosis and contact with local staff)
- Salary: fixum about 70%, variable salary: 30%
- High availability (24/7 to be able to react even in case of emergency)
- Professional career: from technical job (for example crane manufacturer)
- Further education is mainly used in the area of social competence
- Tasks: Negotiate with suppliers (new purchases, for example) and conclude contracts

COMPETENCES/ SKILLS

Further training, language skills, etc.

- Technical / commercial know-how
- Languages (English / German / Chinese)
- Stress Resistant
- Social competence
- Assertiveness
- Love/Passion of technology
- Networking skills! (knows important people)

CHANCES & CHALLENGES

Trends, educational offers, further training possibilities, funding etc.

Chance:
Freedom of design in the job

Challenge:
Pressure → Keep shutdowns short, stay in the budget

Figure 4 - Persona "Maintenance Manager"

As a result of these changes, training needs to be adopted and also current logistics education should take the changing environment into account. This will also guarantee that people with required skills are available in the future. In addition, new job profiles as described above have to be disseminated to potential future port employees to make sure that students and professionals are aware of these job opportunities. Transnational workshops where stakeholders from different ports and companies are also a possible measure to guarantee exchange of know how.

3.5 Effect of PI on other markets

In the following chapter, a short overview of the effects of PI on the other innovative and new markets included in Act. 5.4 – industrial ecology and container market - is provided.

3.5.1 Industrial Ecology

The Physical Internet or the Internet of Things (IoT) can also be implemented in connection with industrial ecology. These two concepts are connected as the IoT can enhance the industrial ecology. One main aspect of the IoT is that physical devices are connected via sensors which collect and exchange data. With those sensors resources such as machines can be remotely monitored and thus also the capability and conditions. If an asset reaches the end of its life-cycle, IoT can aid the asset retrieval by big data analysis and facilitating recycling of components.
In this context, also the traditional value chain may be changed by implementing an IoT-enabled leasing model. Instead of selling an expensive machine (e.g. crane), manufacturers may lease them to their customers. By adding IoT-components, manufacturers can monitor the asset's condition and thereby dynamically repairing the machine at precise times. This will lead to an improvement of the quality of the machine. The same concept may also be applied to buildings – by adding IoT-components the buildings can be monitored facilitating the maintenance.

Even though IoT is connected with many advantages, there are currently numerous limitations. Due to legislation and regulations for new technologies, the governmental lags behind innovation. For example, in Brazil, China or Russia cross-border reverse supply-chains are blocked due to a lack of legal standards to distinguish re-manufactured products from used ones. Reverse supply chains also are influenced by current lack of demand, caused by low residual value of returned products. In addition the data collected by IoT technology itself, leads to major privacy concerns. The following questions arise: Who owns the data collected? How reliable are IoT systems? How vulnerable are technologies to hackers? However, the potential profits and increased sustainable performance predict a tremendous potential for IoT enhanced industrial ecology.[5]

3.5.2 Container

The Physical Internet may also be interesting in connection with the container market since standardized transport units (such as containers) can be defined as a key element of the Physical Internet. The requirements for transport containers within the Physical Internet are manifold. As they are the central units of transport, they have to meet various and sometimes contradictory requirements: transport units should be modular, robust, sustainable to manufacture and use. In addition, international standards and guidelines have be taken into account in order to guarantee acceptance by the market. For example: the most important container types in shipping (20-foot containers, 40-foot containers) are ISO certified, even though different types exist for different types of applications (dry containers, reefer

[5] https://www.greenbiz.com/article/where-circular-economy-meets-internet-things [15.10.2018]

containers, open top containers, flat rack containers). Since the Physical Internet strives for an optimal utilization of the transport capacity the requirements for a standardized container are high. Within the project ATROPINE (Fast track to the Physical Internet) current initatives and examples were identified for the Physical Internet container. The existing solutions aim to optimize the needs of the industry, whereby existing standards (e.g. ISO) are met. The following examples were identified in the project:[6]

- **Joint Modular Intermodal Container[7]**
  The aim of the Joint Modular Intermodal Container is to better use the capacity of 20 and 40 foot containers. It was developed by the US Defense Standardization Department. The containers can be equipped with RFID tags and can be linked to guarantee safe transport.

- **Tworty Box[8]**
  The Tworty Box is a 20-foot ISO container which can be combined with a Tworty Box to form a 40-foot ISO container (Twenty + Forty = Tworty). The aim is to make container logistics for shipping companies more efficient, cost-effective and sustainable by reducing the number of empty container transports in worldwide maritime traffic. Container lines can compensate for an over- and under-allocation of 20-foot and 40-foot containers in ports and hubs by merging or decoupling two Tworty Boxes.

- **CHEP[9]**
  Chep can be named as one of the world's leading suppliers of pallet and container pooling, who also invented the quarter-pallet. The Chep four-way pallet can be picked up and transported from all side and can be stored in a space-saving manner. The latest generation of the Chep quarter pallet extends the functionality with some innovative improvements such as displays which can be securely and quickly attached to the pallet and is lighter than the previous model.

- **Cargoshell[10]**
  Cargoshell developed a collapsible composite container. It weighs a quarter less than a standard container since fibreglass material is used. If the container is transported empty and folded, it requires only a quarter of the space of a conventional container. Thus, more empty containers can be loaded onto ships for transport for example. The containers are more corrosion-resistant than steel, easier to clean and more environmentally friendly to manufacture. The container can be unfolded and folded in 30 seconds by one person using a forklift truck.

- **MODULUSHCA**

[6] mid-term report of ATROPINE project. For further information please contact Oliver.Schauer@fh-steyr.at
[7] http://www.garrettcontainer.com/jmic [15.10.2018]
[8] http://www.tworty.com/ [15.10.2018]
[9] https://www.chep.com/ [15.10.2018]
[10] http://www.cargoshell.com/ [15.10.2018]

Within the three-year research project called MODULUSHCA, a standardized modular container unit for (co-)modal material flows in the Fast Moving Consumer Goods (FMCG) market was developed. These units aimed to support the implementation of a network logistics system in order to significantly increase the overall efficiency. Within the project an interconnected logistics network for the FMCG market should be implemented using modular container units which are connected with each other. In addition, a platform to facilitate organizing logistics processes aiming to reduce costs and CO2 emissions should be implemented. Finally, within two pilot actions the concept should be demonstrated. A big challenge when developing the modular transport containers was to meet more than 30 different criteria: recyclable, leak-proof, stackable, collapsible, uniform labelling, low CO2 consumption in the production process, etc. The modular transport containers should also to be ISO-certified. In addition, they should be ISO standardized, as they must be combined in different sizes according to requirements and fit into all means of transport.[11]

4 Best practice examples

In inland navigation, especially in the Netherlands, the concept of synchromodality in form of pilots is used. This is because of the Netherlands' core competence, as leading nation in transshipment and handling of goods, their know-how in logistics and their pioneer spirit. In addition, the Netherlands offers the infrastructural (extensive waterway network) and economic (volume to be transported) prerequisites in inland navigation for the success of this concept. For example, a trip in the Rotterdam-Tilburg corridor in 2011 could be due to a modal shift to the waterway. Until the end of the pilot, there was a better modal split value than announced. The inland vessel had with a share of 46 % the main part of the modal split; the train had a share of 35 %; the truck had the smallest share of modal split with 19 %.[12]

Concepts such as the Physical Internet are also finding their way into inland shipping in the form of various pioneers such as "smartPORT Logistics" in the port of Hamburg. The aim is to optimize the land-based transport because of the limited capacity by connecting the transport with the goods and thus optimally coordinating transport processes. With the help of a cloud-based platform, which was provided by SAP, the different actors can exchange the relevant information and thus optimally plan the transports. By tracking truck movements using GPS, alternative routes can be proposed in the port to avoid long waiting times. Departures and exits are also controlled to make the transports and transshipment processes as efficient as possible.[13]

This shows that the trend of innovative transport concepts is also particularly relevant for inland shipping. New decision-making processes or the exclusion of the individual

[11] www.modulushca.eu [15.10.2018]
[12] Rossi, 2012, S. 13
[13] Hamburg Port Authority, 2013, s. 13ff

preferences of decision-makers can overcome current prejudices and strengthen the position of inland navigation as alternative means of transport. Ports can serve as particularly relevant transshipment points in future transport networks, allowing to realize bundling effects, which in turn are of benefit to inland waterway transport. In addition, inland waterway transport still offers sufficient spare capacity to meet this increasing demand. Data exchange will play a decisive role in the future. Here, too, existing inland shipping systems such as DoRIS (Danube River Information System) can be integrated into a larger network in order to exploit further potential for improvement.

In the following, best practice examples of initiatives and aspirations of different big European ports are presented. In particular, the ports of Hamburg, Rotterdam, Antwerp and Duisburg are considered.

4.1 Hamburg

With a handling volume (2017) of 136.5 million tons of cargo, including aro und 8.8 million TEU, the Port of Hamburg is the third largest container port in Europe.[14] The HPA (Hamburg Port Authority) strives to make the port processes as efficient as possible through intelligent control systems and the interaction of sensor technology, analysis, forecasting and information systems. Under the banner of "smartPORT - the intelligent harbor", HPA tries to provide the best possible support for the planning and execution of the port processes through digitalization and collaboration.

The goal of the „smartPORT" is to optimize land transport due to the limited road capacity, by interlinking traffic and freight and therefore know when a container needs to be moved. A cloud-based IT platform, provided by SAP, is used to link all the transport and logistic partners and to share all the relevant information about e.g. specific route sections. By monitoring the movements of trucks via GPS, alternative routes can be recommended in real-time and help to avoid waiting times and stress because of traffic jams. Furthermore, a control instrument points the way within and outside the port area while simultaneously considering current traffic movements. There are also apps for truck drivers to simplify the communication with other parties like the transmitting of freight documents.15

smart-Port – the intelligent port, is a state of the arte port model. The smartPort guarantees a smooth and efficient operation. The systems fort the control of the port, which are used by the Hamburg Port Authority (HPA) are world-leading. The port of Hamburg is Germany's biggest seaport.16 "In terms of TEU throughput, the port of Hamburg is the second-busiest

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[14] www.statista.com [09.10.2018]
[15]URL: http://www.hamburg-port-authority.de/en/press/Brochures-and-publications/Documents/HPA_AnnualReport_image2012.pdf p.13-15 [22.03.2018]
[16]URL: https://www.hafen-hamburg.de/en/ [22.03.2018]

port in Europe, after the port of Rotterdam, and also under the 15th-largest ports worldwide. 2017, 8.8 million TEUs (20-foot standard container equivalents) were handled in the port area of Hamburg. Overall the port of Hamburg covers an area of 73.99 km^2 (64.80 km^2 usable), of which 43.31 km^2 (34.12 km^2) are land areas. The natural advantages of the Port location that the branching of the Elbe creates an ideal place for a port complex with warehousing and transshipment facilities."[17] "The port of Hamburg handles around 9,000 ship calls per year, almost 300 berths and a total of 43 kilometers of quay for seagoing vessels, more than 2,300 freight trains per week, four state-of-the-art container terminals, three cruise terminals and around 50 facilities specialized in handling roro and breakbulk and all kinds of bulk cargoes, along with about 7,300 logistics companies within the city limits – these are just a few of the factors making the Port of Hamburg to one of the world's most flexible, high-performance universal ports."[18]

The port of Hamburg is one of the most busiest ports in Europe and is facing a still increasing freight volume which will be transhipped in the port. For 2025 the Hamburg Port Authority expects that in total 296 million tons of cargo will be handled in the port of Hamburg. This leads to the need to expand the handling capacity of the port. Since space is limited in the port area an increase in productivity is needed to be able to handle the volumes. In addition, the environmental impact in terms of negative externalities (e.g. CO2-emissions, pollution) caused by port activities should be minimized as well in the future. In 2012, the Hamburg Port Authority issued a strategic and operational plan including all current and future projects which should help reach this goal. This plan also included various measures which helped to facilitate realizing the smartport Hamburg. However, the work on the smartport already started in 2011 (e.g. installing new infrastructure such as sensors).

In order to develop the smartport, the Hamburg Port Authority has collaborated with various stakeholders from different industries. Public and private partnerships were important to realize the project. The smartport development also ran in parallel with the digitalization of the city of Hamburg which was moving towards a smart city model. Thus, there was the support of the public area, which was interested in transforming the port of Hamburg – which is located in the city centre – in the smart city concept. In addition, partnerships with private companies such as technology providers such as Cisco or SAP were necessary to develop the technological infrastructure.

The Hamburg Port Authority also had some hurdles to overcome during the development process of the smartport:

- different technologies were used the different actors in the logistical chain leading to disparities in data types, equipment and operating systems.
- companies feared to share there information with other stakeholders (especially competitors).

[17]URL: https://en.wikipedia.org/wiki/Port_of_Hamburg [22.03.2018]
[18]URL: https://www.hafen-hamburg.de/en/ [22.03.2018]

- business processes had to be reengineered due to the use of new technology. Thus, change management was needed to show the stakeholders the benefit of the change and teach them how to use new systems. [19]

4.2 Antwerpen

The port of Antwerp handled a volume of 223 million tonnes of cargo in 2017, of which are about 10.5 million TEU (Standardcontainer / twenty feet equivalent unit).[20] This makes the port of Antwerp Europe's second largest port, measured by container throughput. About 91.5 million tonnes of cargo are loaded on inland vessels for onward transport. In cooperation with public and private partners, an attempt is being made to develop new solutions for the expansion of inland waterway transport.[21]

Barge Traffic System

With the Barge Traffic System, for example, the Port of Antwerp provides a service specifically for container barges. The system can be used to book and monitor online time slots for loading / unloading barges. This facilitates planning for both the terminal operator and the inland waterway operator. This service is integrated in "C-point", which is a superior network in the port of Antwerp, where other information systems converge.[22]

C-Point

C-point is a platform that aims for efficient, digital communication among all players at the port surrounding that supports and streamlines administrative and operational activities. The goal is to avoid errors and reduce transaction costs while increasing productivity and efficiency through end-to-end digitization.[23]

Smart Port

In the course of "smart port", current technology trends in the harbor environment are tested. Various pilot projects have been launched, such as the development of an intelligent quay wall, which is equipped with cameras and sensors which reports directly online; the development of automatic image recognition via a camera or the creation of a digital twin of the Port of Antwerp. Since the end of 2017, the Port of Antwerp has also been involved in the subject of blockchain and is trying to collect port use cases together with software company T-Mining. The focus is primarily on container-related processes such as the safe and efficient release of containers or phytosanitary certificates of apples from New Zealand.[24]

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[19] URL: http://transport.sia-partners.com/20160930/internet-things-transportation-port-hamburg-case-study [30.03.2018]
[20] www.statista.com [09.10.2018]
[21] www.portofantwerp.com [09.10.2018]
[22] www.portofantwerp.com [09.10.2018]
[23] www.c-point.be [09.10.2018]
[24] www.portofantwerp.com [09.10.2018]

NxtPort

NxtPort is a data exchange platform that collects and consolidates data from different stages of the supply chain of the Port of Antwerp. The platform enables better data sharing, which in turn leads to greater transparency, efficiency and easier interoperability between existing platforms.

NxtPort's main objective is to unlock the potential of sharing existing data among the port's stakeholders. The NxtPort platform enables faster, cheaper and more efficient data transfers between different actors. The platform also allows for more transparency throughout the shipping process. NxtPort aims to increase operational efficiency, safety and revenue. A second way to unlock the value is to build market applications on the existing data. In this way, the data currently available in the port will not only be shared in a better way, but also the combination of already existing data will lead to innovative solutions. They should create new businesses and new revenue streams for the port community and its individual stakeholders.[25]

All those initiatives and projects are targeting a more collaborative and efficient communication between actors in the port supply chain. Regarding the physical internet roadmap of ALICE the described initiatives and projects can be related to "IS for interconnected logistics" and "Global Supply Network Coordination and Collaboration" as parts of the overall vision of PI.

4.3 Rotterdam

The port of Rotterdam is the largest port in Europe, measured by container handling. In Rotterdam, 13.7 million TEU were handled in 2017.[26] From Rotterdam, the modal share of inland navigation is about 50 % of total freight transport to the European hinterland. For example, between Rotterdam and Duisburg there are six push convoys with a total load of 16,000 tonnes of coal and iron ore each day. The port of Rotterdam is trying to generate products and services through digitization, thereby increasing efficiency and reliability in the logistics chain. Cooperation with customers, partners and various digital platforms plays an important role in this.[27]

Pronto

For each port call, many different operations must be performed at the right time. The exchange of planned, expected and realized times enables more efficient planning and handling of the entire port call. Pronto is an application that allows shipping companies, agents, terminals and other service providers to optimally plan, execute and monitor all

[25] www.nxtport.eu [09.10.2018]
[26] www.statista.com [09.10.2018]
[27] www.portofrotterdam.com [09.10.2018]

activities during a port call based on standardized data exchange. This will allow vessels in the port to save up to 20 % of the waiting time.

The Port of Rotterdam provides with Pronto a common platform for the information exchange related to the Port Call. The platform combines public information, information from participating companies and forecasts from artificial intelligence applications to generate a set of highly accurate information. However, no information about freighted goods is shared. The process progress and the status of events are continuously updated in a dashboard. This allows users to monitor the current status of each process (Container gate-in, Container release, etc.) and, if necessary, intervene. The use of API's, allows users to connect their own systems to Pronto. Once the Estimated Time of Arrival (ETA) becomes known each ship gets its own timeline, which shows all the events or activities during the port call.[28]

Figure 5: Pronto (Copyright Port of Rotterdam)

The advantages that can be generated by a shared use of this platform include shorter port call turnaround times, better predictability, lower emissions or lower bunker and charter costs. Terminals can thus better utilize their capacities and reduce waiting times.

BlockLab

The port of Rotterdam tries to make the exchange of information as safe and as efficient as possible. In addition to the use of artificial intelligence, the port participates in a field trial for

[28] www.portofrotterdam.com [09.10.2018]

Blockchain in logistics (BlockLab). Blockchain solutions for the logistics and energy sector are to be developed and tested.[29]

Mobile OCR

The Port of Rotterdam Authority has also invested in a monitoring system for container transport by road. Currently, the Barge Terminal Tilburg and Certus Port Automation companies are working on a system for the visual, precise identification of trucks and containers in the inland container terminal. Each truck that enters or leaves the terminal is gathered by a portal and scanned for the truck's registration number and container number. This should give shippers and terminal operators the opportunity to monitor container status more transparently and efficiently and plan it more precisely.[30]

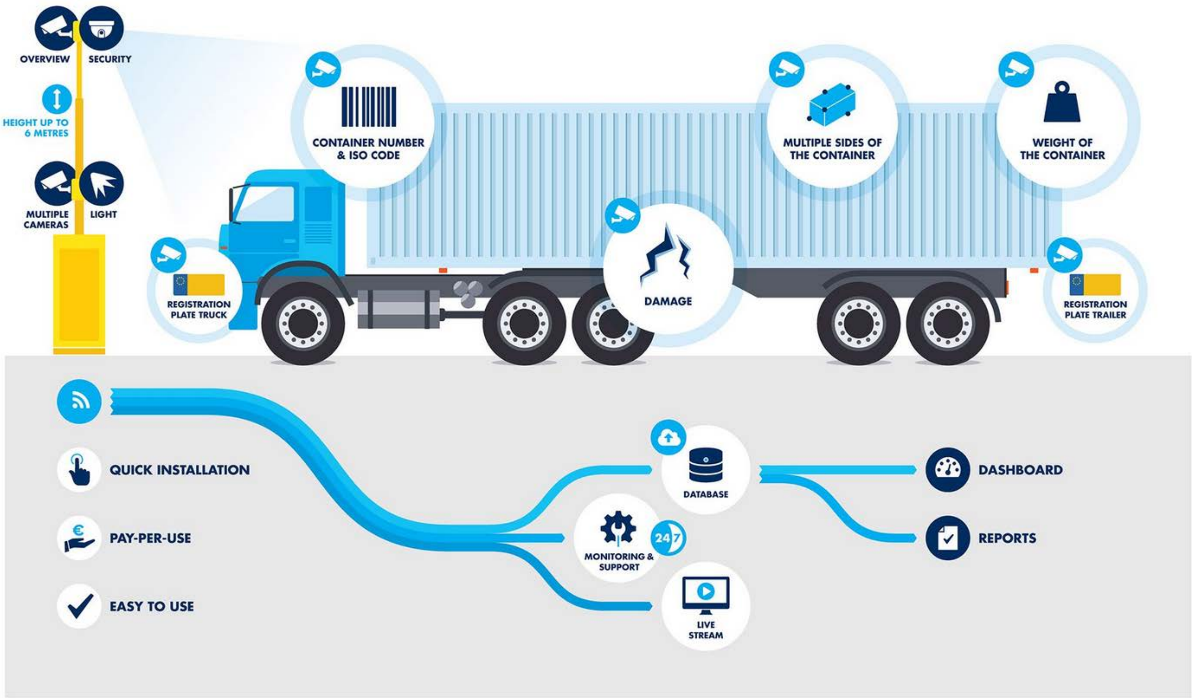

Figure 6: Mobile OCR (Copyrght Port of Rotterdam)

Bunker App

The port of Rotterdam with an annual refilling quantity of about 10 million m^3 of fuel is also one of the top three bunker ports in the world. In addition, Rotterdam is one of the first ports in Europe to bunker LNG (Liquefied Natural Gas). Accordingly, digitalization is attempting to generate improvements and to make information flows to the approximately 20,000 bunker supplies, which are handled via VHF (Very High Frequency, colloquially "ultra-short wave")

[29] www.blocklab.nl [09.10.2018]
[30] www.portofrotterdam.com [09.10.2018]

messages, digitally available in an app. This can save time and displays information in real time.[31]

4.4 Duisburg

With 133 million tonnes of handled goods (2016) and 877 employees, the port of Duisburg is the largest inland port in Europe, considering all public and private port facilities.[32] Efforts are being made to make port processes more efficient and also to avoid congestion, reduce noise and further strengthen inland waterway transport. Following there are several best practice examples from the port of Duisburg.

"Integrated Truck Guidance"

With Integrated Truck Giudance, the port of Duisburg is trying to lay the foundation for optimizing and harmonizing multimodal modes of transport for the hubs of the future. Especially as the faster handling of trucks offers great potential to increase the efficiency at logistics hubs, an intelligent traffic control system was created with the help of which existing infrastructures in the port can be better utilized. Via App, the position of the truck can be determined and the current status in terms of planned and estimated time of arrival by drivers, logistics service providers and terminal operators are collected. Based on the information, operations can be rescheduled if necessary and waiting times can be reduced.[33]

"Start Port"

With Startport, the Duisburg harbor and partners are pursuing the goal of bringing young companies and thus bringing innovations for transport and logistics to the site. By May 2018, the first five teams were already part of the innovation platform.

A team from Duisburg-based Hafen AG supports start-up teams with logistics and supply chain focus, who moved into Duisburg's inner harbor for twelve months. In this way, the startups should develop their ideas in Duisburg to market maturity.[34]

4.5 Portbase

Portbase's Port Community System (PCS) was established in 2009 in cooperation with Port of Rotterdam and Port of Amsterdam and is the digital link between the intelligent Dutch ports. The PCS has an almost nationwide coverage and is available for all port areas. Everyone in the logistics chain can exchange information on containers, general cargo, dry bulk or liquid bulk easily and efficiently via the PCS.[35]

[31] www.portofrotterdam.com [09.10.2018]
[32] www.statista.com [09.10.2018]
[33] www.duisport.de [09.10.2018]
[34] www.duisport.de [09.10.2018]
[35] www.portbase.com [09.10.2018]

Portbase basically consists of 3 components:[36]

1. The application layer with different services (for different actors).
2. A platform with common facilities for all services.
3. A central database that gathers all the information that companies and authorities exchange on Portbase.

The services within the Port Community System address all port sectors: containers, general cargo, dry bulk and liquid bulk. All participants in the logistics chain can exchange information easily and efficiently.

Each target group has its own service package with tailored services within the Port Community System. Some of the services offered are of strategic value to the entire port community and are therefore free of charge to users. The costs of using these services are borne by the shareholders of Portbase. These are, on the one hand, the Port Authority Rotterdam and, on the other hand, the Port Authority Amsterdam.[37]

This shows the possibility of digitization, communication and cooperation across ports and authorities, which can be seen as the basis for the physical Internet.

4.6 Project ATROPINE

The goal of the research project ATROPINE (Fast Track to the Physical Internet) was to bring regional businesses and especially logistics partners together to realize the new concept of the Physical Internet. The University of Applied Sciences collaborated with stakeholders from research including the Benouit Montreuil and 15 Upper Austrian logistics service providers and core industry partners as well as with the European technology platform ALICE, the 'Alliance for Logistics Innovation through Collaboration in Europe'. ALICE developed a comprehensive strategy for research, innovation and market deployment of logistics and supply chain management innovation towards the Physical Internet. Several prototypes, such as the so-called 'smart transport units' that are able to communicate with transport means and or material handling devices were tested during the project. The ATROPINE project team also designed business models, which support the idea of a sharing economy – a fundamental element of the Physical Internet. A major economic benefit of the Physical Internet is that it efficient and effective business models for logistics by sharing assets are elaborated. The project provided Upper Austrian businesses the opportunity to be pioneers in learning about new technologies, products and solutions in the Physical Internet research and business area. Another aim of the project was to prove that companies can optimize their transport costs by cooperating in a Physical Internet network and at the same time increase productivity. In addition, ecological benefits such as lowering greenhouse gas emissions resulting from reducing the consumption of energy and resources.[38]

Results of the project show that, routing within an open and global Physical Internet network such as the one established within the ATROPINE project (the Atropoine-PI network) can lead to a

[36] www.portbase.com [09.10.2018]
[37] www.portbase.com [09.10.2018]
[38] https://www.logistikum.at/uploads/images/PDF/Projektinfoblatt_ATROPINE_en.pdf [15.10.2018]

reduction of resources and travelled distance. A simulation-based optimization algorithm solving of an Atropine-PI network was applied to evaluate the improvements. At the 5th International Physical Internet Conference in Groningen (Netherlands) Haider et al. presented results from the project. Real world data from logistics service providers and shippers from Upper Austria were used. Results of the study show that the Physical Internet can lead to a reduction of traveling distance and number of trucks, if enough volume is bundled. In a second test run the volume was reduced by the logistics service providers - the impact of the Physical Internet was reduced dramatically. As a result, it can be assumed that a sufficient volume of goods is necessary to develop the full potential of the Physical Internet. One limitation of the study conducted was that the data set is comparatively small and thus not representative for the real Physical Internet concept. However, the paper has shown that with the applied algorithm a bundling effect between different players in the logistics world is possible and profitable. One main idea behind the developed algorithm and the model region developed within the ATROPINE project is, that a "global PI network" can be seen as a network of networks. Thus, the algorithm is scalable for larger networks.[39] Learnings from this project may also be conveyed to inland waterway transport and inland ports as important hubs for facilitating a modal shift towards inland waterways.

5 Conclusion

As the results of this report show, the Physical Internet can be seen as an opportunity for inland ports to be crucial nodes in the (European and global) transport system. Since inland ports can be seen as important regulators of transport flows, critical volume can be consolidated in inland ports which is an important prerequisite for the success of this innovative transport concepts. However, numerous actions have to take place to fully realize the concept of the Physical Internet in the future: human resources have to be prepared for the changing tasks in ports, regulations and policy frameworks have to be adapted and investments in infrastructure and technology are required. Even though the specification book may be quite long for realizing the Physical Internet in ports, various best practices and research projects have shown that the concept can have a positive effect on the performance. For the future it may be crucial to take various steps towards the Physical Internet and realizing the different elements step by step. Further research projects, testing the concept of the Physical Internet are also an important step to create awareness for the concept on the one hand and to proof to stakeholders of industry and research that the concept can improve the overall performance of inland ports on the other hand.

[39] Haider et al. 2018.

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