Port Community Systems in the Physical Internet

The potential role of Port Community Systems as information intermediaries in port-related operations in the Physical Internet

M.Sc. Thesis Transport, Infrastructure and Logistics
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portbase®

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Preface

At the start of my thesis, I had never heard about the Physical Internet, nor about Port Community Systems. I was very interested in logistics operations in ports, and especially in the strategic developments that surround them. Now that I have dedicated a year of my life to these topics, I am proud to say that the interest is still there!

I sincerely would like to thank all my supervisors for guiding me through this project. Without them, I would have never been able to achieve this. I would like to thank Prof. Yao-Hua Tan for being the chair of the committee and guiding the important milestone meetings. Also, many thanks to Arjan van Binsbergen for the countless meetings we had, I appreciate the time you put in and the patience you had. I would also like to thank Yusong Pang for the structured way of scientific thinking that you have provided me. It kept me sane! Many thanks to Dennis Dortland, I really enjoyed the meetings with you and had the feeling that we were on the same level. And especially many thanks to Patrick for introducing me to this topic and staying with me till the end. Without your support and knowledge of the subject, this thesis would not have been possible.

Now, I would like to thank my family and friends for supporting me and for continuing to believe in me. Especially, thanks to my girlfriend Jana for distracting me in difficult times, my sister Emilie for her endless support and both my parents, Hetty and Rob, for always believing in me! I love you to the moon and back!

Alexander Oostenbroek 24-1-2022

Executive summary

Introduction

Global supply chains currently are inefficient and unsustainable, due to their overlap and lack of interconnection. The Physical Internet (PI) proposes a paradigm shift in the way we move, store, supply, realize and use goods. The goal of the PI is to interconnect supply chains through modular containers, interfaces and protocols. Sharing of physical resources is essential, as well as sharing of information. For the latter, integral PI information systems are needed. In certain ports, such integral information systems currently exist in the form of Port Community Systems (PCS). These are neutral platforms that facilitate information exchange between port stakeholders, to improve the efficiency of port operations. This research assesses the potential of PCS as information intermediaries in port-related operations in the PI. It does so by proposing a conceptual design of a PI port information system, where PCS fulfil an information intermediary role.

Methodology

To be able to assess the potential of PCS in the PI, a case study analysis is performed at the Dutch PCS: Portbase. This reveals the information that is currently exchanged through PCS. PI literature provides guidelines for the requirements of the information that needs to be exchanged in an information system of a PI port. The outcomes of the case study and the requirements analysis serve as input for the conceptual design of the information system. The design is developed according to the Design Science Research (DSR) methodology. The design is evaluated primarily according to its technical risks and efficacy. Subsequently, the design is validated according to PI and PCS experts.

Design

The case study analysis has shown that Portbase's services facilitate the exchange of compliance related information and logistics related information between active and passive stakeholders through system or web interfaces. The design requirement that is incorporated in this research is that the information system should be able to optimise network flows based on sense-and-respond information.

The designed information system consists of two designs: a high level design and a detailed design. The high level design distinguishes two main port functions: the port call and the transfer of PI containers. Additionally, corresponding sense-and-respond optimisation functions for these functions are defined, according to the information system's requirement. The detailed design zooms in on the transfer of containers, and defines necessary sub functions that are needed to execute this process.

In the conceptual design, full information is assumed. In doing so, necessary information for the execution of the processes in the PI port information system, is defined. Additionally, information from Portbase services are integrated in the design, next to PI specific information. This way, a conceptual information system of a PI port is designed, where a PCS fulfils an information intermediary role. The final design implies a certain role for PCS with respect to their potential in the Physical Internet. The implications are translated into recommendations for PCS, with the goal to increase their potential in the PI.

Recommendations to Port Community Systems

Following from the design, various recommendations to PCS are made. They are: (1) PCS should maintain their role as information intermediary for compliance related services in PI ports; (2) PCS should invest in the development of more extensive services related to track-and-trace capabilities in PI ports; (3) PCS should invest in the development of more extensive logistics related services that can be used for optimisation functions in PI ports; (4) PCS should research to what extent compliance related information regarding the content of containers, can be used for logistics services for optimisation functions in PI ports; (5) To extend its reach towards the hinterland, Portbase should research whether and how it can implement a service to notify the arrival of inland barges at inland terminals, similar to the hinterland container notification at container terminals at deep sea ports.

Discussion

The explicit division of port functions that has been applied in this research, provides several main discussion points. The first is that, in reality, many port stakeholders and functions are vertically integrated and therefore not explicitly split up. For the development of an information system however, it is argued that a division of information modules needs to be made on a function level, regardless of the process owner. The second is that the separate optimisation of port functions might lead to a system suboptimum. Relating this to the general goal of the PI, this is not desirable. At the same time, a bottom-up design approach is preferred. In this regard, it is argued that the separation of optimisation functions provides a good starting point for the incremental way in which information systems in the PI need to be designed.

The full information that is assumed in this research, in reality is not available. Additionally, the federated network of platforms as proposed by the Digital Transport and Logistics Forum (DTLF), does not yet exist. There is a range of organisational and cultural changes that are needed for the transition towards this future that are not addressed in this research. However, it does show the immense need for collaborative mechanisms and data sharing, in order to accelerate the adoption of the Physical Internet.

Conclusion and future research

This research concludes that, with its current offer of services, Portbase can facilitate compliance related services in PI ports. Its facilitation of logistics related services in PI ports is limited. For further integration of PCS in the PI, an expansion of logistics services is needed. A conservative attitude towards the development of services could hinder the variety of Value Adding Services and applications, which could negatively influence the potential of PCS in the PI. Continuing to only develop services internally, or remaining closed off to innovative services from external developers, may hinder the growth that is needed to be of true value in PI ports.

Future research could focus on the potential role of other PCS in PI ports. Furthermore, it is recommended to research the role of PCS in the development of a federated network of platforms in the PI. Additionally, optimisation engines for vessels' terminal choice and PI containers' mode choice may be developed. Another recommendation is to explore the governance measures and organisational changes that are needed for a data sharing environment in which full availability of information is aimed for. As extension of this research, the export of containers, the port choice, and bulk and piece goods may be included in the design. Finally, the addition of other PI port information system requirements in the design, is recommended.

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Acronyms

AIS	Automatic Identification System
API	Application Programming Interface
APM	A.P. Møller-Maersk
ATA	Actual Time of Arrival
ATD	Actual Time of Departure
BPD	Business Process Diagram
BPMN	Business Process Model and Notation
CBS	Centraal Bureau voor de Statistiek
CPU	Central Processing Unit
DSR	Design Science Research
EDI	Electronic Data Interchange
ENS	Entry Summary declaration
EU	European Union
FEDS	Framework for Evaluation in Design Science Research
ICT	Information and Communication Technology
IDEF0	Integrated Computer Aided Manufacturing Definition for Function Modelling
ILT	Inspectie Leefomgeving en Transport
IPCSA	International Port Community Systems Association
IS	Information System
ISO	International Organization for Standardization
IT	Information Technology
LoS	Level of Service
LSP	Logistics Service Provider
MPET	MSC PSA European Terminal
MSC	Mediterranean Shipping Company
NTP	Networked Trade Platform
NVWA	Nederlandse Voedsel- en Warenautoriteit
OLI	Open Logistics Interconnection
PCS	Port Community System
PE	Platform Ecosystem
PI	Physical Internet
QoS	Quality of Service
RWS	Rijkswaterstaat
SPOC NL	Single Point of Contact Netherlands
VAS	Value Adding Services
WLIS	Wagonload Information System

1. Introduction

Seaports have become the main drivers of global supply chains. Annual freight transportation numbers have been steadily growing for the last decades and a great number of our goods are being shipped in containers via seaports. A contributing factor is the increasing connectivity of global supply chains.

A concept that tries to further connect supply chains on a global level is the Physical Internet (PI). It proposes a vision on how to collectively work towards global *sustainable* supply chains. Montreuil, Ballot & Fontane (2012, p.328) phrase it as follows: "the aim of the PI is to universally interconnect logistics networks through world-standard modular containers, interfaces and protocols in order to improve the worldwide efficiency and sustainability of logistics". This asks for a paradigm shift of the way in which current supply chains function. Current supply chains are shaped in a way that there is a lack of interconnection between multiple parallel supply chains, while using the same infrastructure, which is therefore inherently unsustainable. In the PI, various logistics processes along the value chain should become visible and should communicate to each other, which calls for a complete redefinition of supply chain configurations. Because ports are so important in current supply chains, it is expected that they will have an important role in the path towards the PI as well. Specific port-related operations and their place in the PI receive the main focus in this research.

One of the main foundations of the Physical Internet is universal interconnectivity (Montreuil, Meller & Ballot, 2012). It consists of physical, operational and digital interconnectivity. Here, the focus is on digital interconnectivity. Digital interconnectivity means that elements in the PI will have to be able to exchange fact-based information which can be used for efficient real-time decision-making (Montreuil, Meller & Ballot, 2012). Information exchange comprises of exchange between physical entities, constituents and actors. This means that not only containers and movers in the Physical Internet (accordingly called PI containers and movers) have to be able to communicate to each other, but also that all stakeholders within the PI have to be interconnected to communicate to each other.

To achieve digital interconnectivity between stakeholders in the PI, multi-level certified information systems are needed (Montreuil, 2012). Certification is needed for external validation of the competences of the information system, agreed upon by all stakeholders using the information system. For a future PI-environment, these information systems do not yet exist. However, in the current environment of certain seaports, there do exist information systems that already facilitate efficient communication and information exchange between different stakeholders. These are called Port Community Systems (PCS) and are of increasing importance in modern seaports. In the Netherlands, the national PCS is called Portbase. The International Port Community Systems

Association (IPCSA) defines a PCS as “a neutral and open electronic platform enabling intelligent and secure exchange of information between public and private stakeholders in order to improve the competitive position of the sea and air ports’ communities. It optimises, manages and automates port and logistics processes through a single submission of data and connects transport and logistics chains” (IPCSA, 2020). An important part of this definition is the *single submission of data*, which is also called a *single window* or *single entry*. This means that information is submitted only once and is reused for efficient communication in logistics networks. The Port of Rotterdam defines a PCS as “a single entry platform of data in a port for business-to-government messages and business-to-business messages” (PoR, 2020, p. 2). A PCS can be seen as an information intermediary in current port environments. This leads to the question whether a PCS could also serve as information intermediary for port-related operations in the PI.

To answer this question, two knowledge gaps need to be addressed first. They are formulated as follows:

1. It is not yet known **what, how and between who information is exchanged between PCS and its environment**. Descriptive scientific literature on the information exchange between PCS and its environment is lacking. Furthermore, scientific literature on PCS lags behind its operations (Moros-Daza, Amaya-Mier & Paternina-Arboleda, 2020).
2. It is not yet known **what, how and between who, information is exchanged in port-related operations in the Physical Internet**.

In short, this research contributes to both bodies of literature as follows. There is a need for a future certified information system in the Physical Internet, to facilitate digital interconnectivity between stakeholders. At the same time, neutral information exchange platforms in the form of Port Community Systems exist in modern seaports. This research explores the potential of a PCS as information intermediary to contribute to a PI port information system. It does so by analysing the information exchange of a PCS and the expected information exchange in the PI, and by providing a conceptual design of a PI port information system that involves a PCS as information intermediary. In this regard, Port Community Systems might contribute to greater digital interconnectivity between stakeholders in port-related operations in the Physical Internet.

1.1 Research questions

The combination of the knowledge gaps mentioned above, opens up research possibilities. To the best of the author's knowledge, there exists no research that includes Port Community Systems in port-related operations in the Physical Internet. To be specific, no research exists that explores the potential of PCS as information intermediary in PI ports.

Relating the two knowledge gaps to the goal to digitally interconnect stakeholders in the PI in a better, unified way, leads to the following main research question:

What is a potential conceptual design of an information system for port-related operations in the PI, where a PCS fulfils an information intermediary role?

- ***(a) What information is exchanged in PCS?***
- ***(b) How and between who is information exchanged in PCS?***
- ***(c) What information would need to be exchanged in port-related operations in the PI, compared to the information exchange in PCS?***
- ***(d) What is a potential way how and between who this information is exchanged in the PI?***
- ***(e) What role can a PCS have in this potential way of information exchange in the PI?***

This document is structured as follows. First, the research goals, the perspective of the author and the scope are presented. Hereafter, a literature review on Port Community Systems and on the Physical Internet is presented. Topics like data sharing and its governance and information system network structures are also touched upon. A suitable overarching methodology for the research is presented, as well as specific methods and tools that are used to answer the research questions. Results are presented in the form of a case study analysis on PCS operations, requirements for PI port operations, a conceptual design of a PI port with integrated PCS functionalities and implications to PCS in the form of recommendations.

1.2 Research goal, perspective and scope

Goal and perspective

The overall goal of this research is to explore the potential of Port Community Systems (PCS) as information intermediary in port-related operations in the Physical Internet (PI). The perspective that this research applies, is from the point of view of a PCS. In short, the goal is to design a conceptual information system of a PI port, where a PCS serves as information intermediary. What information exchange aspects could be facilitated by PCS, follows from the design of the information system. Implications of this research are presented to the Dutch PCS, Portbase, in terms of their potential role as information intermediary in port-related operations in the PI.

Scope

This research is an explorative and qualitative research. To the author's knowledge, it is the first research that combines the Physical Internet and Port Community Systems from a scientific perspective. Both bodies of literature are very contemporary and show increasing numbers of publications[1]. However, subjects of a wide spectrum are included in both, so scoping of the research is necessary.

The basis of the research rests on the question what role a PCS can potentially fulfil as information intermediary for port-related operations in the PI. There is a focus on one of the PI's foundations, digital interconnectivity. As mentioned before, digital interconnectivity entails information exchange between physical entities, constituents and actors. This research focuses on communication between different actors or stakeholders in the PI. The stakeholders in the PI may own certain physical entities and constituents for which digital interconnectivity also needs to be designed. An example is the physical communication infrastructure for modular PI-containers and for PI-movers. This low-level, fairly detailed type of communication and information exchange is *not* considered in this research.

Furthermore, only cargo *import* processes are considered in this research, as well as the consideration to only focus on port processes in the Port of Rotterdam. This is the choice of the author. The reason for this choice is that the Port of Rotterdam is the largest in The Netherlands and handles more import cargo than export cargo[2]. Also, only maritime containers are included in the analyses. These choices have been made to make the research more manageable. It is argued however that the same principles

[1] Based on search results "Port Community System" and "Physical Internet" on https://www.scopus.com/home.uri
[2] https://www.portofrotterdam.com/en/experience-online/facts-and-figures

that are derived from this research can be applied to container export processes and container processes in other ports, albeit with different specifications.

The choice to focus on the Port of Rotterdam is related to the possibility to cooperate with Portbase, through consultation with Dennis Dortland, Innovation Consultant at Portbase. Portbase is the Dutch Port Community System and was founded by the Port of Rotterdam and the Port of Amsterdam as the independent PCS of The Netherlands. It has the goal to further stimulate freight transport through Dutch ports[3]. To be able to study PCS, Portbase is used as a case. The Port of Rotterdam is one of the leading ports around the globe, which is argued to make Portbase a relevant player in the port community. As stated before, the possibility to access necessary data from Portbase also is a reason for the choice to study the Port of Rotterdam. This means that operations at the Port of Rotterdam receive the attention. Port processes at the Port of Amsterdam and other Dutch ports are out of scope for this research. It is argued that, in essence, operations there are similar to the ones in the Port of Rotterdam.

A wide variety of cargo types is transported through modern seaports. To make the research more manageable, not all types are included in this research. For the analysis of a PCS, it is the author's choice to only include port processes that are related to the handling of a non-refrigerated 40ft. (2 TEU) container, as this is one of the most common freight types. This means that *no bulk, break bulk, roll-on roll-off or perishable goods* are considered in this research. The reason for this is that these existing containers have the closest resemblance to the modular containers proposed in the PI (i.e. PI containers). Furthermore, there is no explicit technique yet to encapsulate bulk and piece goods in modular PI containers. Because of this inherent difference in the type of cargo, further research could follow-up on the design of an information system that includes bulk and piece goods.

In the information system that is designed in this research, full information is assumed. However, often, information is missing, which leads to uncertainty during logistics processes. This is dealt with as follows: if a container does not carry all information that is necessary for its transportation, other containers that do carry all necessary information, are prioritised over this container. This way, shippers are incentivised to provide full information on their shipment, hereby stimulating efficient logistics operations.

The current role of a PCS focuses on specific port operations, and is expected to extend its reach towards the hinterland (PoR, 2020). The potential role of a PCS in the PI will therefore also mainly focus on specific port-related operations, with a possible future outreach to the hinterland. However, in this research, specific *port-related* operations are the focal point. The actual operations in the hinterland

[3] https://www.portbase.com/en/about-us/

are *not* part of the analyses for this research. The reason for this is that because this is an explorative research, first, the potential of PCS in PI port functions is assessed. Hereafter, the potential for hinterland operations in the PI may be assessed. For the design of a PI port information system, hinterland transportation is included as a system function, as it is an integral part of the import process. Still, port operations are of primary importance in this research. In the design presented in this research, inter terminal transport (ITT) is not modelled explicitly. Instead, the port area is considered as one virtual port, where ITT is performed when necessary. In this regard, container terminals are considered as one aggregated entity, whose main function is to unload vessels and hand over containers to hinterland modalities. These functions receive main attention in the design.

2. Literature review

This chapter presents relevant literature on the Physical Internet (section 2.1), Port Community Systems (section 2.2) and data sharing and its governance (section 2.3). It concludes with a short reflection on the identified literature gaps (section 2.4).

2.1 Physical Internet

Open Logistics Interconnection model

The way in which current logistics networks are organised is unsustainable, due to a lack of interconnection between supply chains (Montreuil, Ballot & Fontane, 2012). The Physical Internet (PI) proposes a paradigm shift in the logistics industry for how goods are moved, stored, supplied, realized and used. As Montreuil, Ballot & Fontane (2012) describe it: "The aim of the PI is to universally interconnect logistics networks through world-standard modular containers, interfaces and protocols in order to improve the worldwide efficiency and sustainability of logistics" (p. 328). Modular containers consist of transport, handling and packaging containers (T-, H- & P-containers, respectively) (Montreuil, Ballot & Tremblay, 2016). Packaging containers encapsulate the actual product, handling containers contain multiple packaging containers for easy handling and transport containers contain multiple handling containers for efficient transport. Existing examples of containers with a similar logic are shipping containers, pallets and boxes. However, in the PI, all containers should be modular and easy to connect to each other through standard interlocking mechanisms (i.e. interfaces). Standard interfaces consist of physical interfaces – such as the interlocking mechanisms – and information & communication interfaces, as distinguished by Fahim et al. (2021). Information & communication interfaces comprise smart tags on containers and digital middleware platforms. Standard PI protocols represent a unified way of working throughout logistics networks. Logistics networks are represented with several interconnected layers, which are similar to the layers in the digital internet (hence the name). Montreuil, Ballot & Fontane (2012) developed the Open Logistics Interconnection (OLI) model, which consists of seven layers and is similar to the Open Systems Interconnection model of the digital internet. The OLI model is depicted in the figure below.

Each layer of the OLI model adds value in such a way that the top layer is able to run distributed applications. For the PI, this offers three main advantages:

- Splitting up of complex tasks in smaller, simpler tasks
- Changing and replacing components is easy due to inter-layer interfaces that stay the same
- Interfaces are key for interoperability in the industry, which is critical for the interconnectivity of several systems

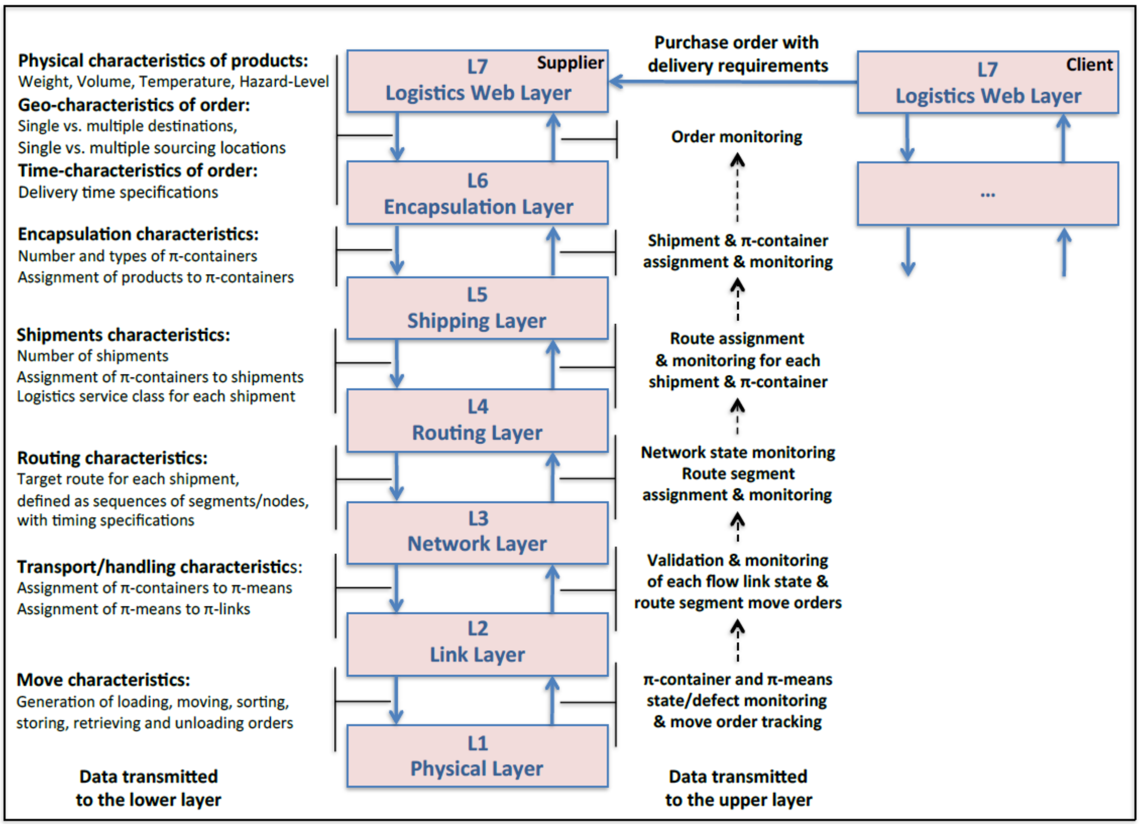

Figure 1: OLI model (source: Montreuil, Ballot & Fontane, 2012)

Thus, logistics networks are represented as layers that essentially have the same functionalities. Because of these similar functionalities, similar layers of different networks can be interconnected. By doing so, logistics networks can be interconnected globally. An important part of the PI is the possibility to control flows across logistics networks, as a consequence of their interconnection. This interconnection happens on an informational level: each layer of a logistics network can access the information on the same layer of another network. An example: if you know the current and future (expected) location of containers and the current and future (expected) state of logistics processes, you can optimally distribute flows of containers across these logistics processes based on predictive control.

The layers of the OLI model are briefly discussed here. The top layer of the OLI model is the Logistics Web, which is defined as “the interface between PI and users of logistics services” (Montreuil, Ballot & Fontane, 2012, p. 331). The main logistics functions, as earlier defined, are: moving, storing, supplying, realizing and using of physical objects. These functions are reflected in different sub-webs (Mobility Web, Distribution Web, Supply Web, Realization Web and Service Web, respectively). Together, these webs make up the Logistics Web. The layer below the Logistics Web is the encapsulation layer. It is concerned with the encapsulation (i.e. enclosing/encasing) of products in specific containers (i.e. PI containers) and therefore deals with transporting containers instead of products.

The shipping layer is concerned with actual shipments of (sets of) containers. It deals with shipment requests from shippers. A shipper is the stakeholder that sends the goods; the carrier is the stakeholder that transports the goods. A shipper might ship multiple orders in one shipment. At the same time, one order might be shipped in multiple shipments. Furthermore, one shipment might be in multiple PI containers, and at the same time, multiple shipments might be in one PI container. The shipment layer contains all information regarding shipments: what container belongs to what shipment and which shipment belongs to which shipper. Each shipment has a destination and deadline, as well as a logistics service class for each shipment, defined by the shipper. A logistics service class can be represented according to a certain Quality of Service (QoS). QoS has been researched extensively. Pullen (1993) presents that not all service aspects can be captured into one QoS measure. Instead, he proposes to use a limited set of QoS attributes, based on the specific circumstances and goals of the service. The Level of Service (LoS) is a similar term to measure the quality of a certain service provider. LoS is an often used quality indicator in transport and logistics (Borille & Correia, 2013; Griswold et al., 2018). In this research, a distinction is made between QoS and LoS: QoS refers to the *desired* service level of a shipper; LoS refers to the *actual* service level of a Logistics Service Provider (LSP). In light of the goal of the PI to facilitate efficient and sustainable transport, the criteria of both indicators are as follows: transportation or handling time, costs, emissions and LSP quality. LSP quality is considered as an aggregated indicator, which may include aspects such as reliability and number of damages.

The OLI model's routing layer is concerned with the actual routing of containers from origin to destination. It does so by providing a best path, according to the network state. The network state is retrieved from the network layer. This layer is concerned with the connectivity of the transportation network. With connectivity of a network, we refer to the work of Dill (2004), who provides several definitions for network connectivity in urban planning, which are argued to be applicable here as well. Two examples are the link-node ratio and the gamma index. The link-node ratio is a ratio between the number of links in a network and the number of nodes. The gamma index is a ratio between the number of links in a network and the maximum possible number of links between nodes. To both ratios applies: the higher the ratio, the higher the network connectivity is considered to be. The network layer monitors the network state by receiving information from the link layer. The link layer provides a digital mirror of physical infrastructure and continuously monitors the state of this physical infrastructure. By digital mirror, we mean a digital representation of a physical object or process, similar to the term digital twin, which is often used to represent this idea as well (Worden et al., 2020). However, because Montreuil, Ballot & Fontane (2012) use the term digital mirror, we choose to do so as well. Finally, the physical layer comprises all infrastructure necessary in the PI. This consists of roads, railway tracks, waterways, but also container terminals and distribution centres. For a more elaborate explanation on the layers of the OLI model, see (Montreuil, Meller & Ballot, 2012; Montreuil, Ballot & Fontane, 2012).

Benefits and adoption of the Physical Internet

The introduction of the PI is believed to lead to several positive effects. Sarraj et al. (2014) argue that these are, among others, a reduction in greenhouse gas emissions, transportation and logistics costs, lead time and travel delivery time. Sternberg & Norrman (2017) provide a critical review of the existing literature. They argue that the adoption of the PI depends on perceived benefits, organisational readiness and external pressure. The perceived benefits are related to envisioned business models, which have to be beneficial for stakeholders to adopt the PI. Organisational readiness of stakeholders determine the adoption with regards to the 'technological blueprints': the degree to which technologies used in an organisation fit to the technologies necessary in the PI. External pressure determines the adoption in such a way that promised effects of adoption influence the willingness of an organisation to adopt the PI. Additionally, Sternberg & Norrman (2017) argue that it is likely that stakeholders will defend their business models and will try to maintain proprietary networks. Therefore, adoption mechanisms and promised effects need to be researched more extensively (Sternberg & Norrman, 2017). This is also reflected in the work by Treiblmaier, Mirkovski & Lowry (2016). They published a review of literature on the Physical Internet, which has recently been updated (Treiblmaier et al., 2020). One of the important themes in PI literature is seamless, secure and confidential data exchange. As the OLI model shows, data exchange is essential. For optimal operations in the PI, this exchange needs to be seamless, which means that fact-based information needs to be exchanged fast (Montreuil, Meller & Ballot, 2012). Additionally, data exchange needs to be secured and confidential, in order to avoid data theft and loss of data sovereignty (Martinez De Ubago Alvarez De Sotomayor, 2019). For seamless, secure and confidential data exchange, different facilitators and barriers are revealed (Treiblmaier et al., 2020). A facilitating factor is the introduction of open, shared and secure protocols for data exchange. Detracting factors are "proprietary solutions, security breaches and measures alleviating the theft of data and goods" (Treiblmaier et al., 2020, p. 260). As mentioned before, proprietary solutions as a detracting factor is reflected in the work by Sternberg & Norrman (2017) as well.

The characteristics of the vision behind the PI are presented by Montreuil (2011). The first vision statement is to 'Encapsulate merchandises in world-standard smart green modular containers' (i.e. π-containers). This diversification of transporting goods in numerous standard modular containers, in contrast to the relatively simple 20-40ft. containers we know today, is one of the foundations of the PI. Standardisation of containers leads to more efficient and sustainable logistics, because less types of containers lead to less ambiguity during handling processes. This way, handling processes can be made more efficient and sustainable. This decrease in ambiguity can also reduce handling time. Additionally, handling costs can be reduced because less types of handling equipment are needed. The second vision statement is 'aiming toward universal interconnectivity'. This not only holds for the (physical) interconnectivity of the π-containers, but also for digital interconnectivity between users of the PI and the Logistics Web. A high amount of synchronisation of information is necessary for efficient and sustainable logistics services in the PI, as can be seen in the different data transmissions in the OLI model (figure 1). Similar to the standardisation of containers, a synchronisation of information leads to less ambiguity in logistics processes, which can increase the efficiency and thereby processes' sustainability. For the other vision statements of the PI, see Montreuil (2011).

Information System network structures

Data transmission from lower levels to higher levels and vice versa is key in the OLI-model. To facilitate this, an Information System (IS) is needed. One of the first papers on the structure of communication networks has been published by Baran (1964). Although it has been published a long time ago, it still provides a good definition for network structures. It is argued that network structures can be basically divided into two types: star-structures and mesh-structures. Star-structures have a centralising tendency. When there is just one central node (or station), the network is fully centralised. When there are multiple central nodes (or servers) that are connected to each other on a hierarchically higher level, the network may be called decentralised. When the network has a mesh structure, it is often called a distributed network. The network structures are depicted in the figure below.

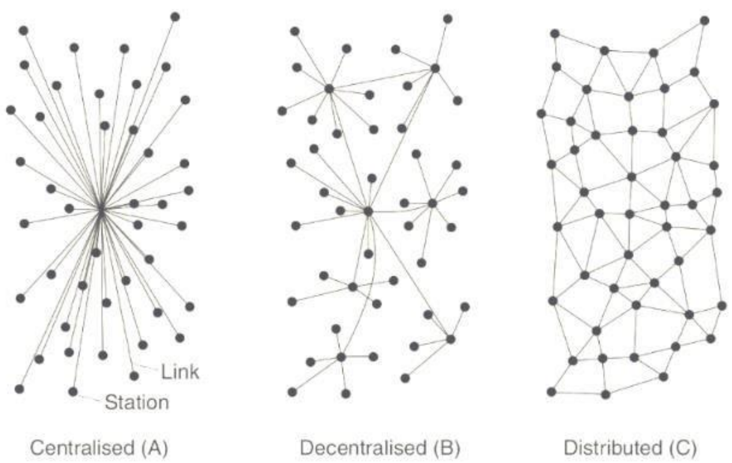

Figure 2: Information system network structures (source: Truong et al., 2016)

Decentralised decision-making is one of the goals of the Physical Internet (Montreuil et al., 2012; Ambra, Caris & Macharis, 2019). By making decisions in a decentralised way, logistics processes can be optimised in their specific environment and decisions can be made quickly and efficiently. However, to coordinate information flows in an efficient manner, some level of centralisation is necessary (De Jong, 2020; Wissink, 2020). These two recent master theses have shown that a certain level of centralisation is needed for effective decision-making in the PI. De Jong (2020) introduced the concept of a Central Planning Facilitator (CPF) to design this centrality. Furthermore, Sternberg & Andersson (2014) have revealed that there is little evidence that fully decentralised freight information systems can be successfully implemented in current freight transport systems. Current freight transport systems need a certain level of coordination, which is difficult in a decentralised system, due to the autonomy of decentralised nodes.

How the IS of the PI should be realised exactly is not yet fully known. The PI roadmap by Alice-ETP (2020) states it as follows: "The information/data sharing mechanisms are not well defined and described thus fuelling all kinds of speculation about business impacts." (p. 21). It also brings forward that the Digital Transport and Logistics Forum (DTLF) addresses the decentralised notion of the PI by proposing a 'federated network of platforms'. The term federated network is often used interchangeably with decentralised networks[4]. There is no hard definition for a federated network structure. In light of this research, it is interpreted here as a decentralised network with platforms that are related to governmental activities and agencies, such as Port Community Systems are now. In the PI, the federated network would then consist of several platforms, each belonging to a country. When looking at the existence of national Port Community Systems nowadays, the question what potential role a PCS can fulfil in the PI becomes even more relevant.

It should be noted that when looking at the network structures discussed here, the perspective is important. The federated network of platforms proposed by the DTLF resembles a decentralised structure when zoomed out. However, when zooming in on one platform and its connected nodes, a centralised structure appears. For this research and its focus on the Port of Rotterdam, it is assumed that a central entity will be in place for information exchange. This assumption adheres to both the federated network of platforms proposed by the DTLF (Alice-ETP, 2020), as well as the research done by De Jong (2020), Wissink (2020) and Sternberg & Andersson (2014).

[4] https://networkcultures.org/unlikeus/resources/articles/what-is-a-federated-network/

Physical Internet stakeholders

According to Montreuil, Meller & Ballot (2010), the PI will consist of three main physical components: PI-containers, PI-movers and PI-nodes. A stakeholder can be associated to each of these physical components. Hacquebord (2020) has named them as follows:

- PI container owners
- PI transporters
- PI hub owners and operators

This distinction of stakeholders provides an aggregated view on the variety of stakeholders in the PI. Stakeholders do not necessarily belong to one single category. Stakeholders can fulfil multiple roles, such as carriers (i.e. PI transporters), as the owners of containers as well. At the same time, PI transporters might also be PI hub owners and operators, such as major carriers owning proprietary terminals. Examples are Maersk owning A.P. Møller-Maersk (APM) terminals in Rotterdam and MSC owning the MSC PSA European Terminal (MPET) terminal in Antwerp.

Physical Internet roadmap (ALICE-ETP)

There is no future information system (IS) for the PI yet. However, there is literature that presents some grip for outlining a potential future IS for the PI. The roadmap by Alice-ETP (2020) provides this outline. The goal of this research is that a combination of the roadmap, an analysis on current port operations and their information exchange through PCS and expert interviews for evaluation and validation, will provide a thorough potential design of an IS in PI ports. Below, the main dimensions in which the PI needs to be developed, are presented (Alice-ETP, 2020).

<u>Logistics nodes</u>

The first development area is concerned with logistics nodes. Ports, providing a multitude of logistics activities, are such logistics nodes. It is stated that processes at logistics nodes should be automated, standardised and connected. One of the proposed developments to achieve this in the coming five years, is: “implement the federated network of platforms concept at nodes level” (Alice-ETP, 2020, p. 9). Hofman (2015) has addressed the federation of platforms. He distinguishes various design principles to form a so called Connectivity Infrastructure: “the set of software components and protocols between those components implementing connectivity between supply and logistic stakeholders” (Hofman, 2015, p. 6). Based on this infrastructure, platforms can provide services to their stakeholders. To create a federated network, protocols between platforms need to be defined in order to standardise data and APIs, so data can be exchanged seamlessly between different platforms.

This proposed development into a federated network reflects the relevance of this research, as we try to make a connection between the demand for such a federated network and currently existing platforms that potentially could be part of such a network.

Logistics networks

Logistics networks should be equipped with door-to-door services. The execution of the service should be left to the service provider, while user level service quality should receive the focus (Alice-ETP, 2020). This implies that pre-determined means of transport for a shipment are not so important anymore. It does not matter how the shipment gets there, as long as it gets there according to a certain quality of service. This quality of service depends on a wide variety of factors. Not only price and lead time are important, but also temperature and for example greenhouse gas emissions. The quality of service of the transport of PI containers, is discussed later on. One of the proposed developments to achieve this in the coming five years, is: "develop and adopt advanced ICT systems necessary to run a synchromodal transport system" (Alice-ETP, 2020, p. 13). A synchromodal transport system is defined by Behdani et al. (2016) as the integration of transport chains by synchronising stationary resources (i.e. transport infrastructure and nodes) and moving resources (i.e. truck, train, barge) continuously to customer demands and needs. Key to this is not only vertical integration in the chain, but also horizontal integration, which results in higher service levels for shippers and increased utilisation of transport means. This continuous synchronisation of resources and demands can be enabled by a federated network of platforms, through standardised data exchange and protocols, as explained above. The demand for advanced ICT systems in the PI reflects the relevance of this research, as we are exploring the contributing potential of an advanced ICT system like a PCS in the PI.

System of logistics networks

To achieve a synchromodal transport system as proposed in the vision of the PI, protocols should be formulated. These protocols should not only accommodate the flow of goods, but should also accommodate information and financial flows. One of the proposed developments to achieve this in the coming five years, is: "continual testing of end-to-end flows across different logistics networks" (Alice-ETP, 2020, p. 17). By testing these end-to-end flows, new coordination mechanisms for novel business models can be developed. This reflects the relevance of this research, as PCS are also continuously evaluating and adapting their end-to-end services to fit to new industry needs and wishes.

Access and adoption

The ICT systems in the PI should be easily accessible to everyone. This means that anyone should be able to access them via open interfaces. One of the proposed developments to achieve this in the coming five years is: "identification and development of digital access points to Logistics Nodes, logistics networks and System of Logistics Networks" (Alice-ETP, 2020, p. 20). This reflects the relevance of this research, as we try to make a connection between currently available digital access points to logistics nodes (i.e. PCS in ports) and the demand for such access points in the PI.

Governance

In theory, there are two ways to design governance in the PI: top-down and bottom-up. A definition of data governance, derived from a literature review article, is as follows: data governance "refers to the entirety of decision rights and responsibilities concerning the management of data assets in organizations" (Al-Ruithe, Benkhelifa & Hameed, 2019, p. 842). Bottom-up design of governance is considered to be the only viable one, "as it will ensure a more gradual and business-driven creation of the Logistics Network" (Alice-ETP, 2020, p.24). One of the proposed developments to achieve this in the coming five years, is: "definition of governance processes and body for defining the rules, addressing barriers and support companies willing to move to open, shared and connected logistics networks" (Alice-EPT, 2020, p. 25). The interpretation of PCS as such (neutral) support companies in logistics networks reflects the relevance of this research.

2.2 Port Community Systems

Port Community Systems as integrator of port processes

First of all, a definition of Port Community Systems (PCS) by the International Port Community Systems Association (IPCSA, 2020), is presented: a PCS is defined as "a neutral and open electronic platform enabling intelligent and secure exchange of information between public and private stakeholders".

As discussed in the previous section, the vision on the PI defines a need for sustainable and efficient transportation and logistics chains. For modern seaports, this implies further integration of processes. Kaup et al. (2021) present that a simplification of administrative procedures will contribute to the ongoing integration of port processes. Additionally, their research puts forward that the adoption of Port Community Systems, will aid in implementing this. A PCS as a driver for the simplification of administrative procedures and for more effective communication in ports, is also reflected in the work by Mayanti et al. (2020).

Furthermore, Caldeirinha et al. (2020) propose in their research that PCS characteristics affect port performance. These characteristics entail the PCS service level, partner network, ship & cargo services, logistics services and advanced services. The port performance is defined as operational performance, effectiveness and efficiency. Their research shows that a wide variety of PCS characteristics can have a positive impact on various port processes.

The research by Kaup et al. (2021), Mayanti et al. (2020) and Caldeirinha et al. (2020) show that the further integration of port processes through PCS positively affects port performance and hereby contributes to more sustainable and efficient transportation and logistics chains.

Emergence of Port Community Systems

Moros-Daza, Amaya-Mier & Paternina-Arboleda (2020) describe in their structured literature review four waves of emerging Port Community Systems over time. The waves are characterized by different measures in the industry:

1. 1982-2000 → Establishment of Electronic Data Interchange (EDI) agreements
2. 2001-2011 → Paperless Trading Initiatives; European Directive for vessel traffic monitoring; Regulation for shared IT systems; Changes to green concepts
3. 2012-2017 → Several directives to law adoptions (eCustoms EU law & EU law for paperless customs; Movement from automation to smart and from green to smart green)
4. 2018-Present → Offering of multimodal services; Introduction of 'SmartPort' concept

Although the literature review is quite comprehensive, they argue that "industry is ahead of scientific research" (Moros-Daza, Amaya-Mier & Paternina-Arboleda, 2020, p. 38). This means that, from a scientific perspective, much is still unknown. Nevertheless, there is valuable literature that can help in describing PCS.

Benefits and adoption of Port Community Systems

Carlan, Sys & Vanelslander (2016) have researched the value that a PCS can bring to a certain port and present the following findings. They define four observed functionalities of PCS. First, a logistics function, which "provides electronic communication for efficient management of the entire logistics chain" (p. 53). Second, a customs clearance function, which "simplifies the import and export control procedures and offers better control of the administrative process" (p. 53). Third, a navigation function, which "guarantees an efficient approach for smooth and safe traffic and optimum planning during arrival and departure" (p. 53). Fourth, a dangerous goods function, which "uses electronic communication to guarantee an efficient data flow for the declaration of the transport of hazardous cargo and the related obligations" (p. 53). Additionally, it is argued that this modularity of functions is important for successful implementation of a PCS, because in this way, specific information of specific stakeholders can be easily connected to each other. Benefits of PCS reported in their literature selection are split into digital economy benefits and community attendance benefits. As the term implies, digital economy benefits have an economical aspect, such as reduced costs of communication. Community attendance benefits have a more societal, community related aspect, such as easier collaboration between different stakeholders. Observed costs of PCS are split into PCS operator costs and PCS user costs. The functionalities and the design of a PCS determine these costs and benefits, which should be evaluated on a modular level. Lastly, Information and Communication Technology (ICT) is one of the main pillars of port competitiveness (Carlan, Sys & Vanelslander, 2016).

As stated before, the adoption of the Physical Internet depends on perceived benefits, organisational readiness and external pressure (Sternberg & Norrman, 2017). Similarly, Mendes Constante (2019) argues that the adoption of PCS not only depends on IT penetration, but especially on the willingness to change among different public and private stakeholders.

The definition of a PCS according to the Port of Rotterdam has been presented in the introduction. Next to this definition, the Port of Rotterdam states that a new approach towards Port Community Systems is needed. They define four distinct design goals for the design of PCS in the future:

1. Software as a service: gradual addition of services is needed

2. Generic modules: through standardisation of processes, generic modules can be added over time
3. Data ownership: it is crucial for security, legislation and commercial value of data
4. Connected to global developments: expansion of focus of the supply chain towards hinterland and global connectivity

These design goals of PCS are highly relatable to those of the Physical Internet. Both PCS and PI focus on increased connectivity and on globally connected supply chains. This research therefore tries to combine the PI vision to PCS operations and ambitions.

Structures of PCS

Not every PCS is the same. Amongst other aspects, business models of PCS diverge. The research by Elbert & Tessmann (2021) shows that some PCS are relatively closed off, and others open up to more external stakeholders. For example, Portbase in The Netherlands has a more transactional business model. It develops its own services, without independent developers being able to add additional Value Adding Services (VAS), whereas the Networked Trade Platform (NTP), the PCS in Singapore, seems to open up more to other stakeholders, such as banks, insurance companies and independent service and platform developers (Elbert & Tessmann, 2021). Trust-building among stakeholders is easier when the PCS and its data are relatively closed off and exclusive. On the other hand, keeping the platform exclusive might limit the "breadth of available functions" (Elbert & Tessmann, 2021, p. 42).

Nikghadam et al. (2021) denote that information sharing in ports is complex, because the "information sharing links are interdependent and interorganisational" (Nikghadam et al., 2021, p. 19). This means that the operations of different port stakeholders rely heavily on information received from other stakeholders. Without effective and efficient information sharing, operations do not run smooth and seamless. They also conclude that "to improve information sharing, ports have to design operational information sharing guidelines fitting into their specific context" (p. 20). Here, it is argued that PCS try to design exactly that. They try to introduce operational information sharing guidelines by developing specific services that match specific needs from port stakeholders.

An interesting document that provides an overview of one PCS structure is given by Portbase in The Netherlands (2018). It shows a layered PCS structure. The slide in question is depicted in the figure below. The system is built on a layer with core infrastructure that is necessary for effective sharing of community data, such as databases for storage of data, CPU's for processing of data and API's for the interfaces with its users. A layer with core processes is built on top of this core infrastructure. This layer is related to the actual port operations and corresponding stakeholders. Port operations can be digitised by integration services offered by Portbase. This results in, for example, cargo agents only having to declare their cargo once through Portbase. Portbase then makes sure that all relevant stakeholders receive the necessary declarations. Once core processes are digitised, a layer with smart solutions can be implemented. Based on the data from the core processes, additional Value Adding Services can be developed. An example is Nextlogic, which optimises barge rotations in the Port of Rotterdam, based on real-time insights in barge locations and quay infrastructure performance.

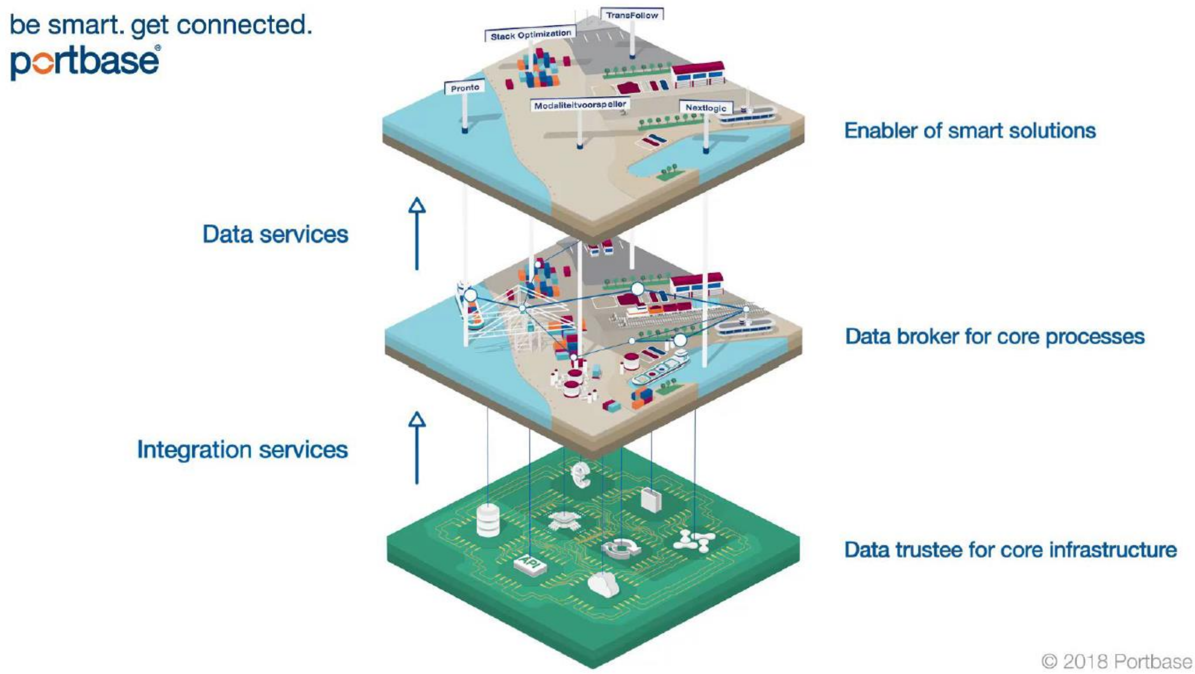

Figure 3: Portbase platform structure (source: Portbase, 2018)

Import of cargo operations at a port:

To make the term ‘port operations’ more comprehensive for laymen readers, a brief description of general port operations for the import of cargo is given below:

- Port call → process of vessel sailing towards a port, navigating through the port waterways and berthing at a terminal quay
- Terminal operations → process of unloading a vessel with quay cranes, moving containers to a storage area (i.e. stack), waiting to be picked up, and subsequently handing containers over for pick up. Generally, containers are picked up by trucks, trains or barges.
- Customs operations → processing cargo declarations from the shipper, assessing a risk level of the cargo, deciding whether or not to physically inspect the container and subsequently to release the container

2.3 Data sharing and data governance

Data sharing

For the Physical Internet to be successful, a high amount of information synchronisation between various stakeholders is necessary. In other words, data sharing is essential. Information technology has already been proven to be a facilitator of horizontal cooperation (Cruijssen, Dullaert & Fleuren, 2007). Horizontal cooperation, which is cooperation between the same stakeholder types, can lead to collective and mutual benefits and is necessary in the PI in order to achieve more efficient and sustainable logistics. Seamless, secure and confidential data exchange is a must, for which universal protocols need to be put into place. The adoption of these PI protocols among stakeholders depends, amongst others, on their perceived benefits.

Wisse (2007) argues that the constant increase in and demand for digital interconnectivity changes the approach to how to manage information. Especially on a larger societal scale, a different approach is needed. He argues that more focus should be put on information management for society as a whole, instead of information management from a traditional business point of view. This way, businesses can focus on their actual value-adding activities. In his words: "My argument is that the less a business needs to invest in readily available information, the more it can invest in efforts to differentiate itself." (Wisse, 2007, p. 12). This confirms the need for information systems in PI ports.

Hofman (2015) proposes a resource-oriented view on data sharing in transport and logistics, which is depicted in the figure below. A resource can be a truck driver, but can also be an entire organisation. Every resource has its own communication system for communicating with their environment and for sharing their data. Through services, interfaces and protocols, a Connectivity Infrastructure can be constructed. The communication systems of each resource are part of this infrastructure. The infrastructure offers generic services to resources through interfaces. Communication between the resources' communication systems is done through standardised protocols. This view on data sharing provides a conceptual structure for data sharing in the Physical Internet.

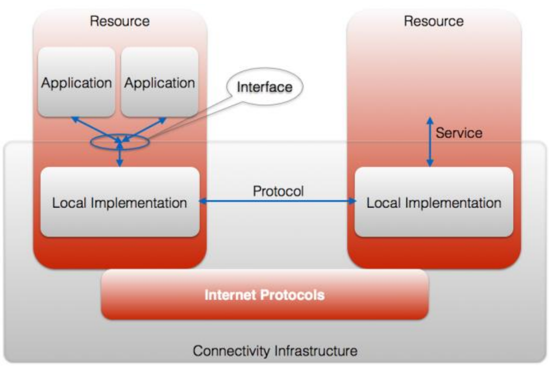

Figure 4: The concepts service, interface and protocol (source: Hofman, 2015)

Data governance

An overview of literature is presented that reflects scientific knowledge on data governance. Al-Ruithe, Benkhelifa & Hameed (2019) present a literature review on data governance and distinguish various definitions. As presented earlier, they conclude that data governance "refers to the entirety of decision rights and responsibilities concerning the management of data assets in organizations" (Al-Ruithe, Benkhelifa & Hameed, 2019, p. 842). Data governance is needed because stakeholders will not share their data unconditionally, as it might contain commercially sensitive information. To achieve a data sharing environment as illustrated above, the decision rights and responsibilities (i.e. governance) surrounding the use of data need to be defined. Various key dimensions for implementing data governance in cloud environments are defined and depicted in the figure below.

Figure 5: Key dimensions for cloud data governance (source: Al-Ruithe, Benkhelifa & Hameed, 2019)

Platforms such as Port Community Systems have gathered a network of stakeholders around them, which is essential for their functioning. In scientific literature, these networks around platforms may be called Platform Ecosystems (PE). A study on how to design data governance in such ecosystems, has been carried out by Lee, Zhu and Jeffery (2018). They state that a platform owner needs to make decisions on how it wants to design the interactions in the ecosystem. This is based on design principles and contingency factors of the ecosystem. Trade-offs have to be made on where to place certain governance factors (e.g. data ownership), either on the owner's side or the users' side. In doing so, a decentralised data governance architecture model is developed, which essentially means that the governance factors that have to be taken into account, are placed more around platform users than around the platform owner. It is argued that this method can be applied to other PEs as well.

Lis and Otto (2021) developed a taxonomy for ecosystem data governance. They define 8 important dimensions of data governance spread across three layers: an interaction layer, governance layer and data layer. The interaction layer typifies the interaction between different stakeholders in the ecosystem. The governance layer typifies the way in which the stakeholders' decision rights and responsibilities in the ecosystem are distributed. The data layer describes the way in which data is handled and used in the ecosystem. They conclude that central stakeholders in the ecosystem can have a large influence on data governance within that ecosystem. Therefore, it is important to clearly distinguish powerful stakeholders.

Khatri & Brown (2010) see data as an organisational asset. They define five data governance domains in which design decisions have to be made (principles, quality, metadata, access and lifecycle). By who these decisions are made, defines on what level of centrality the decisions are made. They call this level of centrality the 'locus of accountability'. This locus is said to be on a continuum between centralised and decentralised. This way, a data governance matrix can be constructed to easily distinguish what design decisions are made at what level of centralisation. It is argued here that this concept can also be applied to the design of the PI. An example of such a matrix is given in the table below.

Decision Domain / Locus of accountability	Data Principles	Data Quality	Metadata	Data Access	Data Lifecycle
Centralized	✓				
↑				✓	✓
			✓		
↓		✓			
Decentralized					

Table 1: Data governance matrix (source: Khatri & Brown, 2010)

2.4 Reflection on literature gap

The literature that has been presented in this chapter provides a steady basis for understanding both Port Community Systems and the Physical Internet. However, with regards to the background of the research, there are still knowledge gaps that need to be addressed. To assess the potential of PCS in the PI (specifically in PI ports), the following gaps still apply, as presented in the introduction:

1. It is not yet known **what, how and between who information is exchanged between PCS and its environment**.
2. It is not yet known **what, how and between who, information is exchanged in port-related operations in the Physical Internet**.

This research aims to address these gaps in the following way. The gap with regards to information exchange through PCS, is assessed according to a case study. By analysing a specific PCS, we can give an answer as to what, how and between who information is exchanged between PCS and its environment. The gap with regards to information exchange in port-related operations in the PI, is assessed according to more in depth desk research and document analysis. Key documents on the expected development of the PI provide answers as to what, how and between who information is exchanged in port-related operations in the PI. This research contributes to both bodies of literature in such a way that the knowledge gaps that are addressed here, are used for the assessment of the potential of PCS in the PI in the form of an information system design. The next chapter elaborates more on the methodologies used in this research.

3. Methodology and methods

This research is a multi-method research. This chapter presents an overarching methodology for the research (section 3.1), as well as various research methods for answering the specific sub questions (section 3.2).

3.1 Methodology

The main research question explicitly proposes a design of an information system in the Physical Internet (PI). The PI is a system that is still largely in the design phase. As mentioned before, no research has yet been performed that explores the potential role of Port Community Systems (PCS) in this design. Therefore, this research is a first, explorative, research that tries to provide a starting point to combine these two subjects. Given the focus on the design of an information system, various design approaches have been considered, of which Design Science Research (DSR) is argued to be the most suitable. For the other considered design approaches, we refer to appendix B. In this chapter, the DSR methodology is described first, after which the choice for this methodology is explained.

Design Science Research is a relatively novel design approach. One of the main contributing articles has been published by Hevner et al. (2004). They distinguish two paradigms for acquiring scientific knowledge: *behavioural* science and *design* science. Behavioural science is problem-oriented and tries to explain real-world phenomena. Design science is solution-oriented and focuses on the creation of something new: designing and validating a certain artefact, which can take on several forms (Offermann et al., 2010). Reflecting on design science, it is argued that: “In the design-science paradigm, knowledge and understanding of a problem domain and its solution are achieved in the building and application of the designed artefact” (Hevner et al., 2004, p. 75). This implies that the *process* of understanding and designing a solution is an essential part of the research, which is suitable for an explorative research, such as this one.

For performing design science in Information Systems (IS), Hevner et al. (2004) developed a framework which can be used as a guideline. It is depicted in the figure below.

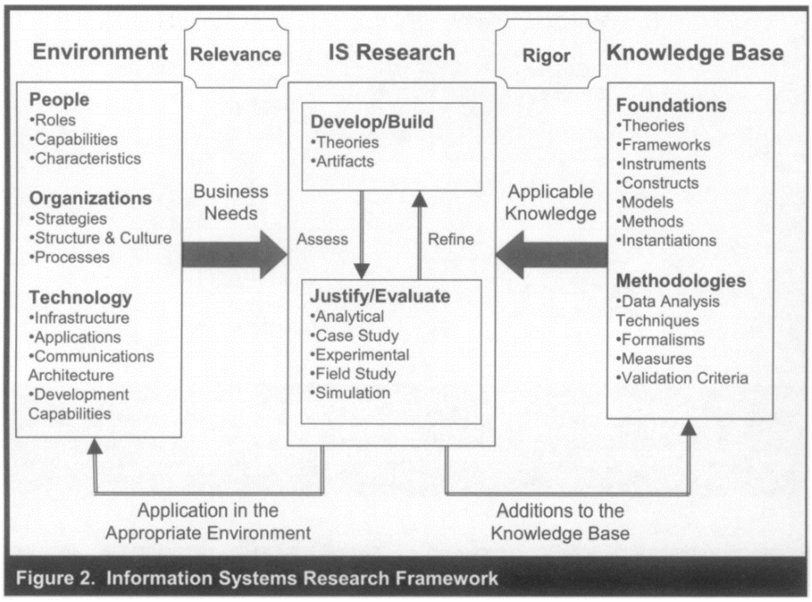

Figure 6: Design Science Research in Information Systems framework (source: Hevner et al., 2004)

In the framework, the research with regards to information systems is conceptually placed in between a certain environment and a knowledge base. The environment consists of the people, organisations and technology that are related to the research area. The knowledge base consists of available scientific literature and methodologies. The relation of the research to its environment reflects the relevance of the research. The relation of the research with the knowledge base reflects the rigor, i.e. the knowledge on which the research should build and eventually should add to. Within Design Science Research, there are two main activities: building and evaluating (March & Smith, 1995), which are reflected in the framework by Hevner et al. (2004). This building and evaluating of the artefact is very much a process of creation, in which the user or client can play a significant role (Peffers et al., 2007). Venable, Pries-Heje & Baskerville (2016) propose a framework for the evaluation of the artefact, in which four evaluation strategies exist: quick & simple; human risk & effectiveness; technical risk & efficacy; and purely technical artefact. To conclude, Hevner et al. (2004) propose seven guidelines for performing DSR: design as an artefact, problem relevance, design evaluation, research contributions, research rigor, design as a search process and communication of research. These guidelines should be adhered to when performing DSR.

Choosing Design Science Research as an overarching methodology seems to fit the research question. There are several reasons why DSR is considered as a suitable methodology for this research:

- The design of an actual artefact is central in DSR. This research tries to design a conceptual information system where PCS is involved in port-related operations in the PI. This conceptual design is argued to be the artefact in DSR.

- An explorative study, such as this one, relates to the notion of DSR that knowledge is gathered through building and applying an artefact. It is argued that such a pragmatic approach fits the main research question that asks to design a conceptual information exchange model where a PCS is involved in port-related operations in the PI.
- The process of designing and evaluating an artefact in DSR, relates well to the involvement of PI and PCS experts. The involvement of experts reflects communication of the research, which is one of the guidelines for DSR and essential for combining knowledge on the PI and PCS.

Following the Framework for Evaluation in Design Science Research (FEDS) by Venable, Pries-Heje & Baskerville (2016), the technical risk and efficacy evaluation strategy is most applicable to this research. The evaluation strategies depend on a balance between a naturalistic and summative evaluation approach for the design. The technical risk and efficacy strategy starts more summative and later, changes to a more naturalistic approach. It relates to design risks that have a more technical background and focus on the correct functioning of the artefact (i.e. efficacy). It is argued here that first, a more summative approach is desired, because the efficacy of the artefact is most important in earlier stages. Later, the implementation of the artefact in the real world is evaluated.

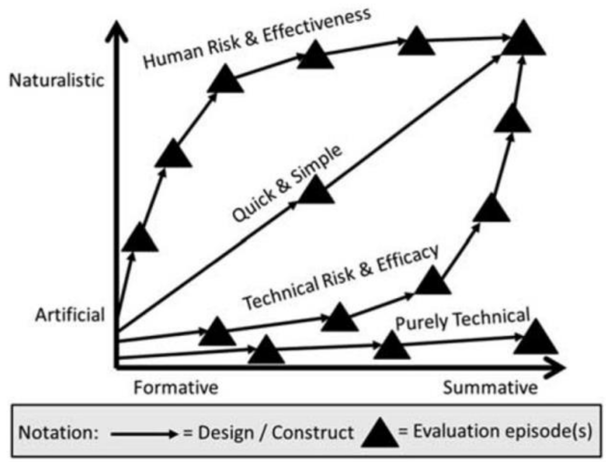

Figure 7: Framework for Evaluation in Design Science Research (source: Venable, Pries-Heje & Baskerville, 2016)

Other design methodologies have also been considered. These are the waterfall model, the V-model and the spiral model. However, due to the lack of applicability (no inherent iteration cycle in the waterfall model, rigid component requirements in the V-model and extensive, iterative risk analysis in the spiral model), these approaches have not been selected. For a detailed explanation on these methodologies, see appendix B.

The overall approach of the research is depicted in the figure below. The information exchange through a PCS forms the analysis of the research and provides answers to sub questions a and b. Sub question c, asking what information should be exchanged in the PI, can be answered by formulating requirements for the design. By combining the results of the analysis and the requirements into a design, and continuously evaluating it according to the DSR methodology, a final design is proposed. This design is validated with experts in both scientific fields (i.e. PI and PCS). The outcomes of the design are translated into recommendations regarding the potential of Port Community Systems as information intermediaries in the Physical Internet.

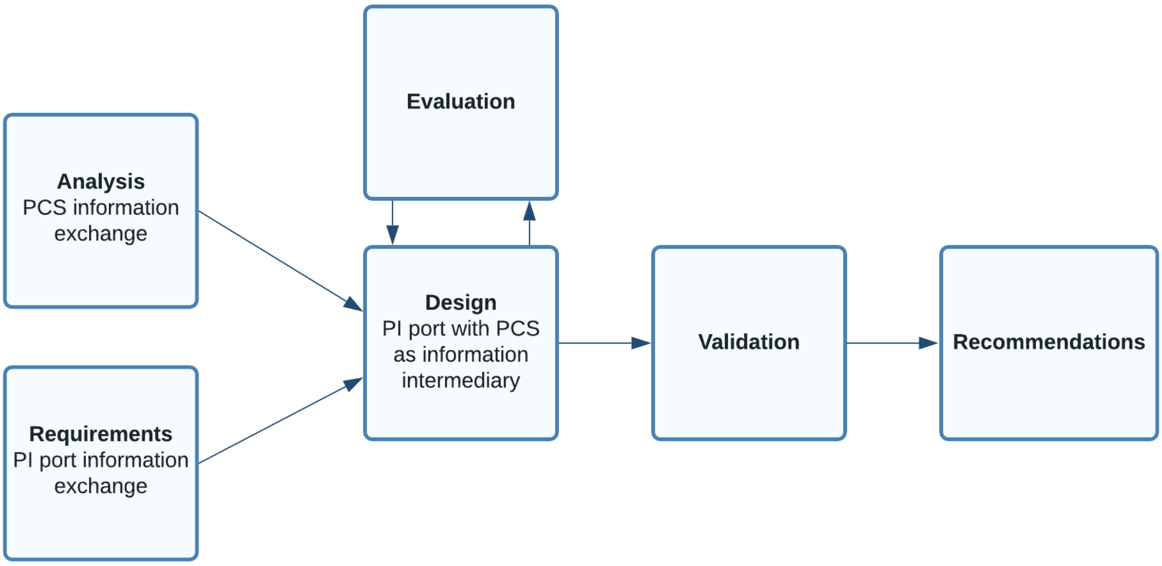

Figure 8: Research approach

3.2 Methods

The research consists of several sub questions. Each sub question has its own deliverables and methods. This section discusses the different methods and deliverables per sub question.

Sub question a and b (“*What information is exchanged in PCS?” & “How and between who is information exchanged in PCS?*”)

Deliverable: information exchange model of a PCS

Methods: Case study & BPMN as tool

Questions a and b can be answered by mapping an information exchange model of a PCS, which shows the specific information that is sent between different stakeholders in a port environment. To do this, a specific port environment needs to be chosen. Therefore, a case study is proposed. There are several operational Port Community Systems throughout the world (Moros-Daza, Amaya-Mier & Paternina-Arboleda, 2020). As stated before, scientific literature on PCS lags behind on PCS operations. This research adds to this scientific literature by performing a case study. The PCS that is chosen in this research is Portbase, the PCS of The Netherlands. The main port of The Netherlands is the Port of Rotterdam, one of the largest and most innovative ports around the globe[5]. Due to the size of the port, Portbase facilitates services for a wide range of stakeholders. At the same time, innovation in the port ensures that Portbase has to adapt to the latest developments. This is argued to support our choice for taking Portbase as a case for PCS. Furthermore, Dennis Dortland, Innovation Consultant at Portbase, has agreed to guide this research and is available for consultation. A case study is a widely used scientific method and "is best defined as an intensive study of a single unit with an aim to generalize across a larger set of units" (Gerring, 2004). Where possible, this research will generalise recommendations and implications for Portbase to the PCS community.

The standard Business Process Modelling Notation (BPMN) is a tool to graphically represent business processes and their interrelations. It is applied here to analyse Portbase's processes. It is an easy to use and understand tool, while still retaining the possibility to capture complex processes (Owen & Raj, 2003). The reason we choose BPMN as a tool for the analysis, is that it allows for a large chain of interdependent processes to be captured in one diagram, in contrast to for example IDEF0, which allows a maximum number of processes in one diagram (International Organization for Standardization [ISO], 2012). This is useful for our analysis, as we capture all stakeholder processes that are related to the import of a container, from being on a deep sea vessel, to being transported to the hinterland. The model that is produced with BPMN is called a Business Process Diagram (BPD).

Sub question c ("*What information would need to be exchanged in port-related operations in the PI, compared to the information exchange in PCS?*")

Deliverable: Requirements for an information exchange model in the PI

Methods: Desk research

Question c can be answered by formulating rigid requirements for the design. These requirements reflect the type of information that would need to be exchanged in port-related operations in the PI. The formulation of requirements is based on desk research, and specifically on document analysis.

Document analysis is a widely used method in qualitative research. Bowen (2009) stresses that the *purpose*, the *context* and the *intended audience* of the document repeatedly have to be kept in mind when using document analysis as a research method. This repetitive nature relates well

[5] https://www.portofrotterdam.com/sites/default/files/2021-06/facts-and-figures-port-of-rotterdam.pdf
https://www.ship-technology.com/features/feature-the-worlds-10-biggest-ports/

to the evaluative nature of the DSR methodology. The documents that are analysed to answer sub question c, are continuously evaluated in the context of this research, which is used to strengthen the requirements.

Sub question d (“*What is a potential way how and between who this additional information is exchanged in the PI?*”)

Deliverable: Conceptual design of a PI port information system, with integrated PCS services

Methods: Conceptual modelling, IDEF0 as tool and expert interviews for evaluation

Question d is related to the actual design of the DSR artefact. It combines the knowledge that has been gathered in the analysis with the formulated requirements. The design is developed in an iterative way with continuous evaluation, according to the FEDS framework by Venable, Pries-Heje & Baskerville (2016). PI experts provide the evaluation of proposed designs. A list of consulted experts is provided at the end of this section.

Conceptual modelling is chosen as a design method for the development of the information system. The reason for this is that the explorative nature of this research asks for a design on conceptual level, rather than on a very concrete level. In this regard, conceptual modelling is considered to be a feasible method for the development of the design. IDEF0 is chosen as design tool, instead of BPMN. BPMN, the tool used for mapping Portbase’s existing business processes, is considered too detailed for a future conceptual information model, as it requires explicit time constraints and information flows (García-Domínguez, Marcos & Medina, 2012). This means that business processes have to be modelled in a sequential way, with a precise definition of every piece of information. IDEF0 does *not* have these requirements. Because explicit time constraints and information flows are not yet fully known for PI ports, IDEF0 is argued to be a suitable tool for designing a conceptual PI port information system.

IDEF0 is a function modelling tool (International Organization for Standardization [ISO], 2012). Function modelling is suitable here, because especially new functions in PI ports are an interesting topic for research. Several functions within a certain environment and their interrelations need to be defined. The functions are modelled by using *input*, *output*, *control* and *resource* variables. Not all functions require inputs, but they all do require output, control and resource variables. A graphical representation of a function with corresponding input, output, resource and control variables is depicted in the figure below. The structure of IDEF0 models is as follows. There is one main function to be modelled, which is on a level called A-0. This function can be split up into multiple sub functions on a lower level, which is called the A0 level. Functions on A0 level can be split up into more detailed sub functions, which is called the A1 level, and so forth. Each higher level diagram needs to contain all input, output, resource and control variables from the lower levels. This way, functions can be modelled with as much detail as necessary.

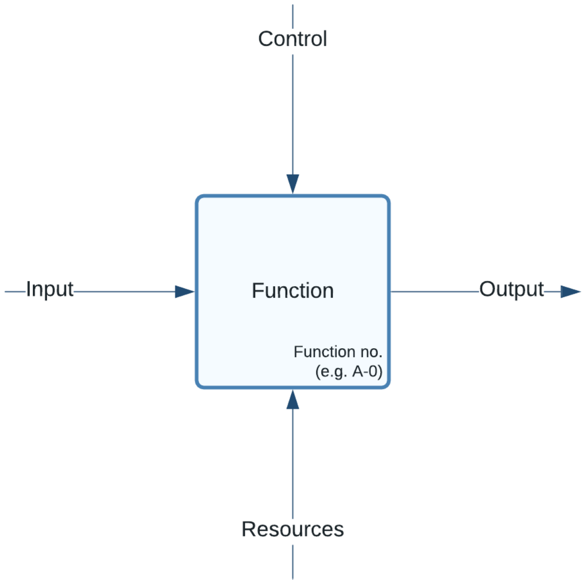

Figure 9: IDEF0 function representation

For the evaluation and validation of the conceptual information system (i.e. designed artefact), semi-structured interviews with PI and PCS experts are used. Semi-structured interviews are interviews where there is no strict set of questions, but the interviewer does provide a certain structure to the interview. The reason we use expert interviews, is that we evaluate and validate a non-existent design. Therefore, conducting interviews is argued to be the only suitable method. Disadvantages of semi-structured interviews are that they are time-consuming to prepare, conduct and analyze, which makes them costly (Adams, 2015). Consequently, retrieving a large enough sample size, is difficult. Advantages are that semi-structured interviews are suitable for "open-ended questions [that] require follow-up queries" (Adams, 2015, p. 367), and that they are useful when you want to know the thoughts of each individual on a topic. Because we want to incrementally develop, evaluate and validate the information system by distinguishing the views of individual experts – and asking follow-up questions –, semi-structured interviews are considered suitable for the evaluation and validation of the designed artefact.

Sub question e ("*What role can a PCS have in this desired way of information exchange in the PI?*")

Deliverable: Recommendations based on outcomes of the design

The last sub question merges the outcomes of the design into recommendations to Portbase. Where possible, recommendations will be generalised to the PCS community as well. Based on the evaluation episodes with each interviewee, recommendations based on the design can be incrementally sharpened.

Consulted experts for evaluation and validation interviews

To be able to evaluate and validate the information system, expert knowledge in both research areas is necessary. Below, there is a list of interviewees whose expert knowledge is used for evaluation and validation of the design developed in this research:

1. Arjan van Binsbergen (Dr.ir.)	a.j.vanbinsbergen@tudelft.nl
2. Yusong Pang (Dr.ir.)	y.pang@tudelft.nl
3. Dennis Dortland (Ir.)	d.dortland@portbase.com
4. Patrick Fahim (Ir.)	p.b.m.fahim@tudelft.nl
5. Lori Tavasszy (Prof.dr.ir.)	L.A.Tavasszy@tudelft.nl
6. Nick Szirbik (Dr.)	n.b.szirbik@rug.nl
7. Rod Franklin (Prof.dr.ir.)	rod.franklin@the-klu.org
8. Benoit Montreuil (Prof.dr.ir.)	benoit.montreuil@isye.gatech.edu
9. Thierry Vanelslander (Prof.dr.)	thierry.vanelslander@uantwerpen.be
10. Pieter de Waard	pieter.dewaard@portofrotterdam.com
11. Mariam Lafkihi (Dr.ir.)	mariam.lafkihi@mines-paristech.fr
12. Salvador Furió Pruñunosa (Dr.ir.)	sfurio@fundacion.valenciaport.com

4. Case study analysis

This chapter presents the case study analysis of the Port Community System (PCS) that is applied in this research: Portbase. The first section (4.1) presents an explanation of the physical processes that happen in a port. In the second section (4.2), the information exchange processes that are facilitated by Portbase, are discussed. The third section (4.3) presents conclusions for sub questions a and b, regarding what, how and between who information is exchanged through PCS.

Reflection on methodology and methods

As stated in the previous chapter, the overarching methodology of this research is Design Science Research (DSR). The framework for DSR in Information Systems (IS) has been depicted in the previous chapter. Here, a short reflection on the relationship between this framework and this research is given. The environment of this research is a PCS. The business needs of the PCS reflect the relevance of the research. Literature and documents on the Physical Internet (PI) form the knowledge base and rigor of the research. In DSR in IS, an artefact is developed. The information system of the PCS is considered a sub artefact. Relating to Peffers et al. (2007), it is developed and evaluated as a case study with the user or client itself: Portbase. In essence, the information system of a PCS is not a new artefact that is being developed, because it already exists, albeit in another format. The development of a conceptual design of a PI port where information from Portbase is integrated, does lead to a new artefact. The method that is used for representing a PCS is a case study. The specific methods for illustrating port processes and Portbase's business processes are IDEF0 and BPMN, respectively.

This chapter describes the business processes of the Port Community System Portbase. It answers the following sub questions:

- ***(a) What information is exchanged in PCS?***
- ***(b) How and between who is information exchanged in PCS?***

To better understand the information flows that will be presented in this chapter, first, the physical processes to which a container is subjected, are discussed. This is from the perspective of a container. Then, the perspective shifts towards that of Portbase. The information that is exchanged between Portbase and its surroundings are analysed, as well as the relation between the exchanged information and the services offered by Portbase.

4.1 Physical port processes

The physical processes that a container goes through during the import process are presented by means of an IDEF0 diagram (International Organization for Standardization [ISO], 2012). Such a diagram decomposes a process into sub processes, each with its own input, output, resources and control mechanisms. Below, a high level (i.e. A-0) IDEF0 diagram of the current import process of a container is presented.

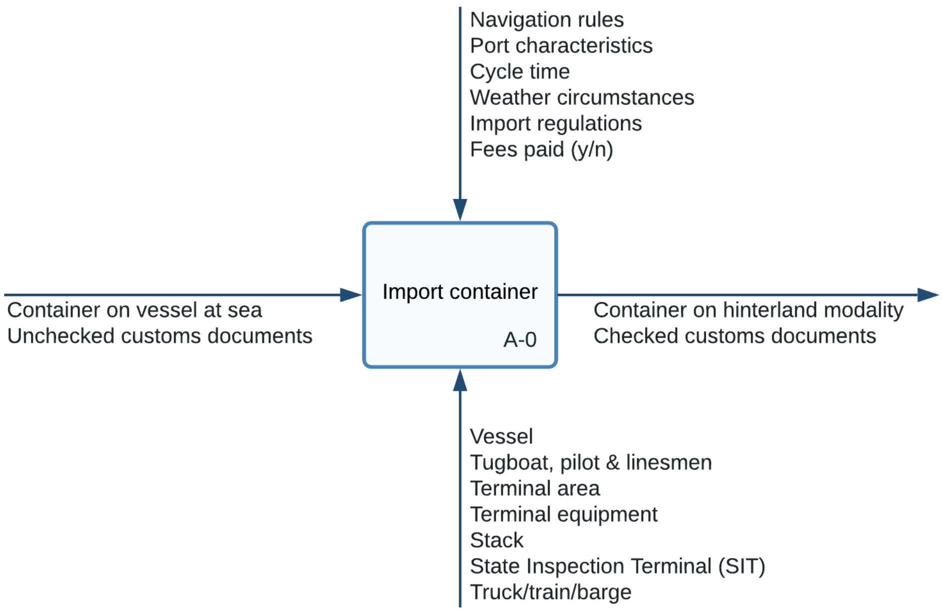

Figure 10: IDEF0 diagram of the import process of a container at the port (level A-0)

As can be seen, a container on a vessel at sea and unchecked customs documents are the input of the import process. This means that they will undergo some sort of transformation, supported by the resources (bottom arrow) and controlled by control mechanisms (top arrow). The output of the import process is an imported container on a hinterland modality, as well as checked customs documents. Navigation rules, port characteristics, cycle times, weather circumstances, import regulations and paid fees determine how the import of a container is executed. The process is supported by the resources vessel, tugboat, pilot, linesman, terminal area & equipment, stack, State Inspection Terminal (SIT) and a truck, train or barge.

A more detailed version (i.e. A0 level) of the IDEF0 diagram is shown below.

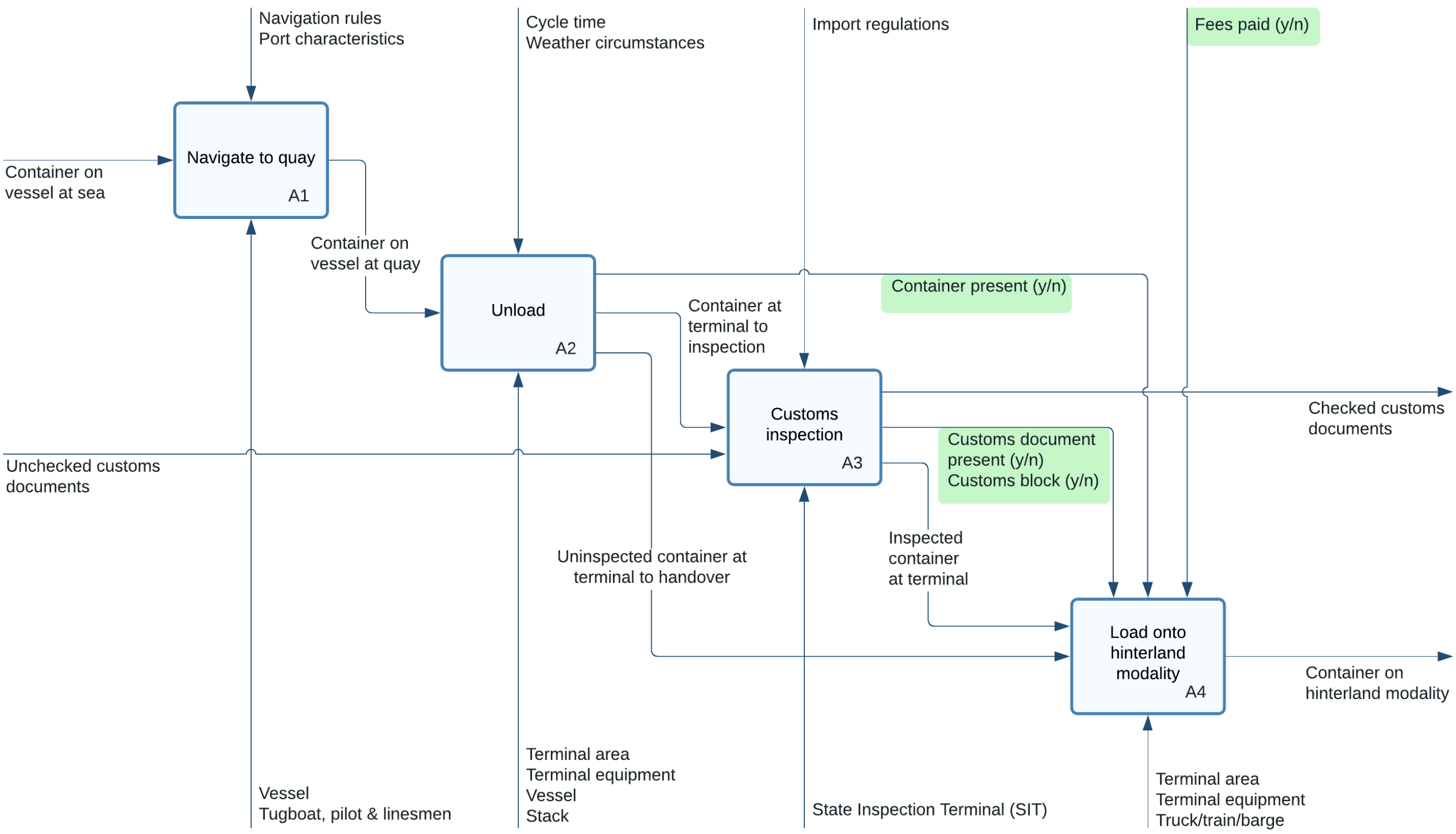

Figure 11: IDEF0 diagram of the import process of a container at the port (level A0)

The detailed version contains exactly the same inputs, outputs, resources and control mechanisms as the high level version. A transformation of the container can be distinguished: from sea to quay, from quay to terminal, from terminal either to customs inspection, or to the hinterland modality. The diagram also clearly shows green boxes, which contain four important status indicators, or checks, in the import process. Only when all four checks can be answered with "yes", the container may leave the terminal using a hinterland modality. The first check in order for a container to leave the terminal, is whether it is present at the terminal. Sometimes not all containers can be unloaded from a vessel. Consequently, it clearly cannot leave the terminal either. The second check refers to whether an import document is present. Only when the right import documents have been submitted to customs and this can be checked at the terminal, the container may be released. The third check is whether customs has blocked the container from leaving the terminal. This can be a consequence of their inspection. Reasons can range from not having the right permit, to the container carrying prohibited cargo. The final check before a container may leave the terminal area, is whether all fees and dues have been paid. Only when the shipper has paid the carrier for the transport of the container, it may leave the terminal. These four status indicators are captured in one of Portbase's services: cargo controller. This service is discussed in more detail later on.

As can be seen in the IDEF0 diagram, there is no inherent feedback loop during the process. The connection of processes means that the functions depend on each other, but the lack of feedback loops shows that the processes are not readjusting their operations on each other. The PI addresses this by connecting logistics processes on an informational level in such a way that operations of one process determine the optimal operations of other processes. For example, customs' inspection operations may affect the optimal planning of terminal operations. When the whole chain of operations in the port shares information to each other, overall efficiency and sustainability may be increased, because of the optimal adjustment of operations on each other.

4.2 Portbase information exchange processes

The PCS in the Netherlands is called Portbase. As stated before, this research takes Portbase as a case study for PCS. Portbase currently processes data of various port operations. In (Portbase, 2020) there is a list of 44 processes in which information exchange about certain port processes takes place. The complete list of port operation processes can be found on Portbase's website[6]. The processes are grouped as follows:

- Ships' calls
- Import cargo
- Hinterland transport
- Export cargo

In (Portbase, 2020) different target groups for the services of Portbase are defined. These target groups are stakeholders of Portbase:

- Agents
- Barge operators
- Customs
- Empty depots
- Exporters
- Food & Consumer Product Safety Authority
- Forwarders
- Importers
- Inspection stations
- Port authorities
- Rail infrastructure operators/hauliers
- Rijkswaterstaat
- Road hauliers
- Royal Netherlands Marechaussee
- Seaport police
- Skippers
- Shipbrokers/Shipping companies
- Terminals

Together with Dennis Dortland, innovation consultant at Portbase, a rearranged list of stakeholders has been constructed. Some stakeholders have been left out, because they are not relevant to this

[6] https://www.portbase.com/en/services/

research (e.g. exporters). Other stakeholders have been clustered, to not make the research too complex (e.g. rail, road and barge operators into hinterland transporter). The relevant stakeholders for information exchange that are included in this research are presented below. Appendix C provides an explanation of the functions of the relevant stakeholders.

- Carrier:
  - Ship agent
  - Cargo agent
- Customs
- Terminal
- Expeditor
- Hinterland transporter
- Nederlandse Voedsel en Waren Autoriteit (NVWA); Netherlands Food & Consumer Product Safety Authority
- Port Authority
- Harbour Master
- Nautical service provider
- Koninklijke Marechaussee; Royal Netherlands Marechaussee
- Seaport Police
- Rijkswaterstaat (RWS): part of the Dutch Ministry of Infrastructure and Water Management
- Inspectie Leefomgeving & Transport (ILT); Human Environment & Transport Inspectorate
- Centraal Bureau voor de Statistiek (CBS); Statistics Netherlands
- SafeSeaNet

For PCS, and for Portbase specifically, three types of information flows can be distinguished. The first is related to the Estimated Time of Arrival (ETA) and concerns logistics flows and routing flows. The second is related to the cargo content, which refers to the actual goods that are being transported. This is important information that is needed for customs clearance. The type of goods determine the clearance level that is needed. For example, the customs procedure for dangerous goods, such as flammable liquids, is different than the one for consumer electronics. The third information flow concerns financial transactions that are related to the physical flow of goods. The financial information flow can serve as a controlling factor for the physical movement of goods. For example, if a payment has not been made, a container will not be transported.

Portbase acts as an intermediary for information exchange between stakeholders in port operations. This means that it can receive and send information. Portbase exchanges information with stakeholders through several services, either via web interface (i.e. webpage) or via system interface (i.e. information systems of concerning stakeholder). Each service is related to specific port operations. For each service, information is exchanged from stakeholders to Portbase or from Portbase to stakeholders. The table below presents the selected services regarding the scope of this research. A short description of each service is provided, together with the stakeholders that are related to the service. Appendix D presents a detailed explanation of all selected services, and shows a Business Process Diagram of the information exchange between stakeholders that is facilitated by Portbase.

Number in (Portbase, 2020)	Service name	Description	Related stakeholder
4.	Vessel notification	Notifies arrival of vessel	Ship agent, Customs, Harbour Master, Nautical service provider, SafeSeaNet
39.	Notification crew and passengers	Notifies arrival of crew and passengers	Ship agent, Marechaussee Seaport police
35.	Seaport statistics	Provides relevant statistics	Port Authority, CBS
14.	Cargo declaration import	Handles summary declarations	Cargo agent, Customs
2.	Notification dangerous goods	Notifies arrival of dangerous goods	Cargo agent, Terminal, Harbour Master, Rijkswaterstaat, ILT, SafeSeaNet
3.	Notification single window	Notifies SPOC NL with notifications and vessel's ATA and ATD	Port Authority, SafeSeaNet
7.	Inspection portal	Overview for status of inspection processes	Customs, Cargo agent, Terminal, Expeditor, Hinterland transporter
8.	Cargo controller	Overview for T&T information	Terminal, Ship agent, Cargo agent, Expeditor, Hinterland transporter
12.	Notification local clearance	Handles simple customs procedure	Customs, cargo agent
16.	Notification import documentation	Notifies customs documents to terminal	Terminal, Expeditor, Hinterland transporter
17.	Transit declaration	Handles full customs procedure	Cargo agent, Customs, Expeditor
1.	Notification waste disposal	Notifies arrival of waste on board of vessel	Ship agent, Harbour Master, Port Authority, SafeSeaNet
41.	Notification ship's stores	Notifies content of ship's stores	Ship agent, Customs, Harbour Master
15.	Declaration food and consumer products	Handles declarations for import of food and consumer products	Cargo agent, NVWA
21.	Pre-arrival cargo declaration import (4h)	Handles Entry Summary Declarations	Cargo agent, Customs
9.	Discharge confirmation report	Confirms discharge of containers from vessel	Terminal, Cargo agent
19.	Veterinary inspection process	Overview for status of veterinary inspections	NVWA, Cargo agent, Terminal, Expeditor, Hinterland transporter
23.	Inland port dues	Notifies arrival of inland barge and handles payments	Hinterland transporter, Port Authority
24.	Wagonload information system	Notifies composition of containers on train	Hinterland transporter, RWS
42.	Hinterland container notification road, rail & barge	Notifies arrival of truck, train or barge	Hinterland transporter, Terminal

Table 2: Portbase services description and related stakeholders

Which stakeholder sends and receives which information, is depicted in the figure below. An incoming arrow means that information is received; an outgoing arrow means that information is sent. The names next to the arrows represent the names of Portbase's services. A distinction has been made between active and passive stakeholders: active stakeholders send and receive information; passive stakeholders only receive information.

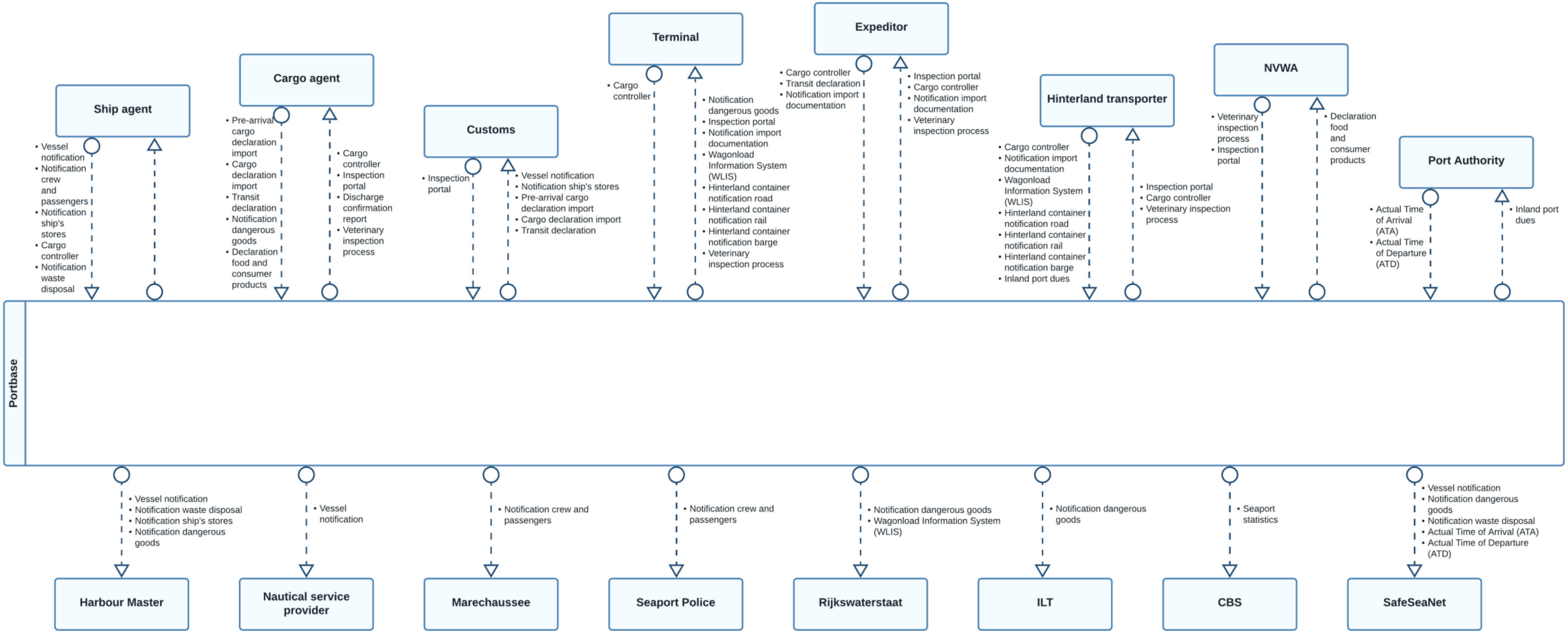

Figure 12: Black box BPD of information exchange between Portbase and its environment

4.3 Conclusion

This chapter has provided an analysis of Portbase's operations. By analysing the information flows between Portbase and its environment, answers to the following sub questions can be provided:

(a) What information is exchanged in PCS?

(b) How and between who is information exchanged in PCS?

What:

A wide variety of information is exchanged between stakeholders through Portbase. It can be concluded that notifications are an important part of Portbase's operations. These notifications, as the word already implies, notifies stakeholders about an event that happens or a fact about cargo related or vessel related aspects. This can be for example the arrival of a ship, or the notification of the presence of dangerous goods.

Additionally, information exchange regarding customs processes is important. Many services for different declarations of cargo exist, as well as services surrounding the inspection process by customs.

How:

The way how information is exchanged between Portbase and its environment comes down to two options: either via a system interface or via a web interface. A system interface means that the stakeholder in question has its own system in which the Portbase service is integrated. For example, a hinterland transporter has its own planning platform in which they can also notify the arrival of a truck driver at a terminal via Portbase. A web interface means that the stakeholder in question can issue or receive its information to or from Portbase via a web browser.

Between who:

Two groups of stakeholders can be distinguished which are defined here as active and passive stakeholders. Active stakeholders are stakeholders that receive information from Portbase, but also send information back. There is actual back and forth exchange of information. Often, the information that is received triggers a stakeholder's process, after which information resulting from this process is sent back. Passive stakeholders are stakeholders that only receive information and base (part of) their operations on the information received.

5. Design requirements

In the previous chapter, the results of the analysis of Portbase's operations have been presented. The relation between Portbase's services and relevant stakeholders has been discussed. The interrelation between the different services can be found in appendix D. By doing so, we now know what information is exchanged between which Port Community System (PCS) stakeholders in the Port of Rotterdam. The information that is exchanged has been defined as message flows, in accordance with Business Process Model Notation (BPMN) syntax. This chapter focuses on the information exchange in Physical Internet (PI) ports, and therefore presents an answer on the following sub question:

(c) What information would need to be exchanged in port-related operations in the PI, compared to the information exchange in PCS?

First, the methods that are applied to answer this research question are discussed. Thereafter, results and answers to the sub question are presented.

Methods

The methods that are applied to answer sub question c, are desk research and document analysis. By exploring available documents and relevant PI literature, several additional information exchange categories can be distilled.

Results

The goal of sub question c is to define what information needs to be exchanged in port-related operations in the PI. Consequently, the question rises where PI information exchange differs from information exchange in current port operations and where there are similarities. It is argued here that the physical processes that currently happen in a port will largely remain in PI ports as well. PI containers will still be on a vessel, will be unloaded at a terminal, will be scanned for security issues by customs and will still be transported to the hinterland by a certain modality. Therefore, the *content* of the information exchange is argued to remain as well. For example, to import a container in the PI, certain documentation about its content will still be necessary. This does not imply that the *arrangement* of the information exchange will also remain. This can and probably will greatly differ. How this information exchange could be arranged or designed, is presented in chapter 6.

Thus, it is argued that the majority of the message *content* of the information exchange that has been analysed in the previous chapter, will remain in the PI. Subsequently, the question rises whether there is any additional information that would need to be exchanged in the PI. The PI roadmap by Alice-ETP (2020) once more provides good support for answering this question. As stated before, the document focuses on several development areas. Below, additional information exchange is discussed per development area.

5.1 Additional information exchange based on PI roadmap

Logistics nodes

The first development area in the PI roadmap is related to logistics nodes. According to the roadmap, one of the developments that logistics nodes have to focus on is an "improvement of the services' visibility" (Alice-ETP, 2020, p. 8). This implies that port terminals, as logistics nodes, have to increase the visibility of the flow of containers through their processes. In other words, port terminals have to provide track and trace information of the PI containers being handled. Fahim et al. (2021) have developed an information architecture for a track-and-trace system in PI ports. Thus, extensive track-and-trace information of PI containers is additional information that would need to be exchanged in PI ports.

Logistics networks

The second development area in the PI roadmap is related to logistics networks. Here, the roadmap provides another useful input for additional information exchange. One generation states that there should be sense-and-respond optimisation of network flows through predictive control (Alice-ETP, 2020). Through intensive information exchange in a port, and through the track-and-trace systems mentioned above, capacities of port services can be made visible (i.e. sense). Based on this, measures can be taken to optimally make use of these capacities (i.e. respond). Additionally, networks should be able to adjust assignments and routings in a dynamic way. By continuously monitoring network states and adjusting operations based on these network states, capacities of port operations can be optimised. An example of a company that provides sense-and-respond services, is Nextlogic. Nextlogic optimises inland barge rotations, based on available network data. Thus, capacity optimisation information is additional information that would need to be exchanged in PI ports.

System of logistics networks

The third development area in the PI roadmap is related to systems of logistics networks. Flows in the envisioned systems of logistics networks are presented as goods flows, information flows and financial flows. This means that next to the flow of PI containers, and the flow of information regarding those PI containers, there should also be a financial flow that accommodates transactions and actual payments. Payments have related meta-information, such as reference or order numbers, that have to be exchanged as well. Thus, payment-related (financial) meta-information would be additional information that needs to be exchanged in PI ports.

Access and adoption

The fourth development area in the PI roadmap is related to access and adoption. It is stated that ultimately, everyone should be able to access the PI. This means that individual consigners and consignees should have direct access to the PI through open interfaces. In current maritime freight transport, there are numerous logistics service providers that operate on behalf of the consigner or consignee. The actual consigner or consignee exchanges documents with this logistics service provider to arrange the transport of cargo. According to the roadmap, the PI should provide these consigners and consignees with digital access points. This implies that these access points should be able to handle all information that is now provided by consigners and consignees to logistics service providers. This is translated freely here as “last-mile document exchange”. Thus, the documents that are exchanged now between consigner or consignee and the logistics service provider, should be exchanged via digital access points in the PI and can be viewed as additional information exchange in the PI.

Governance

The fifth development area in the PI roadmap is related to governance. One of the envisioned achievements is that there should be rules for an open network, where bottom-up development is encouraged by the supervision of governance bodies (Alice-ETP, 2020). Additionally, “routing of cargo through the network and service assignments are managed transparently according to common agreed rules, to ensure fair allocation of costs, risks and responsibilities among the involved providers” (Alice-ETP, 2020, p. 25). This implies that legal information needs to be exchanged between governance bodies and operators of logistics nodes, logistics networks and systems of logistics networks. Therefore, legal governance related information is additional information that should be exchanged in the PI.

5.2 Conclusion

This chapter has answered the following research question:

(c) What information would need to be exchanged in port-related operations in the PI, compared to the information exchange in PCS?

It can be concluded that in the PI, various additional information streams exist. Distilled from the PI roadmap (Alice-ETP, 2020), they are:

- More extensive track and trace information
- Sense-and-respond optimisation information
- Financial information
- Information from and to consigners and consignees through digital access points ("last-mile document exchange")
- Common agreed rules and regulations (governance related information)

As mentioned in chapter 2, the introduction of modular PI containers and a network of information exchange platforms, are two innovations of the PI. These can be related to the additional information streams. Firstly, PI containers carry specific information about their shipment and content. This information needs to be readily available through track and trace services at any point in time. This is processed by information platforms. Based on, amongst others, track and trace information, network flows of PI containers may be optimised. Additionally, track and trace information can provide confirmations on the transfer of cargo from one stakeholder to another, which can be used as a basis for the initiation of payments. Information platforms in the PI need to process this optimisation and financial information. Additionally, they need to process demands of consigners and consignees about the movement of the cargo. Lastly, the decision rights and responsibilities of stakeholders need to be taken into account by information exchange platforms in the form of governance related information.

Requirement:

Multiple additional information streams exist in the PI. To make this research more manageable, we choose to specifically include sense-and respond optimisation information in the design. The reason for this is that it is argued that optimisation functionalities in the PI contribute for a great deal to the increase in the efficiency of logistics. The other additional information streams are captured in some parts of the design, but they are not as explicitly designed as the sense-and-respond optimisation information streams. Therefore, the following requirement is applied:

The designed information system should be able to optimise network flows based on sense-and-respond information

6. Design

The previous chapters have discussed the case study analysis of the information exchange of Portbase (sub questions a and b), as well as the requirements for a Physical Internet (PI) port information system (sub question c). This chapter presents a high level design of the information system (section 6.1) and a detailed design of one of the information system's functions (section 6.3). It also presents the integration of Portbase services in the design (sections 6.2 and 6.4) In this chapter, the following sub question is answered:

(d) What is a potential way how and between who this information is exchanged in the PI?

Methodology

Through the analysis of Portbase's operations, we now know what and between who information is exchanged through Port Community Systems (PCS). We also know what additional type of information should be exchanged in PI ports, compared to the exchange in current ports. This additional information has been formulated in the form of requirements. The analysis and requirements serve as input for a potential design of a PI port information system. By continuous evaluation, a final design is proposed, which is then validated. Based on the outcomes of the design, recommendations to Portbase are given. This approach is depicted in the figure below.

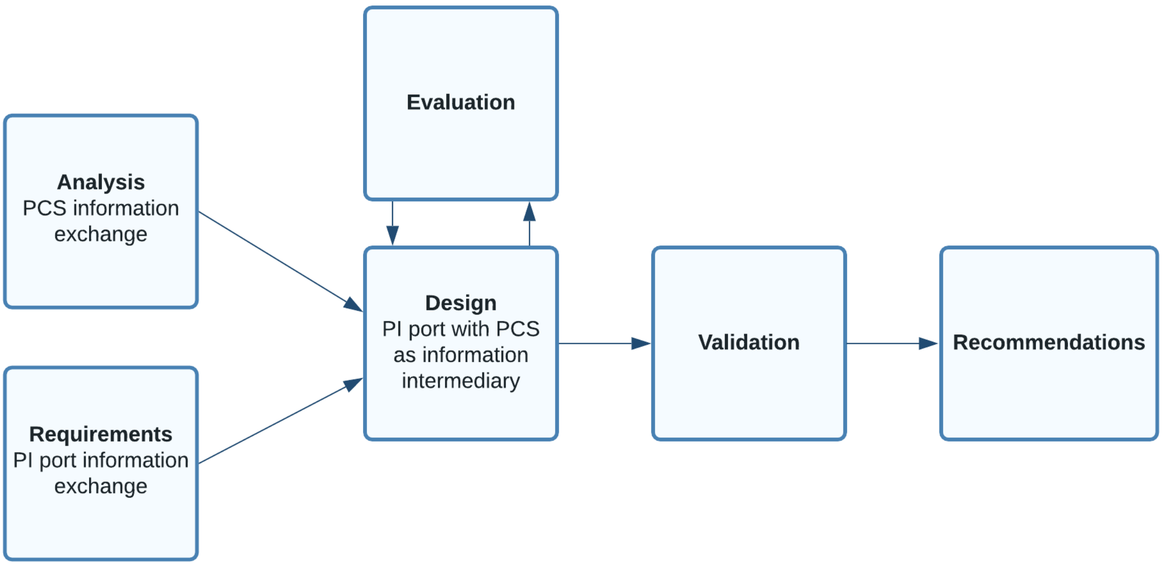

Figure 13: Research approach

As stated in the methodology chapter, the design is developed according to the Design Science Research (DSR) methodology. This means that the design is built and evaluated in increments. Following the framework by Venable, Pries-Heje & Baskerville (2016), the technical risk and efficacy evaluation strategy, is applied. The design tool that is used is IDEF0. The focus in the design lies on the potential use of information from the OLI-model and the use of information available at Portbase. In this chapter, the designed artefact is explained first. The main evaluation aspects, as well as the validation of the design and the consequent recommendations to PCS, are presented in chapter 7.

Design explanation

The proposed design consists of two designs: a high level design (A0 level) and a detailed design (A1 level). They are depicted in figures 17 and 18, respectively. Both designs have the same consistency. The information exchange is designed as information exchange between port functions and the OLI model and between port functions and Portbase.

The information exchange between the different port functions and the OLI model is depicted with green arrows. Every piece of information is related to a specific layer in the OLI model. The layer numbers in the OLI model (figure 1) represent the according layer. Not all layers have been take into account in the research. The physical layer is not included because the scope of this research is related to the *information* regarding physical processes, and not to the actual physical entities. The link layer is not included because of scoping of the research as well. It is assumed that the digital mirror of the physical entities and processes is correct. The logistics web layer is also not included because of scoping of the research. Instead, it is assumed that all information to and from users of the PI is readily available whenever needed.

The information exchange between the different port functions and Portbase is depicted with blue arrows. Every piece of information in the design is related to a specific Portbase service, discussed in the case study analysis (chapter 4). The reason for designing the information exchange using the layers of the OLI model, is that it provides a good structure for the information exchange in the PI. By combining OLI model information exchange and Portbase information exchange into one design, a potential design of an information system of a PI port with PCS as information intermediary is proposed.

In line with Montreuil, Ballot & Fontane (2012), the information that is exchanged per layer in the OLI model, is explained below. As stated, the information from the physical layer, link layer and logistics web layer are not included in the design. Instead, it is argued that through informational synchronisation between all layers, the essential information exchange within this research's scope can be captured in the other, following layers:

1. **Network layer**

   The network layer exchanges transport handling characteristics and monitors the network state. This means that the availability and characteristics of nodes, links and PI transporters is retrieved from this layer. The performance of a Logistics Service Provider (LSP) is implemented as the Level of Service (LoS), which is also captured in the network layer. Also, once a certain node, link or transporter is in use, this is fed back to the network layer of the OLI model. This way, the network layer provides a real-time representation of the state of the network. Additionally, it contains information for predictions of the use of the network. If one of the other layers has assigned a container to a certain route or a shipment to a certain container in the future, the network layer contains this information as well.

2. **Routing layer**

   The routing layer exchanges routing characteristics, assigns routes to shipments and containers and monitors them. A best route for a set of containers, based on the network state and a destination and deadline, can be retrieved from the routing layer. A best route consists of sequences of nodes and links, with timing specifications. The provision of a best route for a set of containers means that the routing layer can also provide a PI transporter (which carries a set of containers) with a best route. Once the decision for the best route has been made, the route information can be fed back to the routing layer of the OLI model, so the network state can be updated according to the targeted route.

3. **Shipping layer**

   The shipping layer exchanges shipment characteristics and assigns shipments to PI containers and monitors them. The shipping layer contains all information regarding the shipment of a PI container, such as destination and deadline. It assigns shipments to containers and therefore knows what shipment is in which container. In other words, it contains information on which container should be at which destination before what deadline. The shipping layer also contains the logistics service class for each shipment. As mentioned in chapter 2, this can be implemented in the design as the shipper's desired Quality of Service (QoS), with criteria transportation and handling time, costs, emissions and LSP quality.

4. **Encapsulation layer**

   The encapsulation layer exchanges encapsulation characteristics and monitors orders. The content information of each container is retrieved from the encapsulation layer. This contains all physical characteristics of the content, such as weight, volume, temperature and a hazard level of the content. At the same time, the encapsulation layer monitors orders that have been assigned to a certain PI container.

Assumptions:

- It is assumed that the digital mirror of the physical entities and processes is correct.
- It is assumed that all information to and from users of the PI is available whenever needed

- It is assumed that the OLI model can provide full information regarding network state, routing options, shipment characteristics and encapsulation characteristics
- As addressed in the research scope, it is assumed that, in case a PI container lacks certain necessary information, other containers are prioritised over the container with missing information. This way, shippers are incentivised to provide full information on their shipment. By doing so, efficient logistics operations are stimulated.
- It is assumed that each shipment has a desired Quality of Service (QoS), a priori defined by the shipper, with criteria transportation and handling time, costs, emissions and LSP quality
- LSP quality is assumed to include LSP reliability and number of damages
- It is assumed that each PI node and transporter (i.e. terminal and truck/train/barge operator) has a performance level. The instantiation of this performance is defined as the Level of Service (LoS), with criteria transportation and handling time, costs, emissions and LSP quality
- It is assumed that the waterway network state includes the availability of stakeholders that provide necessary services, such as the availability of tugboats, pilots and linesmen
- It is assumed that the optimal solution in the design can be based on, amongst others, the comparison of the shipper's desired QoS and the LSPs LoS.
- It is assumed that the QoS of multiple P-containers can be aggregated into a H-container QoS, which in turn can be aggregated into a T-container QoS, as depicted in the figure below

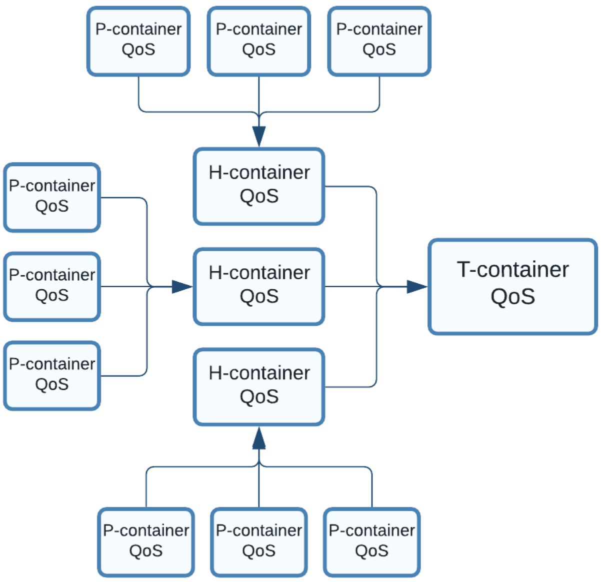

Figure 14: Aggregation of QoS levels

- Similarly, it is assumed that the QoS of multiple T-containers on a vessel can be aggregated into a vessel QoS

- It is assumed that the destination of a PI container can be the final destination, but also a distribution centre in the hinterland. The type of destination and further distribution in the hinterland, is not part of this research
- It is assumed that the majority of the containers on a vessel have to be transferred, instead of transhipped
- It is assumed that a shipper might ship multiple orders in one shipment. At the same time, one order might be shipped in multiple shipments. Furthermore, one shipment might be in multiple PI containers, and at the same time, multiple shipments might be in one PI container.
- It is assumed that the information from the PI layers not only includes historical and real-time information, but also predicted information. For example, predicted information on the future network state, and predicted information on reconsolidated container compositions.
- Carriers often have contracts with terminals regarding the discharge and throughput of their containers. It is assumed that, when a carrier has a contract with a terminal, this may overrule the optimal solution for the PI network. This assumption is based on an evaluation episode, which is discussed in more detail in section 7.1 (i.e. evaluation).
- It is assumed that the optimal mode solution for a T-container contains all information on which it is based, such as content and destination and deadline. This way, the optimal solution can be used for the execution of processes in the transfer of PI containers
- As stated before, PI containers can consist of transport, handling or packaging containers (T-, H- & P-containers, respectively). All containers that are discussed in the design are assumed to be T-containers. Only within the reconsolidation process, T-containers are (de)composed into H- and P-containers, after which an optimal reconsolidation is made for P-containers into H-containers and H-containers back into T-containers

6.1 High level design (A0 level)

This section discusses the high level design of the artefact. The high level design adheres to the bottom-up approach of the design of the PI. Therefore, we define main functions for the import of PI containers to the hinterland:

1. Port call
2. Declaration processing & risk assessment
3. Transfer PI container from vessel to hinterland modality
4. Transport to hinterland

The functions are based on the main physical and administrative activities happening when importing a container. The port call and the transfer function are designed with a separate optimisation function. This is distilled from Sternberg & Norrman (2017) and Treiblmaier et al. (2020). As mentioned in the literature review, they argue that stakeholders in the PI will try to maintain proprietary networks and solutions. Each stakeholder will try to optimise their own operations first, before considering to connect and adapt their operations to those of other stakeholders. This notion is reflected in the design that is proposed here. The declaration processing and risk assessment function has not been designed with an additional optimisation function, because it does not regard physical operations and capacity as in the other functions. The transport to the hinterland has also not been designed with an additional optimisation function, because of the scope of this research, which is limited to port functions. The optimisation functions only provide information to their related port function and only provide optimal solutions within their domain. Thus, several 'islands' within the process of importing cargo will be first optimised separately. The optimisers and their related 'islands' have their own specific goal. The optimisers will provide optimal solutions, based on their respective goals. Below, the functions, the related optimisers and their goals that are defined in the high level design, are explained. Also the input, output, resource and control variables of each function are indicated.

A1. Port call

The port call is defined here as the process of a vessel sailing towards a certain port, navigating through its waterways and berthing at a terminal quay. The *input* of the port call process is a PI container on a vessel at sea. Its *output* is the PI container on the vessel at a terminal quay. The navigation through the port area is determined by certain port characteristics, including navigation rules (i.e. *control*). Carrier contracts with certain terminals can determine (i.e. *control*) at which terminal the vessel is to be berthed. If not, the optimal solution from the optimiser determines at what terminal to berth (i.e. *control*). When a carrier contract overrules the optimal solution, additional pricing for deviation of the optimal solution may be incurred to the carrier (i.e. *output*). After all, the port system is not optimally used. At the same time, such an additional pricing mechanism might incentivise industry to reconsider carrier contracts in future PI ports, and therefore stimulate new business models in the PI.

The choice for a certain terminal is *output* of the process and serves as controlling variable of the optimiser. This way, the optimiser can update its optimal solution for other vessels, according to the chosen terminals by earlier vessels. The port call function is facilitated (i.e. *resource*) by assets of the vessel agent, the Harbour Master, nautical service providers, the Port Authority, the Marechaussee and the Seaport Police. The specific functions of these stakeholders within the port call, are not part of the design. Resulting from the port call, there are changes in the network state and routes. These are continuously monitored and fed back to the respective OLI model layers (i.e. *output*). (Predictive) network and route monitoring has important implications for the PI. According to the (predicted) use of the network and routes, potential bottlenecks can be distinguished early on. This may serve as input for adaptations to the network, as discussed in chapter 8.

A2. Optimise port call

The optimiser of the port call provides an optimal solution for a vessel to berth at a certain terminal, with a corresponding route (i.e. *output*). The optimal solution is based on several aspects, which are depicted in the figure below. Each P-container on board of the vessel has a specific QoS, defined by the shipper. Because the vessel may carry more than ten or twenty thousand containers, an aggregated desired QoS for the vessel is defined. Otherwise, no comparison with the LoS of a terminal can be made. Criteria of the desired QoS and the terminal's LoS are transportation and handling time, costs, emissions and LSP quality.

Additionally, each container has a destination and a deadline. Some destinations or deadlines might create the need for containers to be transhipped, instead of transferred to the hinterland. Therefore, when a majority of the containers' destinations and deadlines ask for transhipment, certain terminals can be put into favour. However, the transhipment function of a terminal is not explicitly included in the design. Instead, it is assumed that the majority of containers need to be transferred to the hinterland. The inclusion of the transhipment function in the design may be addressed in future research. The transfer of containers to the hinterland is defined in process A4 and is designed in more detail in the detailed design.

The optimal solution is also based on the best predicted route for the vessel to certain terminals. This best route is based on the (future) waterway network state. Additionally, the (future) state of terminals determines what terminals can be berthed at. As stated, each terminal has a corresponding LoS. By combining predicted route information with predicted terminal state information and the LoS of each terminal (i.e. *control*), a set of potential terminal solutions can be created. By comparing the solutions with corresponding LoS to the desired QoS of the vessel (i.e. *control*), an optimal route and terminal solution can be proposed for the vessel. The overall goal of the optimiser is to let a set of vessels pass through the port as efficiently as possible. In this regard, it takes the (future) network state and terminal states into account for optimal planning. The port call is optimised by a port call optimiser (i.e. *resource*). An example is PortXchange in the Port of Rotterdam, although PortXchange currently, mainly optimises compliance related processes. The logic that is explained above, is depicted in the figure below.

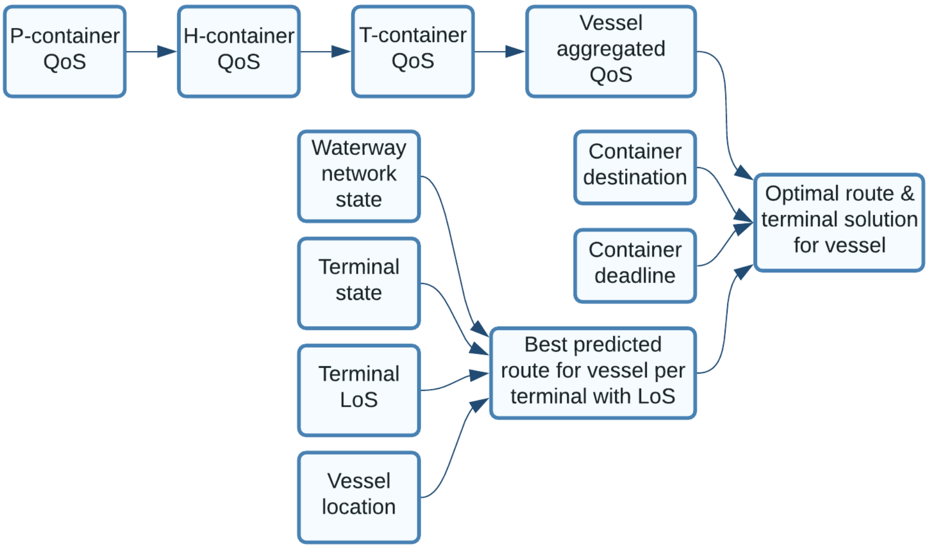

Figure 15: Heuristic for the terminal choice

A3. Declaration processing & risk assessment

The processing of declarations and assessing risks is a customs function. As stated before, a separate capacity optimisation function is argued to be not essential here, because it does not reflect actual physical port capacity as in the other functions. Customs clearly does have a physical capacity in terms of for example manpower, but this is out of the scope of this research. Hacquebord (2020) has already proposed the data pipeline concept to optimise customs operations in the PI. He also proposed to use smart container data regarding the content of a container as *input* for the customs process. This is implemented in the design as content information retrieved from the encapsulation layer. From Portbase, several cargo declarations, originally issued by the cargo agent, can be used as *input*. Several *outputs* are: a cleared declaration when everything is in order and a request to the cargo agent for adaptation of the declaration (Hacquebord, 2020). *Outputs* of the process can be implemented via services of Portbase: declaration anomalies, in case something is out of order, and a planned inspection, based on an invalid declaration or on the risk assessment, can serve as controlling variable of the transfer process through Portbase's inspection portal service. Whether customs decided to block the container and whether the correct customs document is present, also controls the transfer process and can be implemented through Portbase's cargo controller service. The integration of Portbase services in the design is later discussed in more detail. The customs process is guided by several laws and regulations (i.e. *control*) and supported by customs assets (i.e. *resources*).

A4. Transfer of PI containers from vessel to hinterland modality

The transfer function is defined here as the physical transfer of PI containers by a terminal from a vessel to the point where it is placed on a hinterland modality (often called 'gate out'). The hinterland modality can either be road, rail or barge. Within the transfer function, a decision is made with regards to what hinterland mode a T-container should take. A PI container on a vessel at a quay (i.e. *input*) is transferred onto a certain hinterland modality with a destination (i.e. *output*). During the transfer process, a container may be confiscated by customs (i.e. *output*). In case the terminal has made more costs than the shipper has paid for, the terminal may incur demurrage costs (i.e. *output*). The transfer of a PI container to the hinterland, and specifically the mode choice, is determined by an optimal mode solution for each T-container (i.e. *control*). The chosen mode serves as *output* of the process, and consequently determines the optimal mode solution for other T-containers.

The speed of the transfer process depends, amongst others, on the number of quay cranes and their cycle times (i.e. *control*). Additionally, the storage of containers during the transfer depends on stack optimisation (i.e. *control*); the physical inspection of containers during the transfer depends on laws and regulations (i.e. *control*) and the (priority of) handover of containers to the hinterland modality may already be determined by carrier contracts. Similar to the port call process, this might deviate from the optimal solution. Therefore, additional pricing for deviation of the optimal solution may be incurred to the carrier (i.e. *output*). The transfer function is discussed more extensively in the detailed design (section 6.3).

Similar to the monitoring of the port call process, the network state and shipments are monitored throughout the transfer process. Additionally, the actual reconsolidated container composition is fed back to the shipment layer, resulting from the reconsolidation process.

A5. Optimise transfer

The optimisation of the transfer provides an optimal mode solution for each T-container (i.e. *output*), generated by an optimisation engine (i.e. *resource*). The optimal solution is based on several aspects, which are depicted in the figure below. The goal of the optimiser is to provide each T-container with an optimal mode solution for its transportation to the hinterland. Similar to the port call, the best route per mode for each container is determined. Each mode (and transporter) has its own LoS, with criteria transportation and handling time, costs, emissions and LSP quality. According to the destination and deadline of the container, the state of the hinterland network and the availability of each mode (i.e. *control*), an optimal route per mode can be determined. These routes then have a certain LoS, depending on the corresponding mode or transporter (i.e. *control*). The LoS has to be compared to the desired QoS by the shipper. However, the composition of a container on the vessel may be different than when it leaves the terminal, due to the reconsolidation of PI containers. Therefore, a predicted reconsolidated container composition has to be determined (i.e. *control*). According to the specific QoS values of each P-container, its destination, deadline and its content, an optimal reconsolidated composition can be predicted a priori for each T-container. Similar to the aggregation of a vessel's QoS, the P-containers' QoS is aggregated into a T-container QoS.

Thus, there is a prediction on the composition in which each T-container leaves the terminal, resulting from the reconsolidation of containers. At the same time, there are optimal routes per mode for transporting a T-container to a certain destination. By comparing the QoS of the container to the LoS of the transporter (i.e. *control*), an optimal mode solution can be proposed for the hinterland transport of the container. Lastly, a shipper may already have defined a pre-assigned hinterland mode, which then determines (i.e. *control*) the solution for the hinterland mode. The logic that is explained above, is depicted in the figure below.

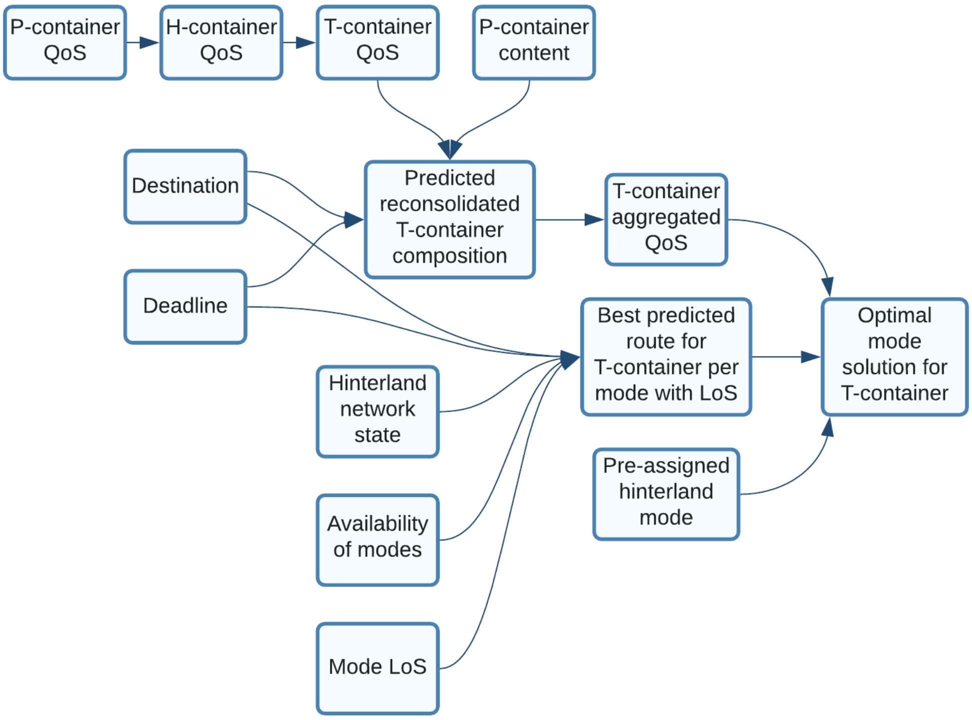

Figure 16: Heuristic for the mode choice

A6. Transport to the hinterland

The transport to the hinterland starts when the truck, train or barge, leaves the terminal (area) with the loaded T-container. The *input* for the transport to the hinterland is a PI container that has been put on a mode with a certain destination. Its *output* is the PI container at the destination. This destination may be a distribution centre, and not the actual destination of the container, but this is out of scope of this research. It is assumed that each PI container has one destination, whether it is its final destination or a distribution centre. The transportation is carried out by a road haulier or rail or barge operator (i.e. *resource*). The route is determined by the best route, which depends on the state of the hinterland network and the shipper's desired QoS (i.e. *control*). During the process, the (predicted) state of the network is continuously monitored, as well as the (predicted) route and the shipment that is being transported (i.e. *output*).

6.2 Integration of Portbase services into high level design

The analysis of Portbase's services has uncovered information that can be used in the design of a PI port information system. The services that have been integrated in the high level design, are discussed per port function below. In figure 17, information to and from Portbase is depicted with *blue* arrows. There is a certain distinction between the different services, which is defined as compliance related services and logistics related services. Compliance related services are services for the compliance to legal matters, such as the notification of dangerous goods to the Harbour Master. Logistics related services are services used for the optimal planning of logistics processes. This distinction is reflected in the design as follows: the majority of compliance related services are integrated into the execution functions in the design; the logistics related services are integrated into the optimisation functions in the design. The services and their respective relation to the port functions (i.e. input, output, control, resource) are discussed per port function below.

A1. Port call

The services that are applicable to the port call, are:

- Control:
  - Vessel notification
  - Notification crew and passengers
  - Notification dangerous goods
  - Notification waste disposal
  - Notification ship's stores
- Output:
  - Notification Single Window
  - Seaport Statistics

The first five services are all compliance related services that control the execution of the port call. The information related to the services has to be submitted during the port call for legal obligations. Outputs of the port call are Actual Time of Arrival (ATA), Actual Time of Departure (ATD) and certain port call statistics. These pieces of information can be used for the two output services Notification Single Window and Seaport Statistics.

A2. Optimise port call

The service that is applicable to the optimisation of the port call (within the scope of this research) is the vessel notification. This logistics service can be used for better optimisation of the port call. When (predicted) arrivals of vessels are known, the vessels can be passed through the port as efficient as possible by assigning a vessel to a terminal with enough capacity and with the right LoS.

A3. Customs declaration processing and risk assessment

The services that are applicable to customs declaration and risk assessment, are:

- Input:
  - Pre-arrival cargo declaration import
  - Cargo declaration import
  - Declaration food and consumer products
  - Transit declaration
  - Notification local clearance
- Output:
  - Inspection portal: declaration anomalies and planned inspection
  - Cargo controller status: customs block and customs document present

The first five input services are all compliance related services. Based on the information from these services, customs can execute the processing of declarations and the assessment of risks. Output of declaration processing can be either a cleared or uncleared declaration. In case of an uncleared declaration, customs can request an adapted declaration to the issuer, based on declaration anomalies (Hacquebord, 2020). Anomalies in the declaration serve as controlling variable for the transfer function. Output of customs' risk assessment can be a planned inspection. This serves as controlling variable for the transfer function as well. Subsequently, two status indicators in the cargo controller service can be updated. The results of the customs process indicate whether a container is blocked by customs and whether the right customs documents are present.

A4. Transfer PI container from vessel to hinterland modality

The services that are applicable to the transfer of PI containers from the vessel to the hinterland modality, are:

- Control:
  - Inspection portal: declaration anomalies and planned inspection
  - Cargo controller status: customs block and customs document present
  - Notification dangerous goods
  - Cargo controller status: container present and commercial release
  - Notification import documentation
- Output:
  - Discharge confirmation report
  - Cargo controller: container present
  - Inspection portal status
  - Wagonload Information System (WLIS)
  - Seaport Statistics

The services that serve as control variables of the process are all compliance related services. The first two have been addressed in A3 above, the others are addressed in the integration of Portbase services into the detailed design (section 6.4). Also, the output services of the transfer process are compliance services and are addresses in the detailed design.

A5. Optimise transfer

The service that is applicable to the optimisation of the transfer of PI containers from the vessel to the hinterland (within the scope of this research) is the hinterland container notification. This logistics service can be used for better visibility in the availability of hinterland modes. It can be seen as an *existing* addition to the OLI model's network layer, which *assumes* visibility in the offer of available hinterland modes. Similar to how the OLI model's network state and mode availability is used for optimisation, is the use of available hinterland modes through Portbase's hinterland container notification service for optimisation.

A6. Transport to hinterland

The services that are applicable to the hinterland transport, are:

- Control:
    - Inland port dues
- Output:
    - Seaport Statistics

The service for inland port dues is a compliance related service that controls how the hinterland transport is executed. It notifies inland terminals about the arrival of barges and can be used for the payment of inland port dues. Consequently, the hinterland transport creates certain valuable statistics as output that can be used in the Seaport Statistics service, such as ATA and ATD.

The high level design is depicted in figure 17 on the next page.

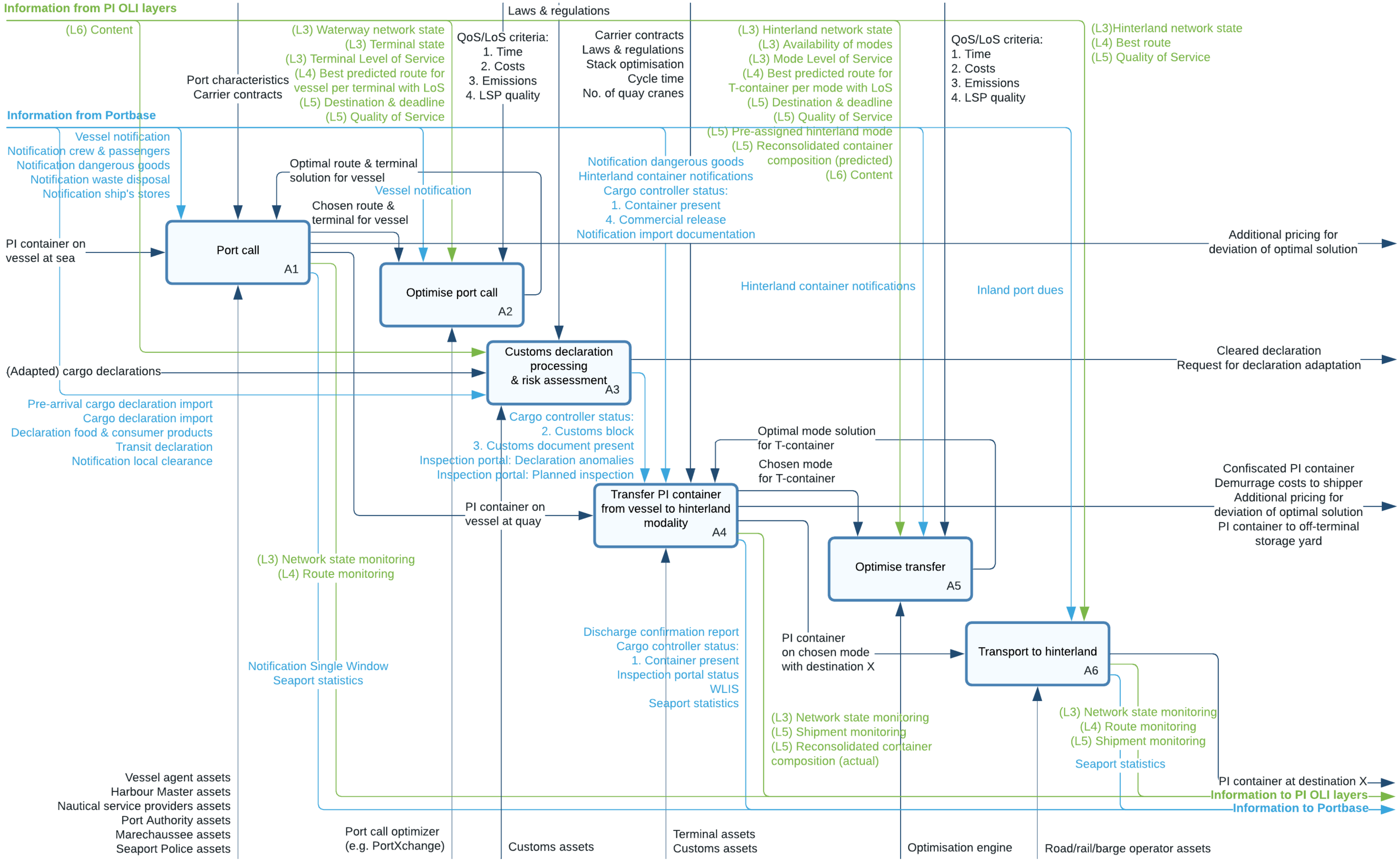

Figure 17: High level design of PI port information system

6.3 Detailed design (A1 level)

The detailed design is an in-depth design of the main port function: *transfer of PI containers from vessel to hinterland modality* (A4). It is at the A1 level, according to IDEF0 syntax, and depicted in figure 18. It focuses on physical operations on PI containers throughout the terminal area. The defined functions during the transfer process, distilled from Fahim et al. (2021), are:

1. Unload
2. Physically inspect PI container
3. Reconsolidation
4. Store at yard
5. Hand over PI containers to hinterland modality/off-terminal storage yard

The different functions or processes in the detailed design are explained below, as well as their input, output, resource and control variables. As mentioned in the assumptions, it is assumed that the optimal solution for a T-container, generated by the optimiser (A5), contains all necessary information on which it is based. This way, the optimal solution and corresponding information can be used for the processes during the transfer.

A41. Unload

After the port call, the ship is berthed and ready to be unloaded. A PI container on the vessel (i.e. *input*) is unloaded by the terminal's quay cranes (i.e. *resource*). The terminal operator is the process owner. The cycle time of the quay crane and the number of quay cranes determine (i.e. *control*) how many containers per unit of time can be unloaded from the vessel. The optimal mode solution for each T-container not only determines what mode should be taken, but also what subsequent processes the container should move to (i.e. *control*). If a container needs no reconsolidation, and the destination and deadline do not demand for direct transfer to a hinterland modality, the container can be stored at the terminal yard (i.e. *output*). If a container needs no reconsolidation, but the destination and deadline do demand for direct transfer to a hinterland modality, the container may be moved directly to the handover process (i.e. *output*). If a container needs reconsolidation, it moves to the reconsolidation process (i.e. *output*). Whether a container needs to be reconsolidated, depends on the container's QoS, and its destination, deadline and content, as explained in the previous section. As stated before as well, contracts that carriers have with a terminal might determine (i.e. *control*) the next steps for the container, such as moving to the handover process, to ensure the quick transfer of the container at the terminal.

A42. Customs inspection

If the customs declaration and risk assessment process (A3) has determined that a container needs physical inspection, the container (i.e. *input*) moves to the inspection process. The inspection is carried out by a State Inspection Terminal (i.e. *resource*) of the customs authority[7]. Together with the content of the container, laws and regulations determine (i.e. *control*) the outcome of the inspection. When the goods are not allowed to be imported, they are confiscated (i.e. *output*). Otherwise, they are cleared. Cleared containers can either be reconsolidated, stored or handed over to the hinterland modality (i.e. *output*), depending on the optimal solution for the T-container. If the container needs reconsolidation, it moves to A43; if the container cannot yet be handed over, it needs to be stored (A44), otherwise, it can be handed over (A45).

A43. Reconsolidation

The reconsolidation function, compared to current port operations, is new in the PI. There exist reconsolidation warehouses currently, but they are not an integral part of port operations as they are in the PI. Containers coming from the unload process, customs inspection or from the storage yard, can be reconsolidated (i.e. *input*). The reconsolidation process is assumed to take place in the terminal area, because another location for this process would lead to unnecessary extra container movements. This notion has been validated during interviews. Therefore, the resource variable of the reconsolidation process is defined as a reconsolidation centre (i.e. *resource*), where the terminal acts as process owner.

As explained in Fahim et al. (2021), T-containers can be decomposed into H-containers and H-containers into P-containers. According to "their optimal routing and consolidation opportunities, which are determined, among others, by the variables of final destination and desired time-window" (Fahim et al., 2021, p. 7), the P-containers can be composed into H-containers and H-containers into T-containers. Here, this whole process is called reconsolidation. The content of the different containers also determines the optimal routing and consolidation opportunities. For example, not all dangerous goods can be stored next to certain other goods.

As stated in the previous section, the optimal mode solution for each T-container is based on, amongst others, an optimal reconsolidated container composition, which is predicted by the optimiser (A5). Therefore, during the reconsolidation process, it is already clear how containers need to be reconsolidated. Again, carrier contracts might overrule the optimal solution (i.e. *control*). After reconsolidation, containers may either be stored or handed over to a hinterland mode (i.e. *output*).

[7] https://www.portofrotterdam.com/en/services/port-customs/state-inspection-terminal

A44. Store at yard

A container that has to be stored can come from the unload process, the inspection process, or from the reconsolidation process (i.e. *input*). Containers are stored and retrieved by terminal handling equipment in the container yard or stack (i.e. *resource*). The terminal is the process owner. The handling equipment at a terminal can consist of a wide variety of vehicles and machinery. Stack optimisation algorithms can determine how to store containers (i.e. *control*). This can be based on predictive control as well, but this is not part of this research.

The optimal mode solution for a T-container determines (i.e. *control*), according to the availability of hinterland modes, when a container needs to be retrieved from the stack. After retrieval, the container is ready to be handed over to the hinterland modality (i.e. *output*). However, it can also occur that there is a new prediction on the optimal container composition, according to changes in the system. For example, the earlier than expected arrival of another vessel can lead to new reconsolidation opportunities. Then, a container would have to be retrieved from the storage yard to be reconsolidated (i.e. *output*). It is also possible that a container is first stored at the yard after unloading and then still needs to be physically inspected. This is captured and determined by the status indicators in Portbase's cargo controller service and discussed later on.

It should be noted that the storage yard that is included in this design, concerns the storage yard on the terminal. However, in the PI, the storage of containers at other yards, away from the terminal, is also possible. This notion resulted from a validation interview with Prof. Montreuil. To implement this in the design, we have added the option for a container to move to such a yard within the handover function (A45). The move to an off-terminal storage yard is determined by the deadline of the container: if the deadline is too far away, the container is stored elsewhere, to maintain sufficient capacity at the terminal yard. A further implementation of this notion is outside the scope of this research.

A45. Hand over PI containers to hinterland modality

The handover of a container to the hinterland modality is the final process at a container terminal. Cleared containers, originating directly from customs inspection, stored containers, reconsolidated containers or containers that have just been unloaded, can be handed over to a hinterland modality (i.e. *input*). The handover can be executed by, again, a wide variety of terminal handling equipment (i.e. *resource*). The container terminal is the process owner.

The handover process is determined by the optimal mode solution of each T-container (i.e. *control*). As stated above, this may also result in the storage of the container at an off-terminal storage yard (i.e. *output*). After placing the containers on the chosen hinterland modality, the containers are ready to be transported to the hinterland destination (i.e. *output*). The hinterland transporter takes the container to its destination before its deadline, according to an optimal route with corresponding LoS. After the handover of the container, the terminal may have made more costs than the shipper has paid for when defining his QoS. This can be incurred to the shipper through demurrage costs (i.e. *output*). This is a result of an evaluation episode, as described in the next chapter.

6.4 Integration of Portbase services into detailed design

As has been discussed in the previous section, several of Portbase's compliance services have been integrated in the design of the transfer function. In figure 18, information to and from Portbase is depicted with *blue* arrows. The services and their respective relation to the port functions (i.e. input, output, control, resource) are discussed per port function below.

A41: Unload

The services that are applicable to the unloading of PI containers, are:

- Control:
    - Inspection portal: planned inspection
    - Cargo controller status: customs block, customs document present & commercial release
- Output:
    - Discharge confirmation report
    - Cargo controller status: container present

Output of the process A3 'declaration processing and risk assessment', is whether customs has planned a physical inspection for the container. This determines (i.e. *control*) whether a container should be moved to process A42. The status indicators in the cargo controller service regarding a possible block by customs, the presence of the right documentation and commercial release by the terminal, determine (i.e. *control*) whether a container may be handed over to the hinterland modality (A45). A logical precondition for this is that the container is actually unloaded, because when the unloading process terminates, not all containers might have been unloaded. The containers that have been unloaded, are documented in a discharge confirmation report and are therefore *output* of the unloading process. One of the statuses in the service cargo controller (i.e. 'container present') is output of the unloading process, as this can be updated according to the discharge confirmation of a container.

A42: Physically inspect PI container

The services that are applicable to the physical inspection of PI containers, are:

- Control:
  - Inspection portal: declaration anomalies
- Output:
  - Inspection portal status

Declaration anomalies are checked during the physical inspection. Therefore, they control the physical inspection process. Output of the physical inspection are status updates during and after the physical inspection. This can be done through Portbase's inspection portal service.

A43: Reconsolidation

According to the analysis of Portbase's *current* operations, there is no direct lead for using specific Portbase information that can be used for future reconsolidation of PI containers. However, certain compliance related information may be used for this process in the *future*. This is reflected in the recommendations in section 7.3.

A44: Store at yard

The services that are applicable to the storage of PI containers at the yard, are:

- Control:
  - Notification dangerous goods
  - Cargo controller status: customs block, customs document present, commercial release

The notification of dangerous goods is used for the safe storage of containers at the yard. The cargo controller status indicators determine whether a container may need to be physically inspected, resulting from a customs block. Also, it determines whether a container may be handed over to the hinterland mode, according to the presence of the right customs documents and the commercial release by the terminal.

A45: Hand over PI containers to hinterland modality

The services that are applicable to the handover of PI containers to the hinterland modality, are:

- Control:
    - Cargo controller status: container present, customs block, customs document present and commercial release
    - Notification import documentation
- Output:
    - Wagonload Information System (WLIS)
    - Seaport Statistics

Only when all four cargo controller status indicators are ‘green’, the PI container may leave the terminal. Therefore, these status indicators control the handover process. The notification import documentation serves as a check for the presence of the right import documentation. Only if the hinterland transporter has notified that he has the right documents, the container may be handed over. An output of the handover process is the composition of PI containers on a train (in case the hinterland modality is rail), which can be fed into Portbase’s Wagonload Information System (WLIS). Additionally, it is designed here in such a way that the terminal can provide Portbase with relevant Seaport Statistics *after* the handover process has terminated. This can be information such as dwell time, unloading time or the amount of containers that have been unloaded by the terminal.

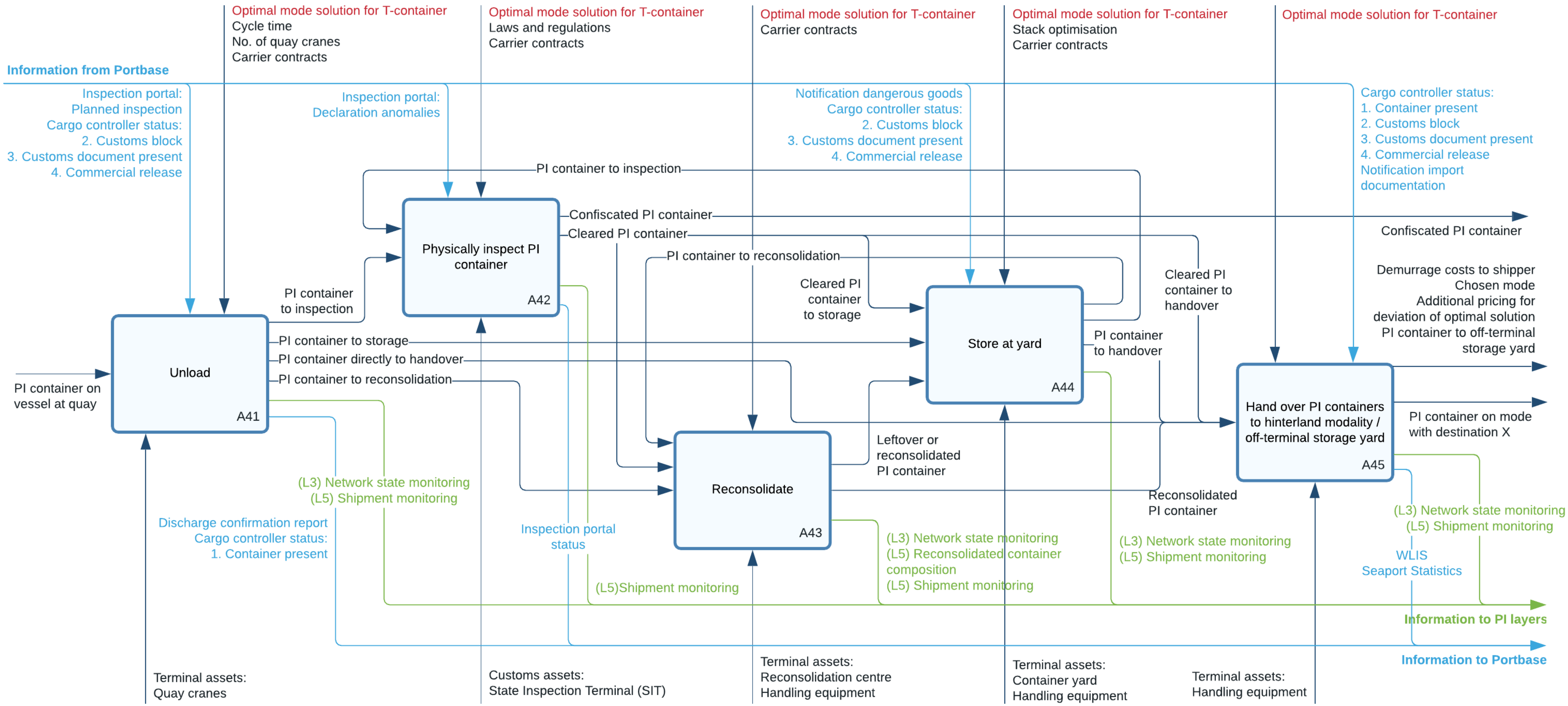

Figure 18: Detailed design of the transfer of containers to the hinterland modality (process A4)

Function	Control PI	Control PCS	Output PI	Output PCS
Port call (A1)	n.a.	Vessel notification Notification crew & passengers Notification dangerous goods Notification waste disposal Notification ship's stores	(L3) Network state monitoring (L4) Route monitoring	Notification Single Window Seaport Statistics
Optimise port call (A2)	(L3) Waterway network state (L3) Terminal state (L3) Terminal Level of Service (L4) Best predicted route for vessel per terminal with LoS (L5) Destination & deadline (L5) Quality of Service	Vessel notification	n.a.	n.a.
Declaration processing & risk assessment (A3)	(L6) Content (i.e. *input*)	Pre-arrival cargo declaration import Cargo declaration import Declaration food & consumer products Transit declaration Notification local clearance (i.e. *input*)	n.a.	Cargo controller status: customs block and customs document present Inspection portal: declaration anomalies and planned inspection
Transfer PI container from vessel to hinterland modality (A4)	n.a.	Notification dangerous goods Hinterland container notifications Notification import documentation Cargo controller status: container present, customs block, customs document present and commercial release Inspection portal: declaration anomalies and planned inspection	(L3) Network state monitoring (L5) Shipment monitoring (L5) Reconsolidated container composition (actual)	Discharge confirmation report Cargo controller status: container present Inspection portal status WLIS Seaport statistics
Optimise transfer (A5)	(L3) Hinterland network state (L3) Availability of modes (L3) Mode Level of Service (L4) Best predicted route for T-container per mode with LoS (L5) Destination & deadline (L5) Quality of Service (L5) Pre-assigned hinterland mode (L5) Reconsolidated container composition (predicted) (L6) Content	Inspection portal status Hinterland container notifications	n.a.	n.a.
Transport to hinterland (A6)	(L3)Hinterland network state (L4) Best route (L5) Quality of Service	Inland port dues	(L3) Network state monitoring (L4) Route monitoring (L5) Shipment monitoring	Seaport Statistics

Table 3: Overview of relevant PI and PCS information in design

In the table above, an overview of all PCS and PI specific information that is integrated in the design is given. It concerns information retrieved from the PI OLI model layers that is used for the control of processes (column 'Control PI'), information retrieved from PCS services that is used for the control of processes (column 'Control PCS'), information fed back to the PI OLI model layers (column 'Output PI') and information fed back to Portbase's services (column 'Output PCS'). Only in process A3, PI and PCS information is used as *input*, instead of as control variable.

7. Evaluation, validation & recommendations to PCS

The previous chapter has presented the design that has been constructed in this research. This chapter discusses the evaluation episodes that have led to the final design (section 7.1), as well as the design's validation (section 7.2). Consequent recommendations following from the design, are presented as well (section 7.3).

7.1 Evaluation

In Design Science Research (DSR), continuous iterative evaluation of the artefact is key. From the start of the design process, input of several experts has repeatedly served as input for the evaluation of the artefact. The designed artefact is evaluated according to the Framework for Evaluation in Design Science Research (FEDS) by Venable, Pries-Heje & Baskerville (2016), depicted in the figure below.

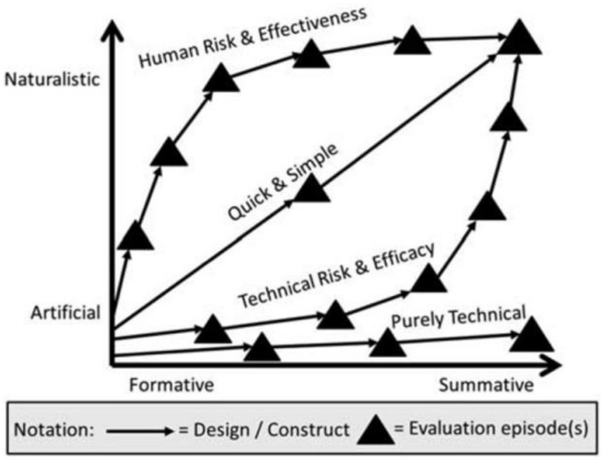

Figure 19: Framework for Evaluation in Design Science Research (source: Venable, Pries-Heje & Baskerville, 2016)

In the framework, the evaluation strategy depends on two dimensions:

- Functional purpose of the evaluation. The purpose of the evaluation starts in a formative way, with the purpose of creating an artefact. As the design process and evaluation continues, the purpose changes more into a summative way, where the artefact is evaluated more on requirements.
- Paradigm of the evaluation study. The design of the artefact starts in an artificial way, where the design is based more on theoretical knowledge rather than on the representativeness with the real world. As the design and evaluation process continues, the connection with the real world becomes more important, and the designed artefact moves to a more naturalistic way.

As mentioned earlier in the methodology chapter, the strategy that is applied in this research, resembles the technical risk and efficacy evaluation strategy. This means that earlier on in the design process, the technical, summative part of the artefact is more important, whereas later on in the process, the representativeness of the artefact with the real world is more important. This is reflected in the different evaluation episodes as well. As mentioned, the artefact has been evaluated with several Physical Internet (PI) and Port Community System (PCS) experts. Below, the main implications of their evaluation and the implementation thereof in the design, are discussed. They are presented in the order in which the interviews have been held. It should be noted that not all interviews are mentioned explicitly here. The reason for this is that some interviews did not lead to a specific implementation in the design.

Expert evaluation interviews:

- Prof.dr.ir. Lori Tavasszy. At this point, the design process is in a very early stage. The way to structure information exchange in the design, is unclear. The main evaluation of this interview, is to scientifically structure the PI information exchange. The evaluation strategy has a formative, artificial approach. Because the PI OLI model provides some outline for information exchange in the PI, a logical addition to the design is to structure the information exchange in the design in such a way that the different port functions exchange information to and from specific OLI model layers.
- Dr. Nick Szirbik. At this point, it is not clear how to incorporate the requirements into the design. It is clear however, that predictive sense-and-respond optimisation information has to be integrated into the artefact. Mr. Szirbik mentions that the design of the information system should be bottom-up, which is also supported by literature. Therefore, an addition to the model is to add separate sense-and-respond optimisation functions for specific port functions in the design. This way, both the requirements and the notion of a bottom-up approach have been incorporated into the design. The evaluation strategy follows a more summative approach.
- Prof.dr.ir. Rod Franklin. At this point, how to structure the information that is needed for sense-and-respond optimisation is not clear. Mr. Franklin proposes to assume full information from the OLI model and to use a package perspective (i.e. PI container) for the approach to structure the information that is needed to create an optimal solution. The potential use of a package-specific QoS for the optimisation is evaluated, as well as the direct input of PCS information into different functions in the design, instead of PCS information being fed to the OLI model. Lastly, Mr. Franklin introduces the fact that LSP costs might exceed the fees paid by the shipper for a certain QoS. This is incorporated in the design as the possibility of a terminal to incur demurrage costs to the shipper. The movement towards a more naturalistic evaluation approach is reflected well here.
- Prof.dr. Thierry Vanelslander. At this point, the design is evaluated in a more naturalistic way. The implementation of the QoS on a package level is evaluated as essentially good for prioritisation. However, Mr. Vanelslander mentions that carrier contracts with terminals are

not taken into account, but are an important aspect of the current port environment. This has been incorporated into the design in two ways. The first is that a carrier contract might determine what terminal a vessel should visit. The second is that a carrier contract might determine the priority of containers being handled at these terminals. In this way, a carrier contract may overrule the optimal solution, as brought forward in the design assumptions.

- Prof.dr.ir. Benoit Montreuil. At this point, the design is evaluated in such a naturalistic way that several use cases are discussed. Some use cases are out of scope of the design, such as the transhipment of containers to another vessel. For the transfer of a container to the hinterland however, an important implication is that containers in the PI are not necessarily stored on the terminal site. Instead, storage of containers may happen at off-terminal storage sites to reduce the burden of high dwell times on terminal operations. This has been incorporated in the design as a separate option in the handover process (A45). If the deadline of the container requires a long dwell time, the container may be handed over to be transported towards an off-terminal storage site. Because this evaluation has been introduced relatively close to the finalisation of the research, further integration of this notion into the design has not been carried out.

Additional to the expert evaluation episodes described above, the supervisors of this research have continuously served as evaluators of the designed artefact. The exact implications of each evaluation episode are not discussed here, but it should be noted that the design has been subject to many evaluations by supervisors.

7.2 Validation

This section presents the validation of the design presented in the previous chapter. The validation is split into three sections:

1. Validation of the use of OLI model PI information
2. Validation of the use of PCS information
3. Validation of physical flow of PI containers

This division of the validation into several aspects structures the approach and makes the validation more comprehensive. Per aspect, various experts are consulted for the validation. Both designs (high level and detailed) are validated according to the same aspects.

The first aspect regards the use of PI OLI model information. Again, it is assumed that the OLI model has full information. However, important for the validation is the origin layer of each piece of information. As stated, for scoping reasons, not all layers have been taken into account in the design. The ones that are included are the:

- Network layer, which is used for the retrieval and feedback of the waterway and hinterland network state, the terminal state, the availability of modes and the characteristics of terminals and modes in terms of Level of Service. The positioning of these pieces of information in the network layer, has repeatedly been validated by experts and supervisors
- Routing layer, which is used for the retrieval of the best route for a vessel or hinterland mode (according to information from the network layer and the shipping layer) and the monitoring of a route during transport. The positioning of these pieces of information in the routing layer, has repeatedly been validated by experts and supervisors. Furthermore, literature underlines this as well (Montreuil, Ballot & Fontane (2012); Fahim et al., (2021))
- Shipping layer, which is used for the retrieval of the container characteristics: destination, deadline, the shipper's desired Quality of Service and a possible pre-assigned hinterland mode. Additionally, in the design, the shipping layer provides the predicted reconsolidation composition of each T-container. The actual prediction might not be part of the shipping layer, but the result is argued to be communicated through the shipping layer, as this is where the information resides regarding assignment of shipments to containers, and therefore also changes in container composition. At the same time, the actual reconsolidated container composition is fed back to this layer, in order to effectively monitor shipments and their assignment to PI containers. The positioning of these pieces of information in the shipping layer has been discussed extensively during evaluation interviews and with supervisors, and is therefore considered valid.

- Encapsulation layer, which is used for the retrieval of content information of each container. It has been repeatedly evaluated and therefore considered valid, that the content information of each container resides in the encapsulation layer.

The second validation aspect regards the integration of Portbase information and services in the design. A validation interview with Dennis Dortland, Innovation Consultant at Portbase, has led to the validation of the integration of Portbase information and services into the design. As stated before, there is a distinction between compliance related services and logistics related services within Portbase. The design process has resulted in an apparent separation between the integration of compliance and logistics services in the design. The distinction between compliance and logistics services was not yet known during the design process. Because this distinction is clearly visible in the design, it is argued that the integration of Portbase services in the design can be considered valid.

The third validation aspect regards the physical flow of PI containers between processes. Because of scoping of the research, only the import and transfer of containers to the hinterland is considered (and hereby no transhipment). Therefore, the container flow in the high level design is fairly straightforward: from on vessel at sea, to on vessel at quay, to on hinterland mode, to destination. The only deviations from this container flow result from the detailed design: physical inspection by customs can lead to confiscation of the container, and, according to the evaluation by Mr. Montreuil, a lengthy storage of a container may demand off-terminal storage of the container. Thus, because of scoping reasons and because of extensive evaluation of flow options, the physical flow of PI containers in the design is considered valid. The physical flow of containers in the transfer process (i.e. detailed design) is deemed valid after extensive evaluation with port operations experts as well.

7.3 Recommendations to PCS

This section presents recommendations to PCS, and specifically to Portbase, based on the design presented in the previous chapter. It hereby answers the following sub question:

(e) What role can a PCS have in this potential way of information exchange in the PI?

In the design, various Portbase services have been incorporated next to information flows from the OLI model. The design shows that PI specific sense-and-respond optimisation functions can exist next to existing port operation functions. The design also shows that compliance related PCS services can be used in the execution of PI port processes, and not necessarily in sense-and-respond optimisation functions. This leads to the following recommendation:

1. PCS should maintain their role as information intermediary for compliance related services in PI ports

As mentioned, logistics nodes should undergo an "improvement of the services' visibility" (Alice-ETP, 2020, p. 8), which implies more extensive track and trace information for PI containers being handled at logistics nodes. Early versions of these kinds of services are already offered by Portbase, such as the inspection portal service for the physical inspection of containers and the cargo controller service for the status of the import process. However, the design also shows that various layers of the OLI model require information flows for monitoring of other operations (i.e. green outgoing flows). Some of these may be implemented by PCS, such as network state monitoring. Although the PI roadmap already provides a recommendation with regards to track and trace information, we argue that this recommendation is highly applicable to PCS. This can be derived from and is also underlined by the designed information system. Therefore, we explicitly formulate this requirement with regards to PCS. This leads to the following recommendation:

2. PCS should invest in the development of more extensive services related to track-and-trace capabilities in PI ports

Additionally, the design shows that the vessel notification service can be used for optimisation of the port call (A2) and that the hinterland container notification service can be used for the optimisation of the transfer of PI containers (A4). This results in the following recommendation:

3. PCS should invest in the development of more extensive logistics related services that can be used for optimisation functions in PI ports

For customs declaration processing and risk assessment (A3), several services regarding administrative documents of the content of containers, serve as input from Portbase. From a PI perspective, this process requires content information from the OLI model's encapsulation layer. The same content information from the encapsulation layer is used for the optimisation of the transfer (A5), specifically for the reconsolidation of PI containers. This implies that the content information of Portbase's services used in A3, could potentially also be used in A5. In other words, the information from compliance services used in A3, could potentially serve as information for logistics services in A5. The information that is needed for the optimal reconsolidation of P-containers into H- and T-containers, consists of the destination, deadline, QoS and content of each container. By combining containers that have a similar destination, deadline and QoS and that have content that is permitted to be transported together, an optimal T-container composition can be generated. This information would need to be shared by Portbase with the terminal, as this is the stakeholder that is assumed to perform the reconsolidation process. Currently however, due to permission issues, such information is not yet shared. Whether and how this information may be shared, by means of authorisation measures, is a point for future research for PCS. In a wider context, governance and organisational measures regarding data ownership and authorisation, need to be researched as well. This is touched upon in the discussion. For PCS, this results in the following recommendation:

4. <u>PCS should research to what extent compliance related information regarding the content of containers, can be used for logistics services for optimisation functions in PI ports</u>

As mentioned earlier, PCS are expected to extend its reach towards the hinterland (PoR, 2020). Portbase's inland port dues service currently serves as a transactional service for inland barges. However, in theory, the service can also be used for the notification of the arrival of inland barges at inland ports. In this regard, the service could work similar to the hinterland container notification service at deep sea ports. Relating this to PI theory, such a service could be used for the optimisation of the next transport leg from an inland port further towards a hinterland destination. This leads to the following recommendation, specifically for Portbase:

5. <u>To extend its reach towards the hinterland, Portbase should research whether and how it can implement a service to notify the arrival of inland barges at inland terminals, similar to the hinterland container notification at container terminals at deep sea ports</u>

8. Discussion

In the previous two chapters, the designed information system of a Physical Internet (PI) port and corresponding recommendations to Port Community Systems (PCS) have been presented. This chapter discusses implications of the research scope and assumptions on the results, as well as additional points of discussion related to this research. First, it discusses general points of discussion, then it discusses the availability of information that is assumed in this research, after which it discusses several specifics of the designed information system.

General

To be able to study PCS, Portbase has served as a case study. In the literature review, it has already been mentioned that business models of PCS diverge. Portbase has a more transactional business model, offers core PCS services and is relatively closed off to external developers of services. Other PCS offer additional services, on top of the core PCS services. Following from the recommendations in section 7.3, this research shows that the core PCS services could potentially be integrated in a PI port information system. Due to the use of a case study, the potential integration of additional VAS offered by other PCS into information systems of PI ports, has not been part of the research.

As mentioned in the recommendations to PCS in the previous chapter, the design suggests that information from compliance related services may be used for optimisation processes in PI ports. This has certain legal and organisational implications. Governance measures that facilitate a more open data sharing environment in ports need to be put in place, as reflected the requirements in chapter 5. To do this, joint forces of (powerful) industry stakeholders could stimulate the political willpower that is needed to address this problem (Lis & Otto, 2021). Additional data governance design dimensions are presented by Khatri & Brown (2010). Furthermore, organisations have to adapt their business models together towards more collaborative structures in order to reap the benefits of information sharing in the PI, as illustrated by Montreuil et al. (2012) and Sternberg & Normann (2017).

The further development of logistics services, as well as the maintenance of compliance services, is recommended to Portbase. An important side note is that, on the long term, the development of more extensive logistics services, should not restrict the development of compliance services. For example, if logistics services are developed for real-time facilitation, compliance services should be able to match this. A discrepancy herein might provide difficulties in the future.

In the design, several stakeholders are incorporated in such a way that each function has one or more process owners, of which the assets serve as the functions' resources. The roles of stakeholders in the design is not addressed explicitly. Therefore, a short reflection on their current and possible future roles is given here. Currently, the stakeholder field consists of governmental stakeholders that mainly facilitate compliance related functions and commercial stakeholders that facilitate various Value Adding Services (VAS). This distinction between governmental and commercial stakeholders will most likely continue to exist in the future. However, the roles will probably change. Currently, there is a natural tendency of commercial stakeholders to adapt their operations to the needs of governmental stakeholders. It is argued here that in the future, this tendency will have to shift slightly towards governmental stakeholders adapting their operations to commercial stakeholders, or at least, governmental stakeholders having to consult the needs of commercial stakeholders in a more constructive way. In this regard, more collaborative structures between commercial stakeholders, but also between governmental and commercial stakeholders, need to be promoted in order to achieve more sustainable and efficient logistics. A specific note on the role of expeditors in the PI is made here as well. The expeditor currently serves as an intermediary for matching shippers' demand for and carriers' offer of transport capacity. Due to the full visibility and exchange of information that is needed in the PI, such a stakeholder may become obsolete. Future research could address this in more detail.

In the analysis, port functions and stakeholder types have been explicitly split up. In reality, many port functions and stakeholder types are vertically integrated, such as the integration of vessel agents and cargo agents into large carriers such as the Mediterranean Shipping Company (MSC). We even see the integration of carriers with port terminals, such as Maersk with A.P. Møller-Maersk (APM) terminals in the Port of Rotterdam or MSC with MSC PSA European Terminal (MPET) in the Port of Antwerp. However, it is argued that splitting of functions is necessary to be able to study and develop information systems for PI ports, because the information system requires information being exchanged between different port functions, regardless of the process owner.

Availability of information

The existence of the OLI model is assumed in this research, as well as the assumption that all necessary information can readily be retrieved from the model. It should be noted that this is not yet the case. Several functions in the design require full information from the OLI model. However, owners of these port functions might not have access to this data, based on the (lack of a) current data sharing environment. As stated before, governance measures with common agreed rules and regulations need to be implemented in order to provide full information, which is needed for the PI to be effective. This research has not focused on these measures. Instead, a more technical aspect as to what data is needed for what function, has been addressed.

Additionally, this research might suggest that the OLI model will be a single distinguishable entity. This is not necessarily the case. Instead, it could reflect a multitude of cloud-based operations in the PI, where various stakeholders facilitate specific OLI model functionalities. In this regard, and in light of this research, PCS could fulfil certain functionalities of the OLI model, such as track-and-trace capabilities in port operations and authentication of customs related information.

As addressed in the review of literature, the PI roadmap (Alice-ETP, 2020) proposes to implement a federated network of platforms throughout logistics nodes. This research has only focused on one logistics node, the Port of Rotterdam. Therefore, the research has only addressed one potential platform and its environment, instead of a network of platforms. A disclaimer is made here regarding the full information that is needed in such a federated network of platforms: full information as such does not yet exist, probably for years to come. Therefore, it is argued here that the focus of the industry should be on the information that *is* already available throughout data platforms, such as PCS. This way, a constructive approach can contribute to the swift development of data platforms for future logistics operations.

Design specific

One aspect of the assumption of full information is that (predicted) network states and optimal routing is assumed. Also, it is assumed that the network state and routes across the network are monitored according to operational activities. In this regard, *predictions* on network states and potential bottlenecks in the network, can be used as input for adaptations to the network. If, for example, predictions indicate that a link in the network may become congested, cargo can be rerouted or link capacity may be increased. This way, predictive control can be used as input for the optimal layout of the network.

In the design, port functions and the optimisation thereof have been split up. However, the separate optimisation of functions, might lead to a system suboptimum. After all, the optimisation of own port operations, is not necessarily optimal for other port operations. PI theory requires a global optimum of logistics operations, and therefore requires that separate optimisation functions are connected and depend on each other. Consequently, the connection and interdependency of optimisation functions in PI port operations, needs to be addressed. However, it is argued that the separation of optimisation functions provides a good starting point for the incremental way in which information systems in the PI need to be designed.

Because of scoping reasons, a vessel's port choice in the PI has not been included. We argue that the choice for a certain port can be modelled in a similar way as the terminal choice has been modelled here. However, an important implication of a possible change in port choice by a vessel in the PI, is the (planned) location of containers on vessels. If, for some reason, the (order of) port calls change, the optimal container location on the vessel may be compromised. Furthermore, additional container movements might be necessary.

An additional pricing mechanism in case of deviation of the optimal solution has been introduced. Such a pricing mechanism might incentivise the revision of business models in the PI. Additionally, the prediction of an optimal solution based on the shipper's QoS, could form the basis for an auction mechanism in the PI. This could work as follows: the shipper bids for a certain QoS, for which a predicted solution can be given. If the bid with defined QoS still satisfies the solution after a certain time span, the solution can be provided to the shipper. However, if another shipper bids for a higher QoS, and we assume ceteris paribus, the solution might be provided to the other shipper. This insight in new business models and potential implementations of such pricing mechanisms in the PI however, has not been the main point of focus in this research.

In the design, the optimisation of the port call and of the transfer of containers is executed by optimisation engines. These need to be developed. PortXchange in the Port of Rotterdam already provides port call optimisation, but is limited to the optimisation of mainly compliance related processes. The development of logistics related optimisation engines therefore is needed.

The destination of PI containers determine operations in the port. However, destinations differ in a very granular way. Therefore, it is recommended that destinations are aggregated in some way. Zoning of destinations may provide a solution for this problem, and may therefore serve as input for future research. Additionally, aggregation of PI containers' QoS levels, which determine port operations, is assumed in this research. How to aggregate QoS levels of PI containers, can be a point for future research as well. The next chapter provides conclusions on the research questions and presents an overview of future research recommendations.

9. Conclusion & future research

The potential role of Port Community Systems (PCS) as information intermediaries in Physical Internet (PI) ports is central in this research. The main research question of this research is stated as:

What is a potential conceptual design of an information system for port-related operations in the PI, where a PCS fulfils an information intermediary role?

To answer this question, the two literature gaps have been addressed in the form of sub questions. A case study regarding information exchange through a PCS has been carried out. The case in this research has been Portbase in The Netherlands. Specific information exchange in the PI has been presented in the form of requirements. The analysis of Portbase and requirements following from PI theory have been used as input for a Design Science Research (DSR) to design a potential information system of a PI port, where PCS fulfils an information intermediary role.

The first literature gap is related to the information exchange between a PCS and its environment. The case study analysis of the information that is exchanged between Portbase and its environment, shows that it exchanges information with several port stakeholders, which are distinguished as passive (i.e. only receive) or active (i.e. send & receive). The type of information that is exchanged consists mainly of event notifications from one stakeholder to another and of administrative customs information. This information can be categorised in two types of services: compliance related services and logistics related services. Compliance related services are used for legal purposes, whereas logistics services are used for the facilitation of the efficient flow of containers through logistics processes. The information between Portbase and its environment is exchanged via stakeholders' system interfaces or web interfaces.

The second literature gap is related to the expected information exchange in a PI port. Following from PI theory, several requirements for PI port information systems are formulated. The information system should capture more extensive track-and-trace information, sense-and-respond optimisation information, financial information, governance related information and information to and from consigners and consignees. In the design of this research, only sense-and-respond optimisation information has been incorporated as a requirement.

According to the DSR methodology, a design has been created that incorporates both Portbase information exchange as well as PI specific information exchange. With regards to the research goal to assess the potential of PCS in the PI, the DSR methodology has shown a good fit. Its explorative and incremental nature have contributed to a design that is able to combine information exchange from both research fields, hereby assessing the potential of PCS in the PI. Leading from the design, several recommendations are made. The recommendations are formulated as general recommendations to PCS, because Portbase is a PCS that mainly provides core services, and not many additional Value Adding Services. It is recommended that PCS should maintain their role as provider of compliance related services, invest in more extensive track-and-trace related services, invest in more extensive logistics related services for the optimisation of PI port functions, research the possibility of sharing compliance related service information with logistics related services, and extend its reach towards the hinterland by developing services at inland barge terminals.

The main research contribution is defined as follows. The design and recommendations have shown that Portbase can fulfil a certain role in PI ports. With its current offer of services, Portbase can facilitate compliance related services in PI ports. The facilitation of logistics related services in PI ports is limited. For further integration of PCS in the PI, an expansion of logistics services is needed. A conservative attitude towards the development of services could hinder the variety of Value Adding Services and applications, as reflected in the work by Elbert & Tessmann (2021). A conservative offer of services could negatively influence the potential role of PCS as information intermediaries in PI ports. Continuing to only develop services internally, or remaining closed off to innovative services from external developers, may hinder the growth that is needed to be of true value in PI ports.

Based on the discussion in chapter 8, there are some limitations to this research, as well as future research recommendations.

The PI not only consists of the movement of physical objects (i.e. Mobility web), for which information systems are needed. Information systems for the storage, supply, realisation and usage of physical objects in the PI, are also necessary. As mentioned earlier, the development of optimisation engines for predictive control of port processes, and the connection of various optimisation processes on an informational level in PI ports, is proposed as future research. A limitation of this research is the choice to only focus on import processes and only include sense-and-respond optimisation information in the design. Other scoping decisions naturally provide such limitations as well. In this regard, further research towards the design of information systems in PI ports might include export processes, other information flows in PI ports as defined in chapter 5, the port choice and bulk and piece goods. Additionally, the role of expeditors in the PI may be an interesting avenue. Another recommendation is to explore the governance measures and organisational changes that have to be pursued in order to acquire a data sharing environment in which full availability of information is aimed for. The lack of the availability of full information is a design limitation. Research towards business models and pricing mechanisms for the prioritisation of PI containers is recommended, as well as the possible aggregation of QoS levels that is suggested in this research. Regarding the diversity of PCS, additional PCS case studies are recommended to assess their potential in the PI. Whether the additional VAS offered by other PCS can for example be integrated into information systems for PI ports as well, is a point for future research. Furthermore, only current services of Portbase are taken into account in the analysis. No research has been done regarding the development of potential future PCS services that could be of value in the PI. In this regard, future research might focus on the possible outreach of PCS towards the hinterland. Lastly, the potential role of PCS in a federated network of platforms is highly recommended. Therefore, whether and how PCS can be of value in such a network of information platforms in the PI, is a point for future research.

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Appendices

Appendix A: Scientific paper

Port Community Systems in the Physical Internet

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Abstract – Global supply chains currently are inefficient and unsustainable, due to their overlap and lack of interconnection. The Physical Internet (PI) proposes a paradigm shift in the way we move, store, supply, realize and use goods. The goal of the PI is to interconnect global supply chains, amongst others, on a digital level. For this, information systems are needed. Seaports, being drivers of global supply chains, therefore also need information systems on an integral level. In certain ports, Port Community Systems (PCS) serve as port's information systems. They facilitate information exchange between stakeholders to better connect port processes. This research explores the potential role of PCS in PI ports. It does so by performing a Design Science Research (DSR). The artefact that is designed, is a conceptual information system that addresses key (PI) port functions. A case study analysis at Portbase, the Dutch PCS, has revealed what information is exchanged between which stakeholders. PI literature provides grip for PI information system requirements. The integration of the PCS analysis and the PI requirements has led to a design of an information system that shows the potential of a PCS in a PI port. The design shows that, according to the current offer of PCS services, PCS' potential role focuses mainly on compliance related processes in PI ports. It also shows that the offer of logistics related services that are needed in PI ports, is limited. It is therefore recommended that PCS focus on an extension of logistics related services that are needed in PI ports. Future research may address the potential of PCS in a federated network of platforms.

Keywords: Port Community Systems, Physical Internet, Information systems, Design Science Research (DSR), case study

1. Introduction

The Physical Internet (PI) is a vision towards global sustainable supply chains. Currently, numerous supply chains across the globe form parallel networks, that are not connected and do not communicate to each other, which is not efficient nor sustainable. To address this, the PI proposes to "interconnect logistics networks through world-standard modular containers, interfaces and protocols" (Montreuil, Ballot & Fontane, 2012, p. 328).

Currently, there is a limited variety of transport containers, of which the large 20ft. and 40ft. are the most well-known. By introducing smaller and modular containers for the handling and packaging of cargo, cargo can be more finely distributed across logistics networks. Additionally, by using the same interfaces and protocols throughout logistics processes, logistics networks can be interconnected and supply chains can work more efficiently and sustainably. To achieve this, universal interconnectivity serves as one of the pillars of the PI (Montreuil, Meller & Ballot, 2012). Universal connectivity consists of physical, operational and digital connectivity. Digital interconnectivity receives the focus in this research and entails the exchange of fact-based information that can be used for efficient real-time decision-making. To achieve digital interconnectivity in logistics networks, multi-level certified information systems are needed (Montreuil, 2012). However, PI information systems do not yet exist.

In certain ports, information systems that digitally interconnect port processes currently exist. These are called Port Community Systems (PCS). PCS are electronic platforms that enable information exchange between public and private stakeholders through a single submission of data (IPCSA, 2020). By reusing data, port operations can work more efficiently. The existence of such information systems in current ports, and the need for certified information systems in the PI, leads to the question whether PCS can serve as information intermediaries in PI port operations. To be able to answer this, we first have to know how information systems in current port environments (i.e. PCS) work and how information systems in future port environments should work (i.e. PI). Apparent knowledge gaps that arise here, are:

- Unknown is what, how and between who information is exchanged between PCS and its environment
- Unknown is what, how and between who information is exchanged in port-related operations in the Physical Internet.

Based on the research relevance and knowledge gaps presented above, the main research question is formulated as follows:

What is a potential conceptual design of an information system for port-related operations in the PI, where a PCS fulfils an information intermediary role?

To address this, a Design Science Research (DSR) approach is applied. DSR is a solution-oriented approach, where something new is created: the artefact (Hevner et al., 2004). The process of designing the artefact is essential in DSR. Through building the artefact, knowledge is acquired on the research domain. Continuous acquirement of knowledge is important in this research, because the PI is a very novel research subject and literature on PCS lags behind on operations (Moros-Daza, Amaya-Mier & Paternina-Arboleda, 2020).

The paper is built up as follows. Section 2 presents relevant literature on the PI, on PCS and on data sharing and its governance. Section 3 discusses the DSR methodology and specific methods that are used. Section 4 presents the analysis of a PCS case study, section 5 addresses the requirements for a PI port information system and section 6 presents the designed artefact itself. Section 7 discusses the evaluation of the design, its validation and specific recommendations to PCS, leading from the design. Section 8 provides a discussion and section 9 concludes the research, together with recommendations for future research.

2. Literature review

2.1 Physical Internet

The Physical Internet (PI) proposes a paradigm shift in the logistics industry for how goods are moved, stored, supplied, realized and used (Montreuil, Ballot & Fontane, 2012). As stated, this is achieved by implementing standard modular containers, interfaces and protocols. Modular containers consist of packaging containers (P-containers), handling containers (H-containers) and transport containers (T-containers) (Montreuil, Ballot & Tremblay, 2016). The encapsulation of physical products happens in P-containers. P-containers can be composed into H-containers for easy handling and H-containers can be composed into T-containers for easy transportation. Similarly, decomposition of T-containers into H-containers and H-containers into P-containers is possible. Standard interfaces consist of physical interfaces and information & communication interfaces, as distinguished by Fahim et al. (2021). Standard PI protocols represent a unified way of working throughout logistics networks. These logistics networks are represented with several interconnected layers, which are similar to the layers in the digital internet. Montreuil, Ballot & Fontane (2012) developed the Open Logistics Interconnection (OLI) model, which consists of seven layers. The OLI model is depicted below.

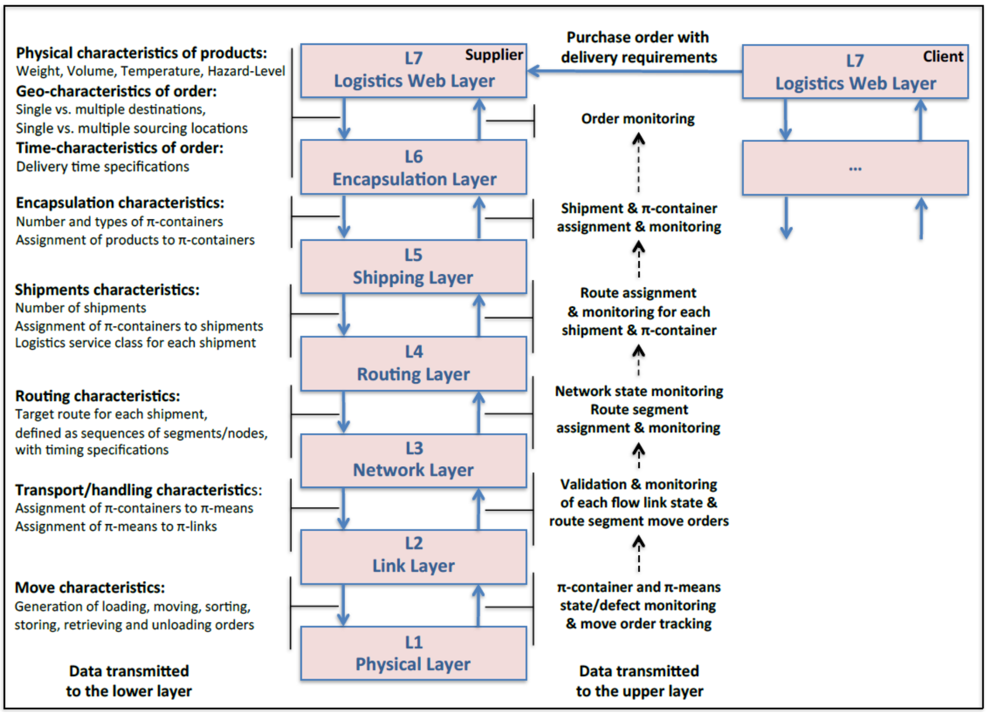

Figure 1: Open Logistics Interconnection (OLI) model (source: Montreuil, Ballot & Fontane, 2012)

As can be seen, a high amount of data transmission is needed according to the OLI model. This stresses the need for an information system.

Information systems can be roughly categorised as centralised, decentralised and distributed (Baran, 1964). One goal of the PI is decentralised decision-making. However, for efficient coordination of information flows, some level of centralisation is necessary (De Jong, 2020; Wissink, 2020). Furthermore, there is little evidence that fully decentralised freight information systems can be successfully implemented in current freight transport systems (Sternberg & Andersson, 2014). To address this, the Digital Transport and Logistics Forum (DTLF) proposes a 'federated network of platforms' in the PI (Alice-ETP, 2020). This implies that each federation has its own platform, where a federation may represent countries. In this regard, national PCS platforms as they exist today, might fit well into this notion.

The proposition of a federated network of platforms is done in the PI roadmap by Alice-ETP (2020). This roadmap provides dimensions along which the PI needs to be developed. The dimensions and corresponding relevant developments, are:

- Logistics nodes → implement federated network of platforms
- Logistics networks → develop advanced ICT systems
- System of logistics networks → end-to-end testing of network flows
- Access and adoption → development of digital access points
- Governance → define rules for open, shared and connected logistics networks

2.2 Port Community Systems

According to the International Port Community Systems Association (IPCSA, 2020), a Port Community System (PCS) is "a neutral and open electronic platform enabling intelligent and secure exchange of information between public and private stakeholders". By doing so, PCS simplifies procedures and facilitates more effective communication (Kaup et al., 2021; Mayanti et al., 2020). Furthermore, extensive PCS characteristics have a positive influence on port performance (Caldeirinha et al., 2020). PCS can therefore be considered as an integrator of port processes, which is demanded in the PI. Integration of port processes through PCS happens in logistics, customs, navigation and dangerous goods functions (Carlan, Sys & Vanelslander, 2016). Additionally, ports have to design operational guidelines for effective sharing of information (Nikghadam et al., 2021). It is argued that PCS try to do this by developing specific services that fit to industry needs and wishes.

Similar to the adoption of the PI depending on perceived benefits, organisational readiness and external pressure (Sternberg & Norrman, 2017), it is argued that the adoption of PCS not only depends on Information Technology (IT) penetration, but especially on the willingness to change among different public and private stakeholders (Mendes Constante, 2019).

PCS can have different structures. Elbert & Tessmann (2021) distinguish PCS that only offer core PCS services and are relatively closed off, such as Portbase in The Netherlands, and PCS that offer more Value Adding Services (VAS) and that are more open to the development of services of external developers, such as the Networked Trade Platform (NTP) in Singapore. They argue that this is a balance between easy trust building and the offer of additional VAS.

An example of a PCS structure is given in the figure below (Portbase, 2018). It consists of several layers.

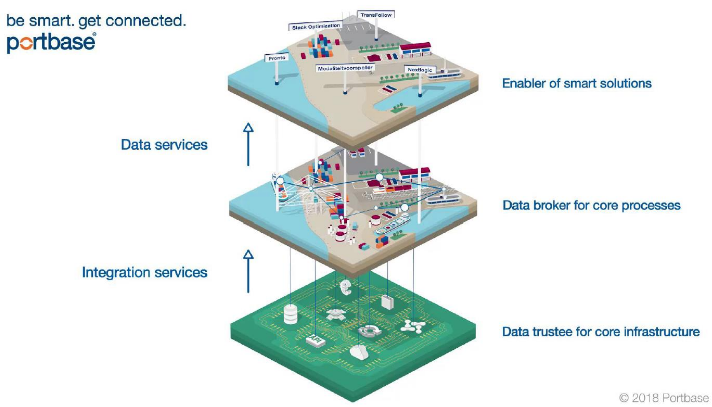

Figure 2: Portbase platform structure (source: Portbase, 2018)

The PCS platform is built on a layer with core infrastructure, needed for sharing of information. Built on top of this layer, is a layer with core processes. This layer is meant for information sharing between core port processes, such as terminal or customs operations. The top layer of the PCS structure is related to the enablement of smart solutions, based on information sharing between core processes. An example is Nextlogic, a company that optimises barge rotations, based on the network performance. There is a similarity between the layered structure of a PCS and the layered structure of the OLI model of the PI, because in both structures, each layer provides instances to the higher layers, and receives services from lower layers. In this way, each layer is able to run distributed applications, based on the services from lower layers.

To be able to run such layered systems, data sharing is essential. Hofman (2015) proposes a resource-oriented view on data sharing in transport and logistics. Every resource, which can be a truck or an entire organisation, has its own communication system that provides services based on interfaces and protocols. The communication systems of all resources form a connectivity infrastructure. Such an approach provides a conceptual structure for data sharing in the PI. However, governance of data sharing is essential as well. Data ownership, powerful stakeholders, and data governance design decisions are several aspects that need to be taken into account for effective data sharing (Lee, Zhu and Jeffery, 2018; Lis and Otto, 2021; Khatri and Brown, 2010).

3. Methodology

The research approach is depicted in the figure below.

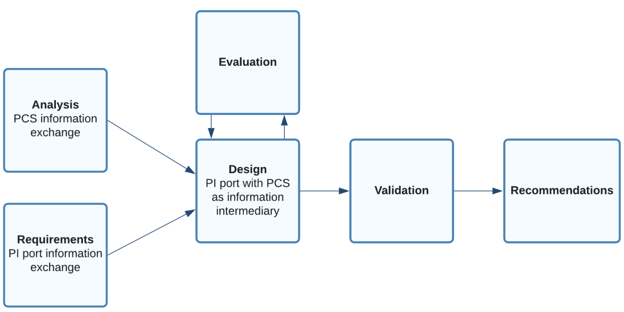

Figure 3: Research approach

A Port Community System (PCS) and its information exchange is analysed in a case study to distinguish what information is exchanged between which stakeholders. Documents on the expected development of the Physical Internet (PI) provide requirements for information exchange in PI ports. By combining the analysis and the requirements into a design, the potential of PCS in PI ports is assessed. Design Science Research (DSR) is used as the design methodology. The artefact is a conceptual information system of a PI port where a PCS fulfils an information intermediary role. The Framework for Evaluation in Design Science (FEDS) by Venable, Pries-Heje & Baskerville (2016) is applied according to the technical risk and efficacy evaluation strategy. Evaluation and validation of the design is done through interviews with both PCS and PI experts. Based on the design, recommendations to PCS are provided, regarding their potential role in PI ports.

To analyse a PCS, a case study at Portbase in The Netherlands is performed. Mapping of information flows is done according to Business Process Model Notation (BPMN) guidelines into a Business Process Diagram (BPD). The formulation of requirements for information systems in PI ports, is done according to the expected developments of the PI in the PI roadmap by Alice-ETP (2020). For the actual design of a PI port information system, a clear distinction between PI port functions is made in a conceptual model. Therefore, conceptual modelling through IDEF0 is applied (International Organization for Standardization [ISO], 2012).

4. Case study analysis

The analysis of the information exchange facilitated by Portbase reveals that notifications are a large part of operations. Examples are the notification to several port stakeholders of the arrival of a vessel, or the presence of dangerous goods on board of the vessel. Another large part is customs related information. Examples are different declarations for the import of cargo, issued by the cargo agent, and information regarding customs' inspection process. The information can be categorised into two types: compliance related information and logistics related information. Compliance related information is information that has a legal background: stakeholders have to provide certain information to comply with rules and regulations. Logistics related information is information that is used for a more efficient flow of cargo through logistics operations. An example is the pre-notification of the arrival of a truck at a terminal, so the terminal can anticipate and plan its operations in a more efficient way.

Two groups of stakeholders are identified from the analysis: passive and active stakeholders. Passive stakeholders only receive information from Portbase, and base (part of) their operations on this information. Active stakeholders not only receive information, but also send back information that is used for the operations of other stakeholders. An example of a passive stakeholder is the Harbour Master. An example of an active stakeholder is the terminal.

5. Requirements

According to the Physical Internet (PI) roadmap (Alice-ETP, 2020), the PI needs development along five dimensions. Each dimension provides developments that are translated into additional information streams for PI port information systems. The information streams are:

- More extensive track and trace information
- Sense-and-respond optimisation information
- Financial information
- Information from and to consigners and consignees through digital access points (here translated as "last-mile document exchange")
- Common agreed rules and regulations (governance related information)

To make the research more manageable, only one information stream has been formulated into a requirement. The requirement is as follows:

The designed information system should be able to optimise network flows based on sense-and-respond information

This requirement specifically targets the optimisation of logistics processes that is needed in the PI.

6. Conceptual design

As stated, the case study analysis at Portbase and the formulated requirement, serve as input for the design, with a Design Science Research (DSR) approach. The proposed design consists of two designs: a high level design (A0 level) and a detailed design (A1 level). They are depicted in figures 4 and 5, respectively. Both designs have the same consistency. The information exchange is designed as information exchange between port functions and the OLI model (green arrows) and between port functions and Portbase (blue arrows). Because of assumptions and scoping of the research, the information exchange with the OLI model only includes the network, routing, shipping and encapsulation layer. The information exchange with Portbase only includes the services that have been included in the analysis (Appendix A).

6.1 High level design

The design adheres to the bottom-up design approach of the PI (Alice-ETP, 2020). We therefore define four separate functions related to the import of containers to the hinterland:

- Port call
- Declaration processing & risk assessment
- Transfer PI container from vessel to hinterland modality
- Transport to hinterland

To incorporate the requirement, the port call and the transfer of containers have been included with separate functions dedicated to the optimisation of their respective process. This separation is distilled from Sternberg and Norrman (2017) and Treiblmaier et al. (2020). Function A3 has no separate optimisation because it does not reflect the optimisation of network flows; function A6 has not been defined with a separate optimisation because of the port-oriented nature of this research.

Not all port functions are described here. Instead, the design of the two optimisation functions is discussed. The goal of the optimisation of the port call (A2) is to let vessels pass through the port as efficiently as possible. To do this, it is argued that the terminal and route choice are the most important decision variables. The goal of the optimisation of the transfer of containers to the hinterland (A5), is to let containers pass through the terminal as efficiently as possible. To do this, it is argued that the choice for a hinterland mode is the most important decision variable.

6.1.1 Optimise port call

Thus, the port call may be optimised by varying the vessel's terminal and route choice. This choice is determined as follows. Containers on the vessel are assumed to have a certain desired Quality of Service (QoS), determined and paid for by the shipper. QoS consists of transportation and handling time, costs, emissions and Logistics Service Provider (LSP) quality. The containers on the vessel determine an aggregated desired QoS of the vessel. Each terminal has a certain Level of Service (LoS) that it can offer, with the same criteria as the QoS. The optimal vessel route to each terminal (with LoS) can be calculated according to the vessel location and network state. By comparing the vessel's QoS to the LoS of available terminals, a terminal choice can be made with corresponding route. Additionally, container destinations and deadlines may determine the terminal choice, in case the majority of containers do not demand transfer but transhipment. This heuristic is depicted in Appendix B.

6.1.2 Optimise transfer

The transfer of containers may be optimised by varying the container's hinterland mode choice. This choice is determined as follows. T-containers leave the terminal with a certain composition of P- and H-containers. Because of reconsolidation, T-containers on a vessel do not necessarily leave the terminal in the same composition. Therefore, the T-container composition after reconsolidation needs to be predicted. This can be done based on the containers' destination and deadline: similar destinations and deadlines can be put together. Also, similar QoS levels determine which containers can be put together, as well as the content of each container (because of laws and regulations). The predicted T-container composition has an aggregated QoS. Similar to the route in the port call, an optimal route can be calculated per mode, based on the network state. Each mode has a certain LoS that it can offer. This way, a best route per mode, with LoS, is calculated. By comparing this LoS to the aggregated QoS of the T-container, the optimal mode solution can be provided. Additionally, if a container has already been defined with a pre-assigned hinterland mode, this determines the mode choice. This heuristic is depicted in Appendix B.

The information that is needed for the optimisations, is derived from the OLI model layers (green arrows). What layer is allocated to which piece of information, is depicted in the design. L3 is layer 3 (network), L4 is layer 4 (routing) and so on. It must be noted that the optimisations run dynamically over time. This means that optimal solutions are continuously generated based on real-time changes in the network state.

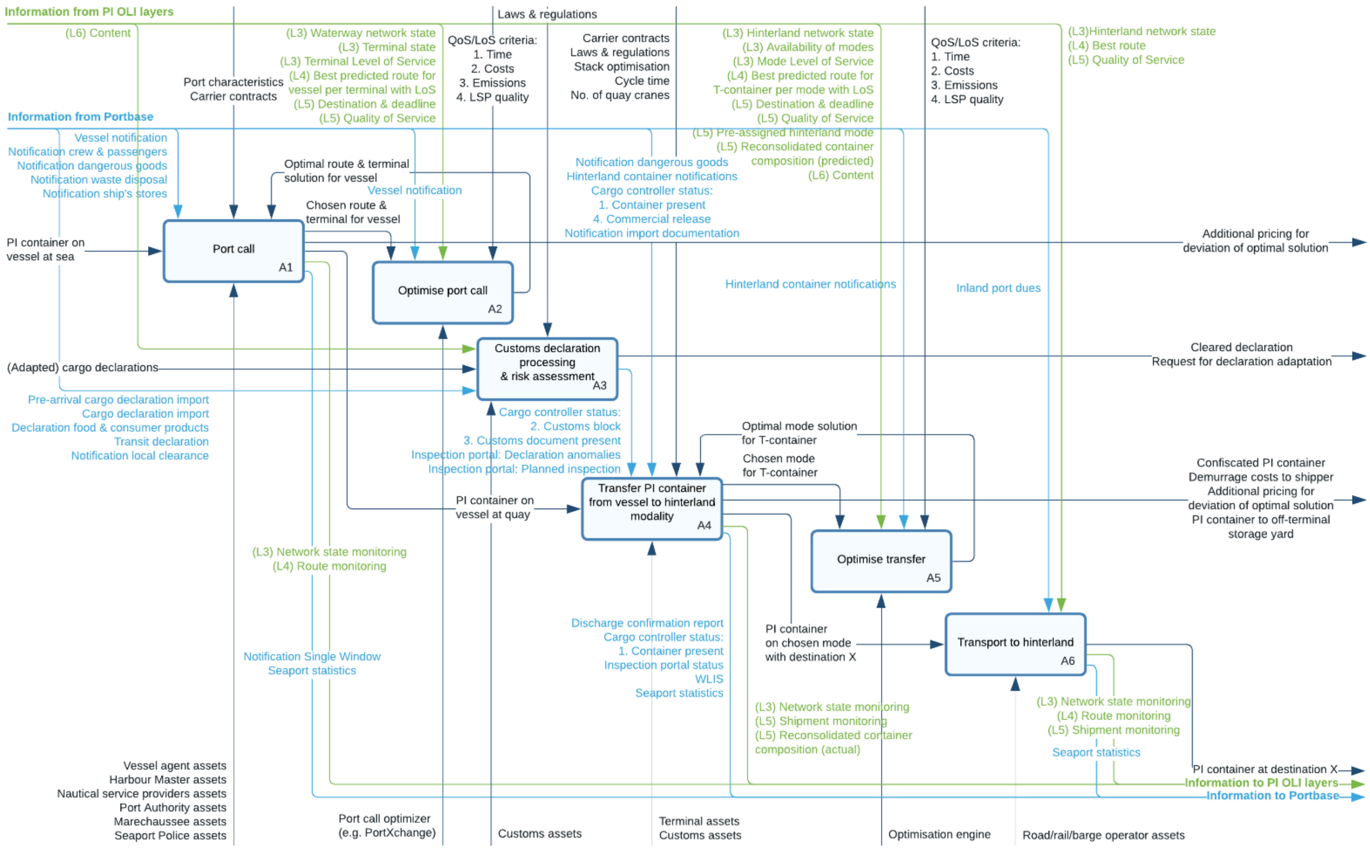

Figure 4: High level design of PI port information system

6.2 Detailed design

The detailed design is an in-depth design of the transfer function (A4). The defined functions during the transfer process, distilled from Fahim et al. (2021), are:

1. Unload
2. Physically inspect PI container
3. Reconsolidation
4. Store at yard
5. Hand over PI containers to hinterland modality/off-terminal storage yard

All five functions are related to physical operations on PI containers. The optimal mode solution, from process A5, determines at each function where a container moves. Additionally, if physical inspection is needed, following from the A3 process, the container moves to process A42. For all other moves, the move is determined by the optimal solution. For example, if the optimal mode solution demands for a container to be picked up shortly, the container may move to the handover process (A45). If not, the container may be stored either at the container yard or an off-terminal storage (A44 or A45). If the container needs reconsolidation, the container moves to A43.

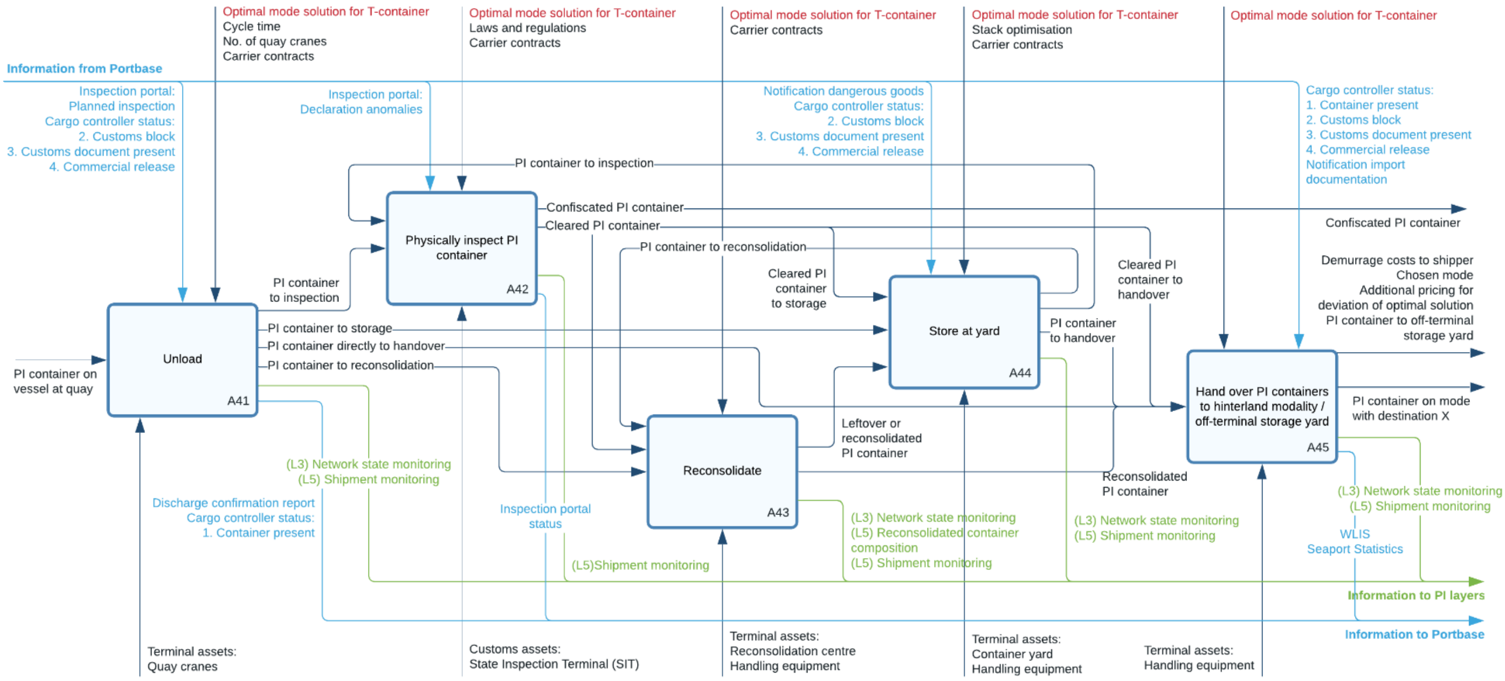

Figure 5: Detailed design of the transfer of containers to the hinterland modality (process A4)

6.3 Integration of Portbase services in design

In both designs, Portbase services are integrated (blue arrows). A clear distinction between compliance related services and logistics related services can be seen. Information from compliance related services serves as control information for currently existing port processes, whereas information from logistics related services can be used for specific PI port processes (i.e. sense-and-respond optimisation: functions A2 and A5). Not all services are discussed here. Instead, the use of logistics related services for the PI port optimisation functions is discussed. For the port call optimisation (A2), the service *vessel notification* serves as control information. To be specific, this service may provide the vessel location that is needed for the vessel's optimal terminal and route choice. For the container transfer optimisation (A5), the service *hinterland container notification* serves as control information. This service can provide the availability of modes that is needed for the container's optimal mode choice.

7. Evaluation, validation and recommendations

The design has been incrementally evaluated according to the Framework for Evaluation in Design Science Research (FEDS) by Venable, Pries-Heje & Baskerville (2016). At first, the technical, summative part of the design is argued to be more important, because necessary information for the optimisations needs to be complete. Later in the design process, the representativeness of the design with the real world is more important. Therefore, the technical risk and efficacy evaluation strategy has been applied throughout the design process.

Validation of the design has been done according to expert interviews. The experts that have been consulted are presented in Appendix C. The validation has been split up into three parts:

1. Use of OLI model PI information
2. Use of PCS information
3. Physical flow of PI containers

The allocation of pieces of information to specific OLI model layers, has been repeatedly evaluated and validated by the experts. The use of PCS (i.e. Portbase) information in the design has been validated by Dennis Dortland, Innovation Consultant at Portbase. The physical flow of PI containers has repeatedly been evaluated and validated by port operation experts as well. Because the design has been validated based on specific *aspects*, as well as on a specific *level of detail* (i.e. detailed design), the design is considered valid.

Based on the validated design, several recommendations are made to PCS:

1. PCS should maintain their role as information intermediary for compliance related services in PI ports
2. PCS should invest in the development of more extensive services related to track-and-trace capabilities in PI ports
3. PCS should invest in the development of more extensive logistics related services that can be used for optimisation functions in PI ports
4. PCS should research to what extent compliance related information regarding the content of containers, can be used for logistics services for optimisation functions in PI ports
5. To extend its reach towards the hinterland, Portbase should research whether and how it can implement a service to notify the arrival of inland barges at inland terminals, similar to the hinterland container notification at container terminals at deep sea ports

8. Discussion

This section provides the most important points of discussion regarding the research. The first is related to the case study performed at Portbase. As with all case studies, researchers need to be careful with the generalisation of implications. However, because Portbase offers core PCS services (Elbert & Tessmann, 2021), it is argued that the nature of the implications can be applied to other PCS that offer similar services. Another point of discussion is that in reality, many port functions and stakeholder types are vertically integrated. In this research, they have been split up explicitly. However, it is argued that for the development of an information system, a separation needs to be made on a function level, regardless of the process owner. The optimisation functions included in the design have been split up as well, based on Sternberg and Norrman (2017) and Treiblmaier et al. (2020). A separation of optimisations might lead to a system suboptimum. However, because of the incremental and explorative nature of PI design and this research, it is argued that the design provides a good starting point for future designs of PI port information systems. The access to necessary data and related measures that are needed to design data governance, are also a point of discussion. In this research, it is assumed that all data that is needed in the information system, is available. In reality, this is not the case. To enable this, governance and organisational measures that facilitate an open data sharing environment, should be put into place. These can be encouraged by (powerful) industry stakeholders, who in turn need to adapt their business models towards more collaborative structures. Although innovation in data governance and business model adaptation is out of scope of this research, it does reflect the need for data sharing in PI ports. Other interesting points of discussions are that predictions on network states and potential bottlenecks in the network can be used as input for adaptations to the network, zoning of destinations might be necessary for effective optimisations of PI network flows and development of PCS logistics services should happen parallel to the further development of PCS compliance services.

9. Conclusions and future research

This research has shed a light on the potential role of Port Community Systems (PCS) in the Physical Internet (PI). To be specific, it proposes a design of a PI port information system, where a PCS fulfils an information intermediary role. A PCS case study at Portbase and PI information system requirements have served as input for a Design Science Research (DSR). The design shows that Portbase can fulfil a certain role in PI ports. With its current offer of services, Portbase can facilitate compliance related services in PI ports. The facilitation of logistics related services in PI ports, is limited. For further integration of PCS in the PI, an expansion of logistics services is needed. A conservative attitude towards the development of services could hinder the variety of Value Adding Services and applications, as reflected in the work by Elbert & Tessmann (2021). A conservative offer of services could negatively influence the potential role of PCS as information intermediaries in PI ports. Continuing to only develop services internally, or remaining closed off to innovative services from external developers, may hinder the growth that is needed to be of true value in PI ports.

Future research could focus on the potential role of other PCS in PI ports. Furthermore, it is recommended to research the potential role of PCS in the development of a federated network of platforms in the PI. Additionally, optimisation engines for vessels' terminal choice and PI containers' mode choice could be developed. Finally, as extension of this research, the inclusion in the design of the export of PI containers, the other information flows in PI ports as defined in section 5, the port choice and bulk and piece goods, is recommended.

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Appendix A: Portbase services included in analysis

Number in (Portbase, 2020)	Service name	Description
4.	Vessel notification	Notifies arrival of vessel
39.	Notification crew and passengers	Notifies arrival of crew and passengers
35.	Seaport statistics	Provides CBS with relevant statistics
14.	Cargo declaration import	Handles summary declarations
2.	Notification dangerous goods	Notifies arrival of dangerous goods
3.	Notification single window	Notifies SPOC NL with notifications and ATA and ATD
7.	Inspection portal	Overview for status of inspection processes
8.	Cargo controller	Overview for T&T information
12.	Notification local clearance	Handles simple customs procedure
16.	Notification import documentation	Notifies customs documents to terminal
17.	Transit declaration	Handles full customs procedure
1.	Notification waste disposal	Notifies arrival of waste on board of vessel
41.	Notification ship's stores	Notifies content of ship's stores
15.	Declaration food and consumer products	Handles declarations for import of food and consumer products
21.	Pre-arrival cargo declaration import (4h)	Handles Entry Summary Declarations
9.	Discharge confirmation report	Confirms discharge of containers from vessel
43.	Import status	Overview for import status of Brexit cargo
19.	Veterinary inspection process	Overview for status of veterinary inspections
23.	Inland port dues	Notifies arrival of inland barge and handles payments
24.	Wagonload information system	Notifies composition of containers on train
42.	Hinterland container notification road, rail & barge	Notifies arrival of truck, train or barge

Table 1: Portbase services description and related stakeholders

Appendix B: Heuristic for processes A2 and A5

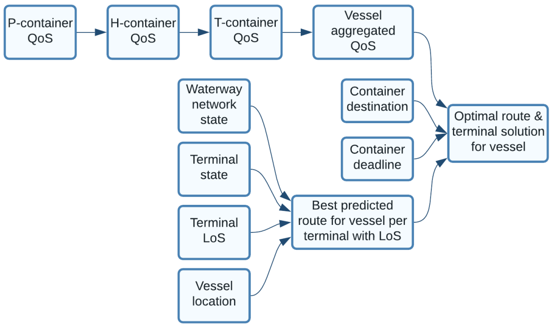

Figure 6: Heuristic for the terminal choice

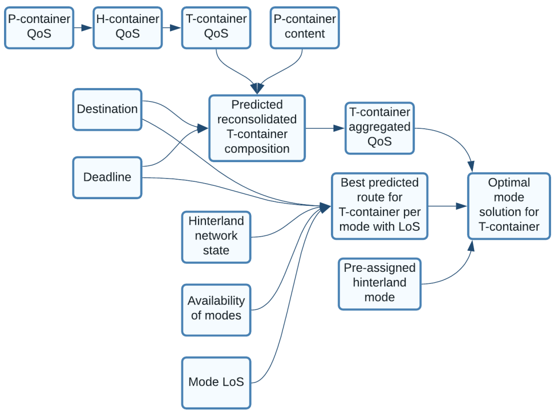

Figure 7: Heuristic for the mode choice

Appendix C: Experts consulted for validation

1. Dr. Ir. Arjan van Binsbergen (a.j.vanbinsbergen@tudelft.nl)
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3. Ir. Dennis Dortland (d.dortland@portbase.com)
4. Ir. Patrick Fahim (p.b.m.fahim@tudelft.nl)
5. Prof. Lori Tavasszy (L.A.Tavasszy@tudelft.nl)
6. Dr. Nick Szirbik (n.b.szirbik@rug.nl)
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Appendix B: Other considered methodologies

As noted in chapter 3, various design approaches have been considered, given the focus on the design of an information system. Design Science Research (DSR) has been the chosen methodology of this research. The other methodologies that have been considered for the design, are presented in this appendix. They are individually explained below, as well as the reason to eventually not use the specific methodology.

1. Waterfall model

   The waterfall model is a model that has been used extensively in scientific research. It focuses on the development of products in a familiar domain (Sage & Rouse, 2014). Boehm's version of the waterfall model includes the following steps: concept definition, requirements definition; architectural design; detailed design; coding; integration; implementation; maintenance and phase out (Sage & Rouse, 2014). In this version, a returning, evaluating path to the previous step is included. However, no inherent, returning, evaluation method for all previous steps is included in the waterfall model. Therefore, it is argued that the waterfall model is not suitable for large, complex projects, where the method does not necessarily follow a fixed sequence. Additionally, the waterfall model is often used internally in an organisation, so users are not primarily included in the system design.

2. V-model

   The V-model is documented in (Sage & Rouse, 2014) as well. Originally, it is a process model for software engineering. However, it is widely applicable in systems design and its components. It consists of a user model, an architecture model and an implementation model. The user model is associated with the user's requirements and the eventual product that should meet these requirements. The architecture model is associated with the system's engineer, who decomposes the problem, designs components and again composes these into the final system design. The implementation model is associated with the design of specific components and their requirements. It is the most detailed level of the V-model. Within these layers of the V-model, continuous testing (i.e. verification and validation) is performed to ensure that the (sub) system meets its requirements. A drawback of this methodology is that requirements need to be very clear, otherwise detailed testing is not possible. Because this research is explorative and components and requirements of the system are not yet clear, it is argued that the V-model is not suitable for this research.

3. Spiral model

The spiral model is accurately described in (Sage & Rouse, 2014) as well. One of the drawbacks of the waterfall model, that it lacks a complete return cycle, is captured in the spiral model. This way, incremental changes can be made, without having to re-engineer the whole system. Each increment serves as the input for the next. Every increment follows the same four phases: identify objectives, requirements and alternatives; identify problems and resolve risks; development of the product; deployment of the product. Sage & Rouse (2014) argue that the deployment of the product mainly is a stepping stone for the next layer or increment of the system design. Because of the incremental nature of the spiral model, it is suitable for large, complex projects, in which layering of designs is necessary. An important part of the spiral model is risk assessment, as it is an inherent part of each incremental design cycle. When comparing the spiral model to the waterfall model and the V-model, it may seem as a suitable methodology. However, because risk assessment is an essential part of the spiral model, and because this research is explorative and therefore risks are not yet fully known, it is argued here that the spiral model is not suitable for this research.

Appendix C: Description of selected stakeholders for case study analysis

Chapter 4 has discussed the information exchange between Portbase and its environment. The environment consists of relevant stakeholders, derived from Portbase (2020). A selection of stakeholders has been made, either because of relevance to or manageability of this research. The table below presents a brief description of the selected stakeholders for the case study analysis. For additional information on the specific stakeholders, we refer to the stakeholders' webpage (see footnotes).

No.	Stakeholder name	Stakeholder description
1.	Ship agent	Agent that is concerned only with vessel-related matters
2.	Cargo agent	Agent that is concerned only with cargo-related matters
3.	Customs	Customs Administration of The Netherlands[8]
4.	Terminal	Cargo terminal where vessel is moored, containers are unloaded, stacked and released to the hinterland
5.	Expeditor	Agent that provides service to synchronise supply and demand of container transport
6.	Hinterland transporter	Road haulier, rail operator, or barge operator
7.	Port Authority	Port of Rotterdam Port Authority[9]
8.	Harbour Master	Harbour Master of the Port of Rotterdam[10]
9.	Nautical service providers	Pilots, tugboats and boatmen
10.	Marechaussee	Royal Netherlands Marechaussee[11]
11.	Seaport Police	Police division responsible for a.o. the Port of Rotterdam
12.	Rijkswaterstaat	Executive agency of the Ministry of Infrastructure and Water Management[12]
13.	NVWA	Nederlandse Voedsel en Waren Autoriteit: Netherlands Food and Consumer Product Safety Authority[13]
14.	ILT	Inspectie Leefomgeving en Transport: Human Environment and Transport Inspectorate[14]
15.	CBS	Centraal Bureau voor de Statistiek: Statistics Bureau of The Netherlands[15]
16.	SafeSeaNet	Monitoring and information system for European maritime traffic

Table 4: Selected Portbase stakeholders

[8] https://www.belastingdienst.nl/wps/wcm/connect/en/customs/customs
[9] https://www.portofrotterdam.com/en/about-port-authority
[10] https://www.portofrotterdam.com/en/about-port-authority/our-organisation/harbour-master
[11] https://english.defensie.nl/organisation/marechaussee
[12] https://www.rijkswaterstaat.nl/en
[13] https://english.nvwa.nl/
[14] https://english.ilent.nl/
[15] https://www.cbs.nl/en-gb

Appendix D: Detailed explanation of Portbase services

This appendix provides a detailed explanation of Portbase services that have been selected for this research, as well as their relation to relevant stakeholders. Figure 12 in section 4.2 shows that some stakeholders only send information, and others also receive information. However, it does not show what information is sent from one stakeholder to another. After all, Portbase serves as an information intermediary. The figures that follow, show what information is sent to which stakeholder, by means of a Business Process Diagrams (BPD). The first figure below is an overview of how the detailed figure should be interpreted. A detailed version is presented later on.

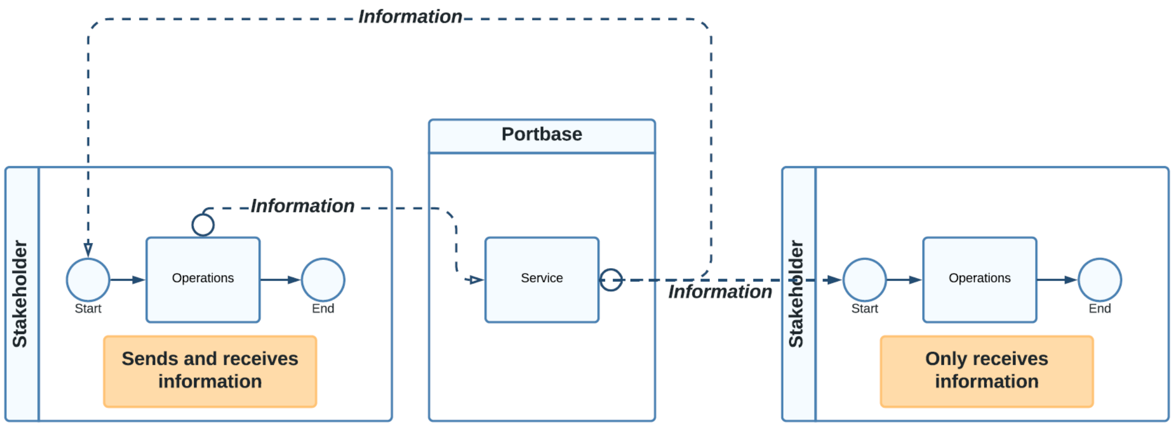

Figure 20: Overview of detailed version of Portbase BPD

The figure can be interpreted easily when starting at the operations of the stakeholder on the left hand side. Operations of the stakeholder result in information that can be provided to other stakeholders. This information is sent to Portbase, through one of its services. Portbase then makes sure that other stakeholders receive the information. Based on this information, others can start their own operations. A division can be made between passive stakeholders that only receive information (right hand side), and active stakeholders that send as well as receive information (left hand side, hence the loop). This structure is applied in the detailed version of Portbase's operations that will follow as well.

The detailed version of Portbase's operations includes the same main components as in the simplified version: 1. Portbase itself, 2. stakeholders that either receive or send and receive information and, 3. the information flows between them. Portbase offers various services (Portbase, 2020). This research is limited to the import of a container from a deep sea vessel via the Port of Rotterdam to one of the hinterland transportation modes road, rail or barge. Therefore, only stakeholders and services that are related to *import of containers* are included. What stakeholders are selected for this research and their explanation can be found in Appendix C. What specific services are selected for this research and a brief explanation can be found in table 2 in section 4.2.

The business processes are discussed here mostly in chronological order, from the deep sea vessel being several days away from arriving at the Port of Rotterdam to the release of the container to the hinterland. The possibility and often necessity to send certain information prior to physical arrival at the port is the reason why Portbase's business processes already start several days before arrival.

Ship agent

The ship agent sends a **vessel notification** to Portbase to notify its arrival. Upon reception, Portbase will forward the notification to the Harbour Master, nautical service providers and customs. The ship agent also sends a **notification crew and passengers** via Portbase to the Marechaussee and the Seaport Police to notify the details of people on board of the vessel. The ship agent provides tracking information for the arrival of the vessel via the service **cargo controller**, announces waste to be picked up from the vessel via **notification waste disposal** to the Harbour Master and notifies the content of the ship's stores via **notification ship's stores** to customs.

Cargo agent

The cargo agent sends a **pre-arrival cargo declaration import** and a **cargo declaration import** via Portbase to customs, a **notification dangerous goods** via Portbase to the container terminal for terminal planning, to Inspectie Leefomgeving & Transport (ILT) for permit checks, to the Harbour Master for legislative reporting, and to Rijkswaterstaat for potential operational hazards. The terminal receives a **notification import documentation** to confirm that the correct documentation is available for the pick-up of the cargo. It depends on the situation who will send the notification. From the Portbase website[16]: "Generally speaking, this is the forwarder, the exporter or the carrier." In this research, the forwarder is called the expeditor. They arrange the submission of the import documentation, and subsequently hire a hinterland transporter. In light of this research, the exporter here is distinguished as the importer, which is argued to be the cargo agent: the one responsible for the cargo and for the submission of the import documentation. Deep sea carriers often arrange the transport to the final destination, and not only to a certain seaport. Therefore, the carrier can also be considered as a hinterland transporter, which is the one who picks up the cargo at the terminal and the one who submits the import documentation. The cargo agent can also send a **transit declaration** to customs if the goods are not imported, but require transit. If the cargo consists of food or live animals, a **declaration food and consumer products** has to be issued. Afterwards, the cargo agent starts a **veterinary inspection process** via the Nederlandse Voedsel en Waren Autoriteit (NVWA), the Food and Consumer Product Safety Authority.

[16] https://www.portbase.com/en/services/notification-import-documentation/

Customs

Customs sends information to Portbase about the status of its inspections. Via the **inspection portal**, it updates cargo agents, terminals, expeditors and hinterland transporters. Additionally, it notifies cargo agents, terminals, expeditors and hinterland transporters on the **import status** of their goods (i.e. whether the pre-notification of import documents has been made).

Terminal

Terminals give, via Portbase's service **cargo controller**, an update to cargo agents, expeditors and hinterland transporters. It provides them with track and trace information of their cargo or the cargo they will carry. A **discharge confirmation report** is sent to the cargo agent to inform them about discrepancies between the planned discharge and actual discharge of containers.

Expeditor

The expeditor gives the cargo agent insights in the whereabouts of their cargo through **cargo controller**. If the parties in the supply chain agreed that the expeditor will administer the **notification import documentation**, then the expeditor sends it to the terminal. The expeditor can also be the party to issue the **transit declaration** to customs.

Hinterland transporter

Similar to the terminal, the hinterland transporter gives the cargo agent insights in the location and status of their cargo through the service **cargo controller**. It can issue the **notification import documentation** directly to the terminal or issue it to the expeditor, who in his turn will issue it to the terminal. The services **hinterland container notification road, rail or barge** provide the possibility for the hinterland transporter to pre-notify their arrival and the exact load they will pick up at the terminal. The **Wagonload Information System (WLIS)** is an 'enabled by' Portbase service, which means that Portbase is only responsible for the construction and maintenance of the system. The WLIS is a system that provides Rijkswaterstaat with information about possibly dangerous goods on rail yards throughout the Netherlands, in case of an incident. **Inland port dues** is an 'enabled by' Portbase service as well. It provides inland shippers with an easy platform to notify their arrival in one of the inland ports in the region of Rotterdam and consequently pay the port fees. It also provides patrol vessels of the Port Authority with the possibility to register inland barges as they sail through the port.

Port Authority

As stated above, the service **inland port dues**, provides the Port Authority an opportunity to register inland barges. Additionally, the service **Notification Single Window** provides the Port Authority the opportunity to submit all necessary information to SafeSeaNet via Single Point Of Contact (SPOC) NL, a portal that collects information on all seagoing vessels in The Netherlands. The Port Authority adds the Actual Time of Arrival (ATA) and Actual Time of Departure (ATD) to already known information from Portbase (vessel notification, notification dangerous goods and notification waste disposal). The Port Authority does this based on information provided by the captain (i.e. vessel agent) or based on Automatic Identification System (AIS) data (International Taskforce Port Call Optimization, 2020).

<u>NVWA</u>

As mentioned before, a cargo agent can pre-notify their cargo for inspections at several stations in the port via the service **veterinary inspection process**. The NVWA subsequently updates the cargo agent, terminal, expeditor and hinterland transporter on the inspection progress of the inspection station in question via the **inspection portal**.

<u>Directly from Portbase to other stakeholders</u>

Seaport Statistics is an 'enabled by' Portbase service. On a monthly basis, it sends data on voyages and cargo to the Port Authority and to the CBS, the Statistics Bureau of The Netherlands (i.e. Statistics Netherlands). Consequently, stakeholders do not need to send their data to CBS themselves.

Cargo controller has been discussed before. It is a service that not only provides track and trace possibilities of import cargo, but also contains all cargo details, like weight, type of goods and whether it concerns dangerous goods. It gives insights to various stakeholders in the process. The most important ones are the ones responsible for pick-up of the cargo: the cargo agent, the expeditor or the hinterland transporter. Cargo controller uses input from various stakeholders. This input determines the import status of the cargo. The import status is depicted by 4 indicators that 'have to turn green' before cargo can be released by the terminal. The status indicators are:

1. Cargo should be present
2. Customs document should be present
3. Customs should have cleared the cargo (customs clearance)
4. Commercial release, which means that all dues must have been paid

The cargo may only leave the terminal when these lights have all turned green.

<u>Intra-Portbase</u>

One of the key points of Portbase is reuse of information. Because of this single submission of data, stakeholders do not have to submit information or documents twice. One example of the reuse of information within Portbase is the connection between the services **cargo declaration import** and

transit declaration. The cargo declaration import service collects the Entry Summary Declaration (ENS) of cargo agents, which contains the necessary concise safety and security information for customs to carry out a pre-arrival risk analysis. These declarations therefore happen before importing certain cargo. The transit declaration does not regard import of cargo. The transit declaration service collects the full declarations for the transit of cargo. Transit of cargo means that the cargo is not officially imported into the EU, but transferred to another member state, and officially imported in that member state. The transit declaration contains information that is already in the ENS. Therefore, this declaration can reuse the pre-notified information from the service cargo declaration import, so the declarant only needs to add the missing information later on in the import process. **Cargo declaration import** is also used as input for **cargo controller**. As mentioned, the service cargo controller checks whether the necessary customs documents of the cargo are present. By consulting the information that has been provided through cargo declaration import, one of the four green lights in cargo controller can be verified.

Another example of the reuse of information is the service **Notification Single Window**, which reuses information from the services **vessel notification, notification dangerous goods** and **notification waste disposal**. As described earlier, the Port Authority needs to submit certain data to SafeSeaNet. Portbase offers the Port Authority the opportunity to reuse information from the three mentioned services, by presenting a template in which only the ATA and ATD have to be filled in. This way, the Port Authority can submit the necessary information to SafeSeaNet in an efficient way.

In the same way as the service cargo declaration import serves as input for cargo controller, the service **inspection portal** serves as input for **cargo controller**. In cargo controller, one of the statuses of import cargo is whether customs has cleared the cargo. When cargo is still in the inspection process, the inspection portal will show this information. When the inspection is finished, the inspection portal will automatically update the customs clearance status indicator in cargo controller.

Subsequently, statuses in **cargo controller** are used as input for the service **notification local clearance**. When the cargo is present, customs documents are present, cargo is cleared and all fees have been paid (i.e. all four lights are green), the cargo is ready to be picked up from the container terminal. This service is used as a simplification of customs procedures, which leads to less formalities for the pick-up of the cargo. When the hinterland transporter possesses the right permits, the cargo agent may issue a simplified import document.

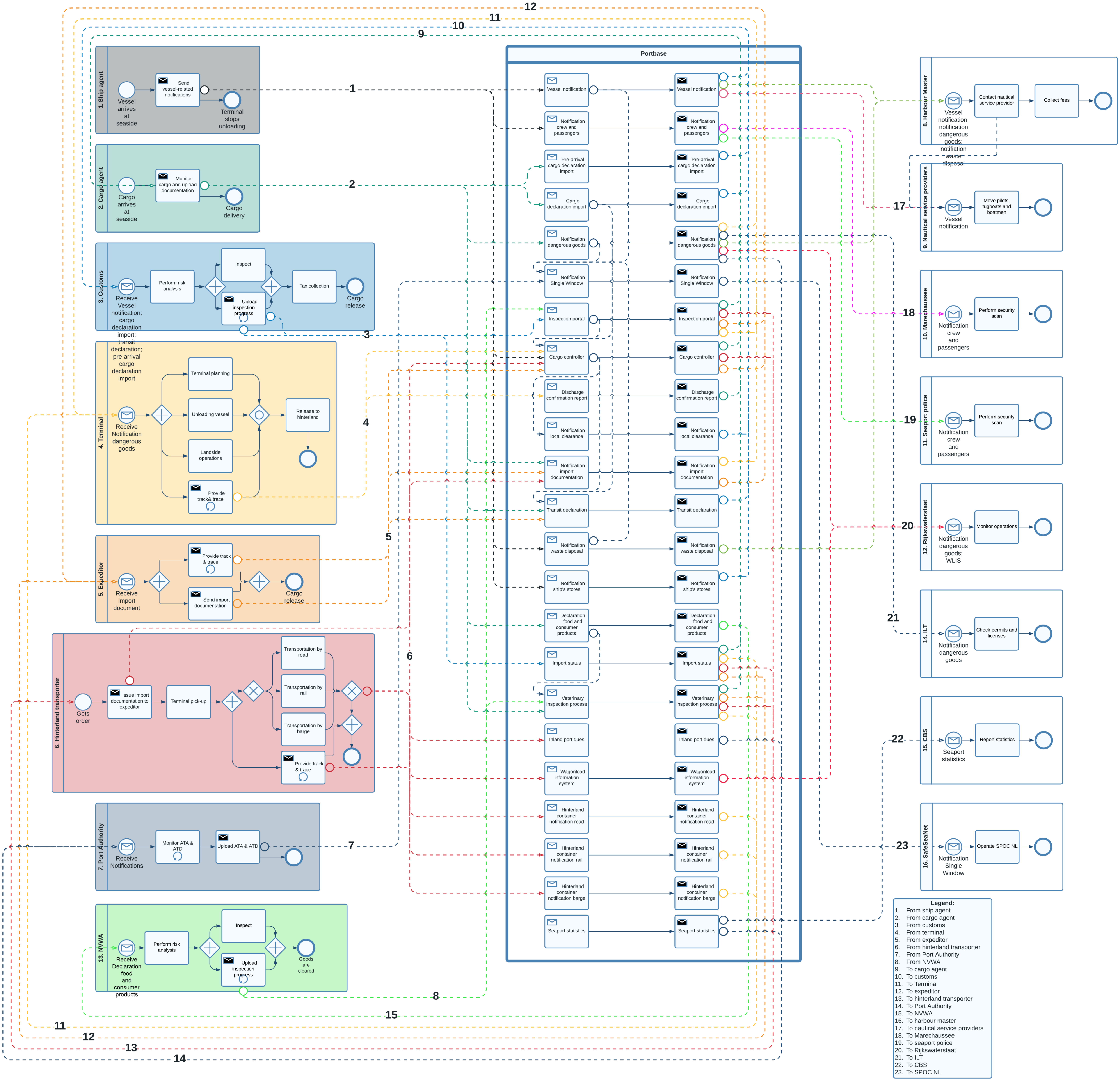

Figure 21: Business Process Diagram of information exchange through selected services of Portbase