Data Sharing in the Physical Internet: A Capability-Based Approach for Trustless Logistic Networks

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Abstract

Physical Internet (π) promises a more sustainable logistics network through hyperconnectivity between companies and high automatization. However, many logistic companies are reluctant to enter such a network, as they fear sharing sensitive commercial data with competitors and/or a central orchestrator. Therefore, we introduce a fixed set of 'capabilities' (services a specific company offers) which allow for the flexibility and exactness to define logistic companies. Based on these capabilities, we propose a decentralized scheme wherein 1) logistic companies only need to share these 'capabilities' openly with the network and 2) the logistic network is modelled based on these capabilities and routing algorithms can be applied. We tested this concept both by applying it in an ABM model based on real data and by in-depth interviews with potential participants for a real-life test. The approach shows promising preliminary results on both tests, although more research is needed to confirm these findings.

1 Introduction

Physical Internet (π) is, as it is inspired by the Digital Internet, conceived as an interconnected network of networks. Montreuil et al. (2012) describe it as such: "The Physical Internet enables to shift from private supply networks to an Open Global Supply Web-enabling the physical equivalents of Intranets, Virtual Private Networks, Cloud Computing and Cloud Storage". Indeed, collaboration is a key element in improving the efficiency of supply chains as a whole and logistics specifically (e.g., Audy et al., 2012; Ha et al., 2011), increasing both profitability and sustainability of the chain. From the earliest research on Physical Internet, the advantages of flow travel, transportation and supply chain inventory were made clear. Even without a modal shift, a division by four in logistics generated CO_2 emissions was predicted. (Ballot et al., 2011). Despite these results, only a few real-life collaborations between transport companies exist (Basso et al., 2019), with many citing a lack of trust as a relevant impeding factor.

With the Physical Internet Living Lab project (PILL), we aim to implement a real-life application of the Physical Internet, allowing competing companies to work together in a trusted environment, without the need for a central orchestrator. For our test case, we focus on ISO containers moving to and from the Port of Antwerp-Bruges (PoAB) towards the hinterland. This setting is ideal for testing the application of the Physical Internet in practice for two reasons. First, ISO containers are already standardized. This makes it easy for them to be handled by different entities during a route, allowing for the dynamic routing envisioned in Physical Internet. In addition, the hinterland of the Port of Antwerp-Bruges offers a very dense network with different logistic actors and different modes of transport available. Congestion issues for road traffic - both in the port and on the surrounding highways - increase the potential for alternative modes to be used. Although we focus on container traffic, we aim to develop a framework that can easily be expanded to other locations or flows.

In accordance with the prevalent view in literature, we conceptualize Physical Internet as a decentralized and interoperable network of software clients that allows collaboration and data sharing across the entire network of logistics nodes. The benefits of our holistic approach are best demonstrated by using it for route planning, which is considered a primary concern for the Physical Internet. In our case, we consider routes as a combination of different (uni- or multimodal) transport legs, with or without temporary storage (offering different options both in space and in time). As a test case, we developed a tool that will be tested in real life by 10 companies and in a fictional setting by an additional 7 companies in the Flanders region in April (first iteration) and September (second iteration) 2023. Seemingly similar route planning tools have been developed by logistic communities, logistic companies and ports over the past few years. However, they all offered a centralized solution, which created distrust amongst (smaller) players afraid of losing independency from the platform. Also, they offered either a system where only fixed schedules could be consulted (without booking logic) or a system where capacity needed to be shared. The first offered too little advantage, and the second required too much sensitive data to be shared. These concerns were confirmed by our advisory board members.

In the remainder of this document, we will first explore the relevant literature on horizontal collaboration in freight transport and the levels of data-sharing and trust this implies. Next, we will introduce our proposed solution in section 3. We will show that this solution could provide solutions with both from a modelling/route-finding point of view and a human, privacy-sensitive point of view in section 4. We will end with our main conclusions in section 5, including some avenues for further research and the limitations of our study.

2 Literature

Horizontal collaboration in freight transport has been applied in the industry for some time (see Saenz et al. (2015) for some examples). In academia, the field is relatively young. Pan et al. (2019) conducted a thorough review of the existing literature and found 6 solutions for horizontal collaboration and 7 implementation issues considered. Interestingly, Physical Internet is the only horizontal collaboration solution to take a decentralized approach, whereas the others either imply fixed relationships between partners or a neutral platform or orchestrator. Another interesting conclusion is that communication between collaborating companies is an aspect that has not yet received significant attention, while these aspects were found to be crucial for efficient collaboration (Min et al., 2005). When evaluating the opportunities and impediments of horizontal cooperation, Cruijssen et al.(2007) found that, although SMEs clearly agree with the opportunities of collaboration (increased productivity, reduced costs, larger contracts, ...) the issue of finding suitable partners and the fear of unfair division of gains (especially when dealing with a larger partner) are holding them back. Similarly, Plasch et al. (2021) found that transport companies saw the potential benefits of collaboration in Physical Internet, but stressed the importance of trust to do so. They suggest the factor needed to provide this trust is a 'central orchestrator' or 'trustee', suggesting a certain level of centralization within Physical Internet.

Centralized data sharing is a widely suggested strategy for interconnectivity in literature, which involves storing all data at or sharing it through a single platform (e.g. Baumgrass et al., 2015, Maneengam & Udomsakdigool, 2021, Maneengam & Udomsakdigool, 2020). However, this approach has limitations, as it poses potential threats to data integrity, privacy, and other weaknesses (Rejeb et al., 2019). This can hamper adoption due to a lack of trust and reluctance to share data and the complexity of collecting and processing high volumes of data (Hopman et al., 2022). In contrast, recent research suggests that decentralization is a future trend in logistics collaboration (Pan et al., 2019a; Simmer et al., 2017). Decentralization avoids the potential for organizations that control the data to grow too powerful and exploit their position against the general interest of the network. Hopman et al., (2022) analyzed the effects of different levels of centralization on 2 case studies by using an ABM simulation with real data. They found that a high level of decentralization was beneficial in the case of container hinterland transport by road as it allowed for flexible adaptation to changing circumstances. This confirms the validity of our case as a real-life test for the Physical Internet.

When bringing the concept from theory to practice, we have to take into account that the concept of Physical Internet implies a form of collaboration between logistic companies that is both flexible and extensive (Hofman & Dalmolen, 2019). Extensive collaboration requires a high level of trust between the companies involved. However, trust building requires that both parties show they have the 'ability to perform to promise', which implies both the commitment and the skill/assets to fulfil the promises made (Fawcett et al., 2012). This is a process that needs time and effort and requires accepting a certain level of vulnerability (Wieland & Wallenburg, 2013). In a fast-changing context such as Physical Internet, where the aim is to create ad hoc collaborations to optimize and/or flexibly reroute shipments, these investments cannot be made for each potential party. Therefore, to bring the optimization potential of Physical Internet to reality, a framework that allows for extensive data sharing while still protecting each company's commercial privacy is needed. This aspect has received less attention in research so far, despite the importance of information exchange in horizontal collaboration, especially when evolving to (near-to)-real-time optimizations envisioned in Physical Internet (Pan et al., 2019).

In the larger part of the studied literature, the Physical Internet is assumed to be fully functional (within the considered network boundaries), and decisions are made automatically and on the spot. Indeed, Treiblmaier et al. (2016) noted that there is a tendency to look at Physical Internet as a final state that either exists or not. However, participation in a fully automated π–network requires a high level of trust in Physical Internet, especially when implementing the system in a multi-company environment without previous collaboration. As such, we state there is a need to focus on intermediate steps towards Physical Internet. Therefore, we aim at a short-term implementation of a minimal Physical Internet network involving different companies to build this trust. To achieve this goal, we decided to consider the human (or business) as the deciding agent. This approach increases the confidence of the users as they remain in control. With this decision comes the consequence that the concepts used need to be people-readable, while still being machine-readable (to allow for route-finding). Also, as there is no baseline trust in the proposed system, we need to reduce the amount of information to be shared to a minimum, while still providing enough information to allow for efficient route-finding. Therefore, our approach has been designed not to require the exchange of such sensitive data, as the shared information only pertains to the services provided by logistics companies.

To achieve our goal, we build upon the notion of π-nodes proposed by Montreuil et al., (2010). They define π-nodes as “locations expressly designed to perform operations on π-containers […]. Generically, the π-nodes are locations that are interconnected to the logistic activities”. They defined 9 different types of π-nodes, each with its own specific definitions. Translating to more common logistic terminology, these are hubs, terminals, warehouses etc., that are part of the π-network. While many papers cite this paper referring to the general concept of Physical Internet, only a limited number specifically look at π-nodes. Furthermore, those who do, focus on the development and optimization of a specific type of node: Oktaei et al. (2014) and Gardanne & Meller (2012) optimize a road-road transit node, Ballot et al. (2012), Walha et al. (2014) and Chargui et al. (2020) do the same for a road-rail hub. We found no papers that explore the different types of nodes from a more conceptual view.

The contribution of our work is twofold.

(1) This paper presents a novel approach to formally describe logistics networks in terms of the capabilities that π-nodes are offering to the network. This allows a formal way of routing discovery and optimization as a foundation for a true collaborative Physical Internet;
(2) We propose a fully decentralized network of π-clients relying on the sharing of capabilities only, without the need for sharing capacities. Both the decentral nature of the network and the limited requirements for information sharing address the trust-related concerns that have hampered the adoption of earlier collaboration networks.

3 A network defined by capabilities

This study employs a formal approach to analyze the π-network, which is conceived as a system of π-nodes differentiated by the services they provide. With this approach, we achieve several objectives. Firstly, it enables the construction of a decentralized network structure, facilitating a more democratic distribution of power and control. At the same time, the approach limits the amount of sensitive data that needs to be shared between nodes, enhancing privacy and security and e further ensuring trust. Finally, it provides a relevant framework for routing in the Physical Internet, which can help improve efficiency, reduce costs and increase sustainability in the logistics industry.

Decentralization

In accordance with Hens et al., (2011) we propose an event-based decentralized orchestration, which allows for decoupling in space and time and increases scalability. In this approach, changes to the network are published as an event, leaving it up to the receiver to react (or not). We apply this event-based decentralization in two ways:

- Updates of the network state: every member of the network publishes its service offerings defined in terms of π-capabilities to all other members the network. Receivers can decide if this information is relevant for their local copy of the network and if so, make adaptions. This approach avoids the need for constant updates prompted by irrelevant parts of the network (e.g. a change in railway schedules to a region where a producer has no clients, or a low water level alert when no waterway trips are planned)
- Capacity requests: once a potential route is calculated, the requesting company sends a capacity request to the involved transport companies and/or node operators. This is a 1-

on-1 communication, thus limiting the sharing of sensitive information to the partners directly involved.

Using this approach, we avoid sharing sensitive commercial information openly with the network. The only information required to share, is information most of the logistic companies already share openly on their websites. Given its intentionally limited footprint, this information can also be efficiently distributed across the network via established peer-to-peer technologies (e.g. Benet, 2014; Weil et al., 2006) We posit that this approach can effectively scale to large logistics networks, including dense European intermodal hinterland networks. To further ensure such scalability, we can employ cut-off parameters that serve to limit the amount of local data required for route discovery.

Capabilities

However, the definition for each capability is not always clear, and the information is labor-intensive to retrieve for a large set of companies. To make route planning possible in this context, we need a standardized way to communicate these service offerings to the network. We propose the term ‘capability’ for these service offerings. However, contrary to their approach of predefining specific types of nodes, we propose to define nodes by the set of capabilities they offer. This way of working allows for high flexibility in design nodes with different capabilities (as is the case in reality), while still profiting from the clear definitions offered by these capabilities. To define the capabilities, the types of nodes defined by Montreuil et al., (2010) served as our main inspiration.

Using these concepts, we have modelled the Port of Antwerp-Bruges hinterland logistics network for container transport using an ABM, replicating the real-life network operated by our advisory board members and their partners. This enabled us to validate the completeness and soundness of our approach. We also used the ABM to identify which capabilities were indeed necessary and which should be adapted or could be ignored in this setting. We came to, resulting in the following list of relevant capabilities for our case:

- Transit (M): The transfer of carriers, such as container trailers, between inbound and outbound vehicles, with optimization as the primary consideration.
- Store (A): The storage of π-containers during a route, full or empty, under agreed-upon conditions (e.g. maximum time and cost).
- Gateway (Γ): A point of entry or exit for containers in the π-network to or from different parts of the network, typically lower or higher-level networks. Container terminals that serve as gateways to hinterland networks are examples of this.
- Depot (Δ): The temporary storage of unused containers after a route is ended.
- Composer (Ω): The composition of smaller containers into larger ones or vice versa.
- Hub (Φ): The unimodal or intermodal transition from incoming movers to outgoing movers between different logistics parties.
- Service provider (Σ): capable of fulfilling a service. These services can be considered as ‘wildcard’ capabilities that need to be defined in the model, such as cleaning, weighing etc. This is an extension of the aforementioned paper.

Other capabilities introduced by Montreuil et al. (2010), such as π-Switch and π-Sorter, remain relevant but have been kept out of our early models for the purpose of limiting complexity. By introducing a fixed set of clearly defined capabilities, any logistics company can be defined by the set of capabilities they offer and the location at which they are offered. This way, the proposed framework offers a level of abstraction in the network that ensures both flexibility and exactness. Flexibility is needed to incorporate the diverse nature of actual logistic companies without loss of information. Exactness is needed to allow for correct modelling of the network and for the routing algorithms to function.

Routing

By combining the π-nodes with their π-capabilities with a set of π-transporters along the edges between them, a network is created in which routes can be found.. Consider a routing function

$$P_c\,(s, n) \rightarrow s', n'$$

with routing constraints *c* allows for transitioning from a starting state *s* and a π-node *n* to a new state *s'* and node *n'*. In our experimental model for hinterland logistics of ISO containers, a routing state is defined in terms of the container state and the mover state as follows:

$$s = \begin{cases} \text{Container state} & \text{(full or empty)} \\ \text{Container location} & \text{(a } \pi\text{-node)} \\ \text{Container ready} & \text{(a point in time)} \\ & \\ \text{Mover id} & \text{(a } \pi\text{-mover)} \\ \text{Mover modality} & \text{(road, rail or inland waterway)} \\ \text{Mover state} & \text{(with our without container)} \\ \text{Mover location} & \text{(a } \pi\text{-node or a } \pi\text{-vertex} \end{cases}$$

The container ready time is the point in time when the container will be ready. It represents the latest departure time of the container from its current node, which may be determined by the storage limitations of the node or the departure schedule of the next mover.

The routing constraints are defined as follows:

$$c = \begin{cases} \text{order type} & \text{(import or export)} \\ \text{pick-up location} & \text{(a } \pi\text{-node)} \\ \text{drop-off location} & \text{(a } \pi\text{-node)} \\ \text{composer location} & \text{(a } \pi\text{-node)} \\ \text{composition time window} & \text{(a start and end time)} \\ \text{earliest pick-up} & \text{(a point in time)} \\ \text{latest drop-off} & \text{(a point in time)} \end{cases}$$

For instance, after retrieving an empty shipping container from a depot, the transition

$$P_c\,(s, n) \rightarrow s', n$$

from a pick-up location node *n* with capability Δ (depot) may transition the mover state from *without container* to *with container* (i.e., a pick-up transition), whereas the location remains the same. Although the set of valid states and transition functions may vary between different types of π-networks, such as urban logistics and parcel delivery networks, the same basic approach for defining valid transitions can be used to drive the routing algorithm.

4 Testing the theory

4.1 Building a routing algorithm

The decentral network allows clients to synchronize with the evolving network state. Routing can then be done locally on the replicated network state. Different routing algorithms can be applied by different companies, using the same network information. To prove efficient routing could be achieved using our proposed concept, we developed a first version of such a routing algorithm. Existing research on routing algorithms for Physical Internet is limited. Sarraj *et al.* (2014) use an A* algorithm to route containers in their multimodal logistic network. On a unimodal network of a small scale, Fazili *et al.* (2017) use a mixed integer programming (MIP) method to search the optimal routes. For scalability and interpretable purposes, we used an A*-based routing algorithm, adapted to allow for the decentralized information sharing and our capability scheme: Physical Internet A* (PIA*). The nodes and transport means among them are translated into the vertices and edges on a directed graph in the model. A shortest-path algorithm is then devised to find routes for containers.

We define the following terms:

- A vertex is defined by container location, container state (empty or full) and timestamp. Note that this information is part of the container state defined in the previous chapter.
- An edge represents a set of states and transitions that move a container between two different locations, in time, by a particular mover.
- A route combines a set of vertices and edges, which transports the container from its origin to the destination before a specified time. It is represented by a sequence of valid transitions between states, as explained in section 3.

*Figure 1: Pseudo code of PIA**

Algorithm 1: Pseudo code of PIA*

```
Input: NetworkState{Vertices, Edges}, Container, LatestDeliveryTime
Output: Set of routes
R ← set of incomplete routes;
C ← set of complete routes;
R.add(initial route which contains only the original vertex) ;
while C.size() < the desired number of routes to find OR R.size() > 0 do
    i ← the top route in R;
    Remove i from R;
    F ← all the feasible routes by expanding on the last node to all of its
      adjacent nodes (a direct edge in-between exists);
    R.addAll(F);
    for each route in R do
        Calculate actual + estimated cost;
        if the last node is the destination then
            Move the route from R to C;
        end
    end
    Rank R by cost ascending;
end
return C in the order of cost;
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Figure 1 shows the calculation steps performed in the routing algorithm. The routes are then presented to the decision maker and ranked depending on their overall performance. This performance is calculated by a weighted function of different aspects of a solution, such as distance, monetary cost, duration and greenhouse gas (GHG) emissions. The input parameters for this cost function are normalized by scaling, based on their known respective maximum values.

In order to validate the capability-based routing, we used an Agent-Based Model (ABM). This type of model has been used by several authors, to mimic the decentralized tendency of Physical Internet by modelling each decision-making unit as an individual entity (e.g. Sarraj et al., 2014, Sallez et al., 2016, Walha et al., 2016). Walha et al., 2016). In our setting, the decision-making units were the expeditors (requesting a route and selecting a preferred route), the node and transport operators (accepting or declining a request) and the movers (moving containers and experiencing disruptions). We were able to run various simulations on a set of scenarios, thanks to the data received from PILL's partners. Example data to be utilized include historical demand based on containers entering/exiting terminals; schedules for trains and barges and their free capacity; origin and destination of containers transported by road and historical data on driving times between different nodes (TomTom); historical road disruptions based on disruption data from the Flemish Agency of Road and Traffic (AWV) road measurements.

With this exercise, we proved that routing of containers can indeed be achieved using our proposed concept and returns valid routes. In the next step, we will use this ABM model to test and measure the benefits of the proposed "capability sharing" versus the conventional "capacity sharing" reservation mechanism by simulating how the two processes behave given the same logistics flow. Besides the quality of the routes and speed of calculation, we will also evaluate the level of commercial privacy obtained in each instance. A similar exercise has been done with an alternative routing algorithm, also developed within the PILL project and returned good results on all measures (Sun et al., n.d.).

4.2 Stakeholder interviews

After constructing the first version of the application, we are conducting a round of open interviews with a diverse set of logistics stakeholders to introduce them to the concept and ask for their participation (25 have been completed so far). Additionally, another 10 semi-structured follow-up interviews were conducted (up until publication date) to go through the functionalities of the route planner for targeted feedback. The interview guideline and a coded overview of participants can be found in the annex to this paper. Only elements relevant for the topic of the current paper are discussed in the text. An additional paper is planned to discuss the overall results of the real-life test after its completion.

The majority of interviewees were positive about the concept of a decentralized network, regardless of the necessity to share data with competitors. Many stakeholders have already warmed up to the idea or are even considering decentralized applications of their own.

"*I was already convinced that this is the way forward.* [G3]"

"*I was actually contemplating a similar concept a few years ago*. [T4]"

Only two interviewees mentioned their concern about sharing information with their competitors. The main concerns that did pop up were related to the cyber security of an open platform and collaboration with parties without a former contract. The former is a technology challenge, the second requires more attention in follow-up projects. In an industry where collaboration with a new partner still requires significant administrative efforts, how can a platform enable these "digital handshakes" to facilitate open collaboration?

By introducing the concept of capabilities, the data requirements of our proposal are sufficiently limited to not deter even more hesitant stakeholders. They evaluated the fact that actual sensitive data (like real-time capacity) is only shared anonymously and on a 1-on-1 basis to finalize bookings as a strong point of the proposal. This duality of data sharing (open and 1on1) was generally considered sufficient.

When discussing the general definitions of the capabilities, most stakeholders said to find them clear. The only exception was [N8], who had difficulties with the distinction between Depot and Storage. We can therefore conclude that the general description was well received by our stakeholders. In further testing, we will verify if they are fully able to combine these capabilities to define their own nodes. However, two interviewees had difficulties interpreting the concept of ‘nodes’ as such. ‘Locations’ was suggested as a more understandable word.

5 Conclusions

We have presented a scalable decentral π-system that provides logistics service users with the ability to explore alternative logistics routes and solutions without the involvement of third parties that may exert control over the network. We have intentionally limited the scope to hinterland container logistics using a limited set of capabilities for clarity reasons. Adding more capabilities to the mix may offer more flexibility and optimizations in routing. Further study is needed to explore the full potential of the decentral capability-based network. Looking beyond hinterland networks and shipping containers can extend the benefits of our approach to other transportation methods, such as (break)bulk transportation. Additionally, one can look at modelling more local logistics (sub)networks such as urban logistics and parcel delivery networks, leveraging the abstraction layers Physical Internet offers or rather larger intercontinental transportation networks using air cargo and ocean vessels.

The system provides data security by (1) storing data locally and (2) limiting the amount of (sensitive) data to be shared by separating “capability” from “capacity”. Validation of the concept with potential users confirmed that they find this approach both comprehensible and trustworthy. Some remarks were made as to the naming of the different capabilities, but all agreed the general framework is promising. Follow-up interviews will be conducted after the real-life testing to ensure stakeholder support remains.

We showed that the route discovery algorithm, which is founded on a formal definition of logistics node capabilities, is feasible and can be applied in a decentralized system and capability framework. Further testing will be done to compare the performance of this algorithm to existing algorithms, comparing the level of privacy, quality of the routes and speed of calculation.

Moreover, beyond operational use, the system can also be utilized for simulation purposes. Such a model may facilitate the assessment of potential network changes, including the addition of inland terminals, the implementation of additional scheduled services for trains and barges, the establishment of inland container stores and depots, and the relocation of production and storage facilities. The ABM infrastructure can also be used to assess the effectiveness of routing algorithms or to simulate the impact of disruptions of critical infrastructure in dense logistics networks.

Additionally, an important remaining question regarding the adoption of Physical Internet as we present it, it is the need to attain a critical mass. The mere promise of more optimal logistics planning in itself will not drive the necessary adoption, as these benefits will only fully develop when enough participants join the network. However, standards-based peer-to-peer data exchange, which facilitates a much-needed digital transformation in logistics, could offer the added value that is needed. We encourage to study and develop interoperability standards in the context of the different supply chain processes that facilitate collaboration across the decentralized π-network. In turn, this will drive the adoption needed for obtaining the critical mass to interconnect the Physical Internet.

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7 Annexes

7.1 Annex 1: List of interviewees

Code	Transporter	Node Operator	Expeditor	Cargo Owner	Governance Roles	Policy Roles
T1E1	x		x			
T2E2	x		x			
T3	x					
T4	x					
T5	x					
T6	x					
T7N1	x	x				
N2		x				
N3		x				
N4		x				
N5		x				
N6		x				
N7		x				
N8		x				
E3			x			
E4			x			
E5			x			
C1				x		
C2				x		
OE1*			x			
OG1*					x	
OG2*					x	
G3					x	
OP1*						x1

* Sector organizations

- Logistic roles:
  - Transporter: responsible for the actual movements of goods
  - Node operator: responsible for the operations within a π -node
  - The Cargo owner (shipper or consignee): party currently responsible for the cargo
  - The Expeditor: responsible for the planning of the route cargo takes
  - The Asset owner: is the entity that owns the specific assets (containers)
- Policy roles: governing the physical network and rules applied to the physical cargo
- Governance roles: governing the digital network and rules applied to data

7.2 Annex 2: Interview Guideline

The interviews were set up in two steps:

- A first open interview in which the concept of Physical Internet was explained and the potential participant was asked whether they were interested
- A second semi-structured interview in which the tool was explained and evaluated in detail. For this second interview, the following guideline was used:

Goal of test:

- Validate the data sharing model
- Validate the key flows of the platform

Research questions:

- Does our data model allows for the current way of working of the stakeholders?
- Is there a difference between the requirements for the different stakeholder types (forwarders, terminals, transporters)
- Do transporters feel comfortable sharing this data?
- Is the data in the wizards correct for
    - Adding a node, capability, transport
    - Create a booking
    - Confirming a route

Add a node

- Look at the nodes table, complete the wizard to add a location
- Is anything missing in adding the location?
- Is longitude / lattitude relevant?

Add a capability

- Complete the wizard to add a capability
- Are the capability categories clear and complete?
- What costs would you add and how?
- Do you feel comfortable adding this?
- Are all the steps clear?
- Is any data missing?

Add a transport

- Complete the wizard to add a transport
- Does it make sense to add a pool name?
- Are the container categories correct?
- How would you add your timetable
- Is the way to add a schedule clear?
- How would you add cost?
- Is anything missing?

Create a route

- Fill in the flow for booking a route
- Is any data missing?
- Who determines this data?

Overview routes

- Review the page with the routes, look at a detail of a route and book a route
- Is this enough information to book a route?
- Would you remove any of the routes of change the order?
- Do you mind that it’s anonymous?

Capacity check

- Look at the route request table, check the detail of a route and confirm or cancel the route
- Do you have enough information to make a decision?
- Could you answer this right after seeing the request or is there a planning moment to wait for?
- How frequent would you be able to confirm/refuse a request per day?

7.3 Annex 3Algorithm 1: Pseudo code of PIA*