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DOI

[10.1057/s41278-021-00203-9](https://doi.org/10.1057/s41278-021-00203-9)

Publication date

2021

Document Version

Final published version

Published in

Maritime Economics and Logistics

Citation (APA)

Nikghadam, S., Molkenboer, K. F., Tavasszy, L., & Rezaei, J. (2021). Information sharing to mitigate delays in port: the case of the Port of Rotterdam. *Maritime Economics and Logistics*, 25(3), 576-601. <https://doi.org/10.1057/s41278-021-00203-9>

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Information sharing to mitigate delays in port: the case of the Port of Rotterdam

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Accepted: 23 October 2021
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Abstract

Reliability of service times has long been a concern of many ports around the world. This paper presents an approach to mitigate delays in service times through improved information sharing in ports. The approach is based on a mapping of information sharing links and their association to the root causes of frequently occurring delays. We identify the kind of information which is critical in mitigating delays. Critical information links are then re-ordered to create an information sharing arrangement between the actors, which further condenses and simplifies the required information sharing actions. We apply the proposed approach to the Port of Rotterdam. Quantitative data of 28,000 port calls is complemented by qualitative data collected through direct observations and expert interviews with port actors, including the pilot organization, a tugboat company, the boatmen organization, the harbour master, a terminal and a vessel agent. Besides the suggested arrangement for information sharing, the case reveals the critical position of pilots, a vulnerable position of tugboat companies and the minimal contribution made by the terminal towards information sharing. The increased pressure on ports by ever larger vessels seems to bear its fair share for delays and bottlenecks in the smooth execution of port operations.

Keywords Port call process · Nautical chain · Delay mitigation · Information sharing

1 Introduction

International trade is growing and with maritime transportation representing approximately 90% of the global trade volume, ports are becoming busier (Lind et al. 2020). In response, ports try to become smarter and more efficient, aiming to serve more vessels in shorter times by reducing port delays (Paixão and Marlow 2003).

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In the past years, ports have reinvented themselves from cargo transshipment nodes to an integral part of supply chains, as important hubs for materials and information flows. Latest developments in the digital technologies of Industry 4.0, such as blockchain, Internet of Things (IoT) and Physical Internet have pushed ports beyond their traditional limits and have provided new opportunities for their development (Fahim et al. 2021; Parola et al. 2020). Although ports have transformed radically, some aspects of port operations still need improvement. For example, one of the key issues in many ports is delays. Disruptions and deviations from the initial plan occur frequently, resulting in delays (Cheon et al. 2018; Park et al. 2021). While exact figures are not available, shipping companies report that up to 80% of their vessels face delays in ports along their route (Notteboom 2006). These delays disrupt port call processes, increase congestion, decrease service reliability and lead to inefficiency for both vessels and ports. Where delays can be mitigated, this enhances port efficiency, sustainability and safety.

The complexity of port operations severely challenges the mitigation of port delays. Vessel arrival times to the ports are typically uncertain. Even though vessels must submit their estimated time of arrival (ETA) and estimated time of departure (ETD) in advance, these estimates are usually inaccurate. The submitted ETAs are often too optimistic and they are adjusted many times (Veenstra and Harmelink 2021). Once a vessel arrives at a port, *nautical–technical* services, i.e. pilotage, towage and mooring, must be readily available. Only when the availability of berth, tugboats, pilot and port fairways are confirmed, are vessels allowed to enter the port. When any of these services is unavailable, vessels have to drift, loiter or anchor outside the port, which exacerbates delays. Inaccuracies in vessel arrival times, as well as uncertainties in handling processes due to, e.g. weather, challenge port planning and usually oblige port actors to coordinate their services on short notice. Although port actors may share information to align operations under normal circumstances, information sharing during delays is less well developed.

In recent decades, the maritime sector has provided a growing number of digital solutions to support information sharing processes (Urciuoli and Hintsa 2021). The main exponent of this movement is Port Community Systems (PCS): electronic platforms that connect multiple actors inside the port domain, allowing them to share digitized data and information. PCS are widely used in major ports such as Rotterdam, Antwerp and Singapore. They generate value by facilitating data and information sharing between different stakeholders, including terminals, the port authority, shipping companies, vessel agents and freight forwarders (Aydogdu and Aksoy 2015). So far, however, PCS do not provide solutions for operational coordination of port operations between port service providers, such as pilot organizations and tugboat companies. Although bilateral information sharing is common between port service providers, investigation of their information needs is still at the stage of experimentation. In port management practice, information sharing solutions still need to develop.

Previous work has extensively addressed the importance of information sharing as a key enabler of port efficiency, resilience, agility and sustainability (Paixão and Marlow 2003; Bichou and Gray 2004). The emphasis has been on improvements in information flows by means of digitalization. Nevertheless, the significant question



of *which* information has to be shared with *whom* has not yet been addressed in the literature. This gap is remarkable because the first step to improve information sharing in ports is not just improving the information flow, but also understanding the information needs of the port and its actors. This paper aims to address this gap by examining information sharing in ports, to support the sharing of relevant information among the relevant parties for mitigating service delays.

To identify where coordination is most necessary, and where efficiency gains can be achieved, we focus on the most frequently occurring delay causes. Here, the main function of information sharing is to create a timely initial notice of such delays, thus allowing actors to limit the propagation of the delay or to reduce its impact. We contribute to the literature by presenting an approach that determines the critical information sharing links for mitigating delays. By providing a case study for the Port of Rotterdam, we demonstrate the value of our approach in practice. The proposed approach relies on (1) the mapping of port processes and information sharing links, (2) identification of the root causes of frequently occurring delays and (3) the mapping and ordering of critical information sharing links associated with the frequently occurring delays and their causes.

This paper is organized as follows. Section 2 provides a review of the scientific literature about information sharing in ports. Section 3 defines the main characteristics of the port services and the nautical chain. Section 4 introduces the approach. In Sect. 5, we apply the approach to the case of Port of Rotterdam. Section 6 discusses the findings and implications for practice. Finally, Sect. 7 concludes the study and puts forward future research directions.

2 Literature review

The impact of information sharing on the performance of businesses has been an important subject in many different domains, including maritime logistics. Information sharing is recognized as a key challenge in the movement towards smart, agile and green ports (Lind et al. 2020; Paixão and Marlow 2003; Park et al. 2020). The benefits and necessity of information sharing have been well-recognized by the maritime industry (Zheng et al. 2020). The benefits include improvements in cost and time efficiency, reliability, flexibility, responsiveness, resilience and sustainability (Kanamoto et al. 2021; Lind 2019; Fruth and Teuteberg 2017). The literature suggests that improved collaboration between maritime logistic actors through better information sharing will reduce the uncertainties along the logistic chain, both in hinterland and foreland, enhance reliability, efficiency, flexibility (Heaver 2015), improve resilience (Shaw et al. 2017) and boost performance (Bichou and Gray 2004). Most studies report time and cost improvements as results of improved information sharing, vertically between ports and port users, as well as horizontally with adjacent ports (Lau and Li 2015; Takebayashi and Hanaoka 2021). In addition to efficiency improvements, sustainability is another reason to enhance the information sharing of ports. Notteboom et al. (2020) emphasized the role of ports in green supply chains, indicating that information sharing is key for green shipping, green port operations and green inland logistics. Empirical evidence from short sea shipping



shows that further information sharing between the relevant parties will improve operational speed optimization in slow-streaming and hence lead to fuel savings (Schøyen and Bråthen 2015). Besides the studies on the benefits of improved information sharing, there is another stream of literature that addresses the problems that occur as a result of insufficient information sharing. For example, a lack of information sharing regarding waiting times and turnaround times are found to frustrate hinterland transport (Wiegman et al. 2017). Or, a variety of coordination problems can occur in the entire transport chain if the required information is not shared between the shipping lines, terminals and hinterland transport companies (Van Der Horst and De Langen 2008).

The degree and quality of information sharing between port actors is challenged by several contextual factors, including the complexity of port-related operations, organizational silos, privacy and confidentiality issues, lack of incentives, security issues, conflicts of interest, information overload and information quality (Van Der Horst and De Langen 2008; Lanzini et al. 2021). The presence of various organizations makes it difficult to determine which organizations are relevant for information sharing. Also, there can be a mismatch between a user's real information requirements and the perception of these requirements by the information owner (Shaw et al. 2017). Information needs of different stakeholders in maritime hinterland processes were identified in a study by Wiegman et al. (2017). However, the study did not include the nautical side of the transport chain. Another challenge to information sharing is that actors may not have an incentive to share information of sufficient quality. A wide variety of relationships exists with asymmetric information availability, power and interest, limiting information sharing for reasons such as confidentiality, privacy and conflicts of interest (Bichou and Gray 2004). For example, terminals possess information that can benefit Port Authority's business, but sharing it can be disadvantageous for the terminal's own business (Zerbino et al. 2019). In sum, although port logistics is very data intensive, it is challenging to access value-adding quality information considering the parties' diverse needs and interests.

To overcome the challenges of information sharing and facilitate the collection of up-to-date data, information and communication technology (ICT) developments try to enhance safety, security and traceability (Parola et al. 2020; Lee et al. 2016). Carlan et al. (2016) analysed recent digitalization projects and initiatives aimed at improving the information flow in maritime logistics, including information systems in seaports such as Port Community Systems (PCS) (Carlan et al. 2016). The implementation of PCS was found to improve information sharing, increase time reliability for port users (Zerbino et al. 2019) and play a significant role in port competitiveness (Tsamboulas et al. 2012). However, the benefits of PCS have been on information sharing between port users rather than information sharing between port actors. Whether and how PCS will play a role in operational information exchange between port actors is still unclear.

From the above, we conclude that the scientific debate is no longer about whether information should be shared, but about which information to share with whom. Many studies have looked at information sharing between ports and port users but, to date, there has been very little research that focuses on information sharing within the port domain itself. In addition, information sharing between essential services



such as towage, pilotage and mooring operations has yet to be addressed in the literature. This gap is remarkable, as earlier research does recognize the importance of information sharing as far as port operations are concerned (Notteboom et al. 2020). Filling this gap calls for approaches that investigate information sharing arrangements in relation to the reliability of port services, which is the main purpose of this study.

3 The nautical chain and its process

In port studies, defining the scope of the study is very important because many logistics processes are at the interface between the sea and hinterland. This process continuity makes it difficult to identify where the port processes start and end (Bichou and Gray 2004). In this section, we present the scope of our study, including the actors and processes involved and the definition of the nautical chain. Ports support the turnaround processes of vessels with traffic management, piloting, towage and mooring as main services. We call this chain of services the Nautical Chain (NC). We refer to the executing organizations involved as the actors of the NC. These are the Harbour Master (HM), vessel agents, terminals, the pilot organization, tugboat companies and the boatmen organization. The HM is the responsible authority for smooth and safe shipping and it provides services from the Harbour Coordination Center (HCC) and the Vessel Traffic Services (VTS). The HCC controls the tactical planning of accessing and exiting vessels of the port area, while the VTS assists the safe handling of vessels at an operational level. The vessel agent, the shipping company's representative at the port, arranges all administrative tasks related to the port visit for the vessel, such as ordering nautical services. The terminal provides berth for the vessel and operates the (un)loading process. Among the actors of the NC, the pilot organization, the tugboat company and the boatmen organization together are called the nautical service providers. We note that, as opposed to the concept of *port service chain* (Talley et al. 2014), the services beyond the turnaround processes of vessels, such as hinterland rail and truck services, are not included in the NC.

The process of a vessel's call at a port can be summarized as follows. For an incoming vessel, well before arrival, the vessel's agent requests a berth from the terminal for the unloading and loading procedures. After the terminal's confirmation, the vessel's agent reports this to the HCC, which assesses nautical safety, port health, security and capacity. The agent is obliged to report the vessel at least 24 h before ETA. If the HCC approves the vessel's report, administrative clearance is provided. Without clearance from the HM, the vessel is not allowed to enter the port. Before the vessel arrives, it frequently submits and updates its ETA, which is consecutively forwarded to nautical service providers. When the vessel arrives at the port, the vessel captain makes operational contact with the VTS operator, who checks the details of the vessel report and registers any updates when necessary. If port traffic allows, with the guidance of VTS, the vessel starts communicating with the pilot organization, to take a pilot on board for pilotage. After the pilot has boarded the vessel, the vessel enters the harbour. Under the pilot's command, when tugboat assistance is needed, the pilot orders tugboats to connect and tow/push the





Fig. 1 NC services for an incoming voyage

vessel to the designated berth. Once arrived, boatmen help moor the vessel. Here, the NC service for incoming vessels is completed and the terminal can begin cargo handling operations. Note that, typically, large vessels require pilotage, towing and mooring services. However, exemptions can be made for certain vessels under strict conditions, for example, Ro-Ro vessels frequently visiting a dedicated berth, for instance once every two days, can obtain a pilot exception certificate. Some terminals with frequent vessel visits are allowed to perform their own mooring services. Fig. 1 presents the overview of the NC services for incoming vessels.

For outgoing vessels, the vessel agent orders a voyage. The agent thus reports the vessel's ETD to the HCC. The HCC assesses the administrative clearance. Next, the nautical service providers plan their services. As soon as a vessel is ready for departure, i.e. when all nautical service providers are present and terminal operations have finished, the pilot makes operational contact with the VTS operator to start pilotage. When the vessel is ready to leave, the boatmen un-moor and the tugboats tow to help the vessel leave the berth. After the vessel has safely sailed out of the harbour, the tugboats disconnect and later, the pilot leaves the vessel, completing the pilotage. Finally, the vessel notifies the HM that it has successfully departed.

The descriptions above explain the NC services when all operations proceed as planned and no disruptions happen. Whenever delays occur, the NC actors ideally perform additional coordinating actions supported by sharing of process information. The quality of the coordination depends on the quality of the information sharing. In the next sections, we introduce our approach to identify those information sharing links that are critical for improved coordination of the NC.

4 Approach

The leading principle behind our approach is that port actors need to flag potentially occurring delays as early as possible. They can only do so if they are informed in a timely manner about the occurrence of delays. Once a potential delay is signalled inside the system, actors need to inform each other to take mitigating or hedging actions. Our aim is to identify the information sharing links that are critical for mitigating port delays. This consists of three main steps:

1. Creation of an inventory of information sharing links.
2. Identification of root causes of frequently occurring delays.
3. Identification of critical information sharing links.

Figure 2 depicts the approach and the main techniques used.



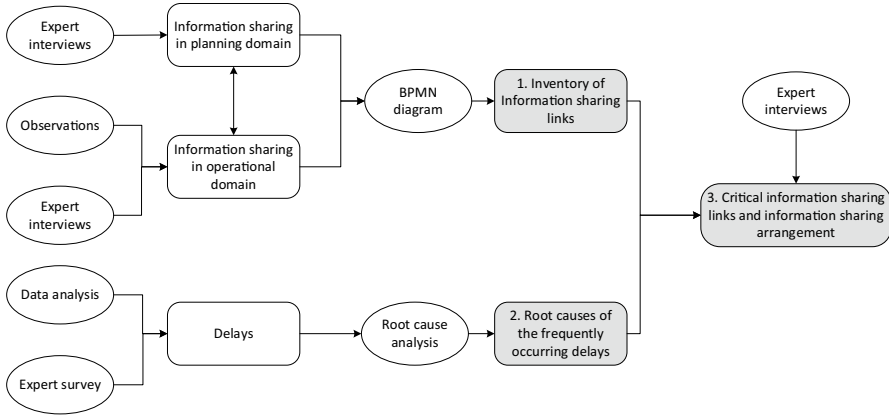


Fig. 2 The proposed approach

4.1 Step 1: Creation of an inventory of information sharing links between actors

The first step involves identifying and mapping information sharing links between the NC actors, which is done following diagramming standards, such as Business Process Modelling Notation (BPMN). The main source for this step is the port’s guidelines for navigation, service provision and messaging, internally as well as with the client vessels. The formal modelling requires a synthesis of these guidelines and validation with experts from different service providers. This step is particularly important because not all the information sharing links, especially bilateral communications, are officially documented in information procedures and are often difficult to track.

4.2 Step 2: Identification of root causes of frequently occurring delays

This step investigates the frequently occurring delays and identifies parts of the process where delay mitigation is needed the most. This includes quantitative analysis, based on port call data, as well as qualitative analysis, through root cause analysis, which helps identify the events that may have occurred before the delay and may have caused the registered delay. For example, a case that is registered as a towage delay regards an earlier delay in terminal operations which keeps the assigned tugboats busy for longer periods. This, in turn, propagates on the tugboats’ later assignments. This step leads to the identification of those delays that require action. Also, it identifies the first activities at which potential future delays can be signalled, which is an important input for delay mitigation.

4.3 Step 3: Identification of critical information sharing links

In this step, we combine the findings of the above two steps and associate the information sharing links related to each delay. For each delay, we investigate (1) what



kind of signalling information is needed for the initial notice of a delay, (2) who can produce this information and (3) which actors should be updated. In a case of a towage delay, for instance, we investigate ‘who notices the delay first?’, ‘what kind of information is needed from which actors to notice the occurrence of the delay?’ and once the delay is certain ‘who needs to be updated?’. By re-constructing the chain of events from the root cause until the delay, various opportunities for communication and management action can be considered. As far as information links occur between the same parties and/or concern the same subject, links can be grouped. These groups form the arrangement for sharing of critical information. As the design of these measures is situation (i.e. port) dependent and often relies on latent knowledge about the planning of execution of processes, it is advisable to work with local experts, from the HM for instance.

Below we describe the approach in more detail, demonstrating it at the same time for the Port of Rotterdam.

5 Case study

In this section, we discuss the application of the approach to the Port of Rotterdam. The Port of Rotterdam is the largest port in Europe, hosting almost 30,000 sea-going vessels each year. A recent study reported the Port of Rotterdam as the most efficient port among ports of 17 different countries (de Oliveira et al. 2021). The port of Rotterdam (PoR) is a landlord port. In a landlord port, the Port Authority owns the port areas and infrastructure and leases them to companies responsible for their own business. The HM is a division in the Port of Rotterdam authority in charge of rules and regulations for the use of the waterways in and around the port area. In the Port of Rotterdam, multiple public and private actors operate the NC’s services.

5.1 Inventory of information sharing links

We distinguish information sharing in the planning domain from that in the operational domain. For the planning domain, we conducted semi-structured interviews with the planning departments of the NC actors in the period of October–December 2019. We interviewed seven experts and managers each from the planning departments of pilots, the tugboat company, the boatmen, a terminal, the HCC, a liner vessel agent and the Port Authority itself. We asked the experts to explain the communications involved in delivering their services to incoming and outgoing vessels. For the operational domain, five semi-structured expert interviews and field observations were conducted in the same period. The interviewees were a pilot, tugboat captain, a boatman, a VTS operator and a policymaker at the Rotterdam Port Authority. For field observations, the authors took part (for a day) in the services of a pilot, a boatman and a tugboat captain, documenting the actual communications between the actors and asking experts to explain the information sharing guidelines that apply during the operations. After we derived the information sharing links, we validated the results with experts. An overview of the information sharing links between the



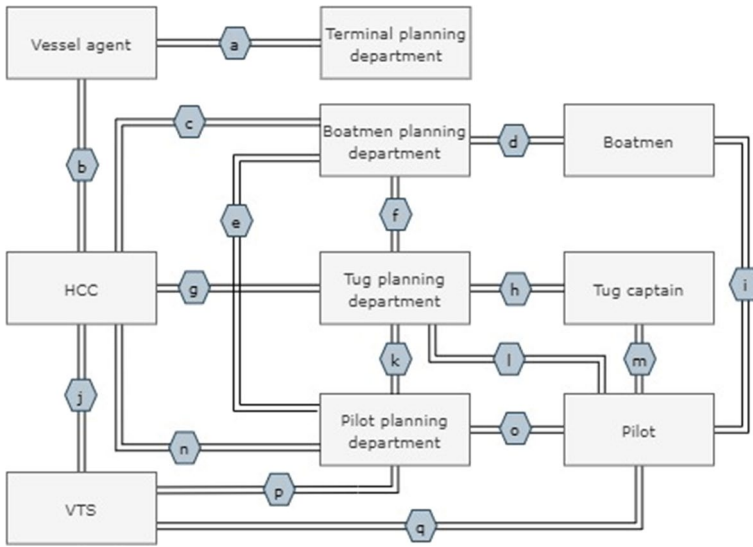


Fig. 3 Information links between actors of the nautical chain (BPMN conversation diagram)

actors of the NC is shown in Fig. 3. A detailed explanation of these information sharing links is provided below.

According to the process description above, we distinguish different purposes of information sharing in chronological order as follows.

Vessel agent’s updates regarding terminal planning (a, b): The agent is responsible for sharing the vessel and voyage information with the HCC and the terminal planner. Agents provide static details to the HCC, such as the vessel’s draft and the required number of tugboats. In addition, depending on terminal and voyage plans, vessel agents send multiple updates regarding changes in the ETA and ETD; still, reported estimated times are not always accurate (Parola et al. 2017). The information exchanged between terminal planning and HCC is shared via the vessel agent.

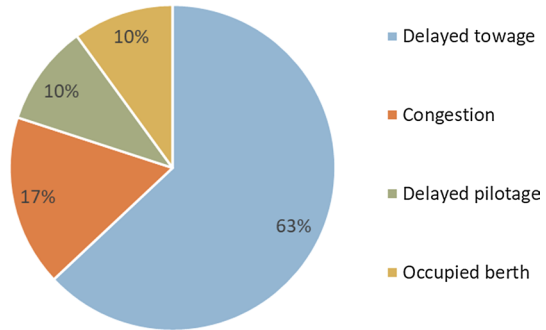
Port traffic planning prior to vessel arrival and departure (j, p): Before vessel arrival and departure, the HCC exchanges information with the VTS for port traffic planning. The VTS is also linked to pilot planning, to communicate vessel arrival and departure to pilot planners. To assure safety of the port, extra attention is paid on planning the visit of the deep-draft, tidal-bound and dangerous cargo carrying vessels.

Planning of nautical service providers (c, g, n, e, f, k): The boatmen planning, the pilot planning, the tugboat planning and the HCC are all linked to each other, to share information regarding the proposed ETA and ETD of planned vessels. They individually plan the deployment of their resources and, upon request, modify their plans together. Multiple communications via phone, e-mail or very high frequency (VHF) radio may be needed when a nautical service provider is not available at the requested time.

Deployment of nautical service providers by their planning departments (o, h, d): The pilot planning, tugboat planning and boatmen planning share the details of the



Fig. 4 Direct causes of delays for incoming voyages



next scheduled assignment with the boatmen crew, the tugboat captain and the pilot. Vice versa, updates of ongoing operations are shared from the boatmen crew, the tugboat captain and the pilot with their planning departments.

Vessel's manoeuvring (i, m, q): When nautical service providers are all present at an assignment to provide their services, the pilot gives orders and exchanges information via VHF radio with the boatmen crew and the tugboat captain. In addition, the pilot and VTS operator continuously communicate regarding the vessel's intentions and port traffic. Sometimes phone calls are also needed to make quick arrangements.

5.2 Root causes of more frequently occurring delays

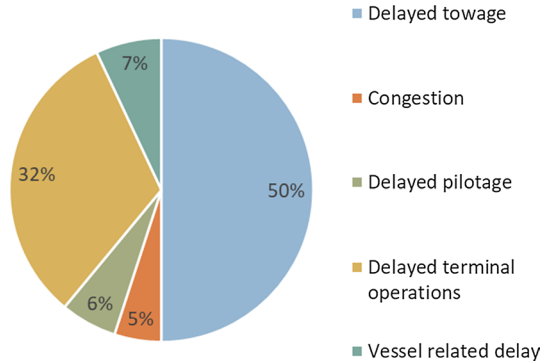
Delays can have many causes, which are often interrelated. A systematic understanding of the main causes of delays and their relations is needed, to make sure that we address as many delays as possible and the need for information sharing is thus minimized. The technique of root cause analysis helps to achieve that purpose. To identify root causes of main delays in the PoR we analysed port call data and conducted further interviews. We used a database of registered vessel delays by the HM, which also identifies which service was delayed and for how long. We obtained data regarding delays between October 2019 and 2020, involving in total approximately 28,300 sea-going voyages. We analysed the data to identify direct causes of delays and the probability of occurrence of each individual cause, based on Eq. (1).

$$\text{Probability of occurrence of delays due to cause } i = \frac{\text{Number of registered delays due to cause } i}{\text{Total number of delays}} \quad (1)$$

Figures 4 and 5 show the direct causes of delays for incoming and outgoing voyages, respectively. In both cases, delayed towage accounts for most of the delays. The second main cause of delay for incoming voyages is congestion and, for outgoing voyages, it is delayed terminal operations, followed by congestion and delayed pilotage. Mooring operations are almost always on time for both incoming and outgoing voyages.



Fig. 5 Direct causes of delays for outgoing voyages



The above-mentioned delays include only direct causes of delays and not the root causes of these delays. For example, a delay is registered as delayed pilotage when a vessel has to wait for the pilot, either because the pilot is not available at the requested time and rescheduling is needed, or because the pilot arrives with a delay to the scheduled assignment. The latter case may occur when the previous assignment of the pilot was delayed, or when a pilot is required with different qualifications than originally requested. This example shows that the root causes behind the direct causes of delays vary. Hence, it is important to identify them first to tackle them individually. Identifying such indirect causes is done by root cause analysis. We conducted two semi-structured in-depth interviews, with a policymaker at the HM department of the Port of Rotterdam and the VTS manager, in February 2020, asking them about potential root causes of delays. We asked what kind of delays can happen prior to the direct causes of delays shown in Figs. 4 and 5. In total, we identified no less than 45 root causes and illustrate them in the cause-and-effect diagram of Fig. 6.

As there is no separate data regarding the frequency with which such root causes occur, we conducted expert surveys to identify the most frequently occurring causes of delays. We translated the cause-and-effect-diagram into a survey template and asked ten port actor experts to highlight the frequently occurring ones. The experts included a manager of the pilot organization, a tugboat company, the boatmen organization, the HCC, the ECT terminal, a pilot, a duty officer of the HM control centre, and a policymaker of the Rotterdam Port Authority. Importantly, the results of surveys showed a strong consensus about frequently occurring causes of delays. The most frequently occurring causes are highlighted in red in Fig. 6 and listed below. In 16 of the 45 causes, there was complete unanimity about whether a root cause of a delay occurs frequently. For instance, all ten respondents agreed that capacity shortages of tugboats and pilots, and passages of large vessels are frequent causes of delays, while all ten respondents remarked that delays due to fog restrictions and technical problems do not happen frequently. We used a rather strict cut-off point of 90% consensus level to determine frequently occurring causes of delays, i.e. when at least nine of the ten experts agreed. Accordingly, the following list resulted of frequently occurring root causes:

(RC1) Delayed pilotage due to a pilot capacity shortage



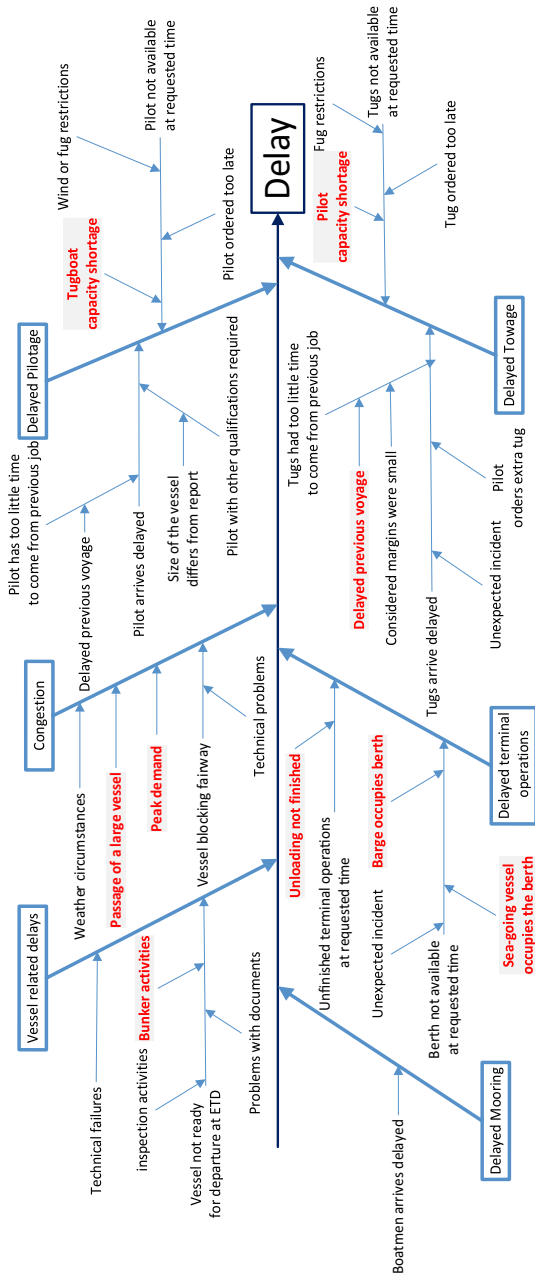


Fig. 6 Cause-and-effect diagram of delays in the Port of Rotterdam



- (RC2) Delayed towage due to tugboat capacity shortage
- (RC3) Delayed tugboat arrival to an assignment due to a delay of the previous vessel
- (RC4) Berth unavailability due to occupancy by an inland barge
- (RC5) Berth unavailability due to occupancy by a sea-going vessel
- (RC6) Terminal's delay due to unfinished loading activities
- (RC7) Vessel's delayed departure due to unfinished bunker activities
- (RC8) Fairway congestion due to peak demand
- (RC9) Fairway congestion due to passage of a large vessel.

Based on the identified frequently occurring root causes of delays, the next step is to identify the related information sharing actions. These are described in the next section.

5.3 Critical information sharing links

We combine the findings of previous steps and complement them with an expert interview with a policymaker at the HM, to provide additional validation of critical information sharing links around frequently occurring root causes of delays. For each of the nine frequently occurring root causes, we asked three questions as follows: 'Who notices a delay first?'; 'For the initial notice of a delay, what kind of information is needed and from which actors?'; 'Which parties should be updated regarding the delay?'. For the frequently occurring root causes of delays, the following information sharing links were identified as critical.

(RC1) Delayed pilotage due to pilot capacity shortage: The initial notice of a shortage in pilot capacity depends on the information available to the pilot planner with regard to the demand for pilots and the available pilot capacity. Demand for pilot is submitted by the vessel agent to HCC (b). Updated ETA of the vessel and demand for pilot is submitted from VTS to the pilot (q). Pilot capacity is updated by pilots when they start and complete their assignments and update the pilot planner (o). When the pilot planner notices that pilot capacity would be insufficient to respond to pilot demand, a request for a delayed ETA and ETD is sent to the HCC, the tugboat and the boatmen planning departments to inform them that the pilot's arrival will be delayed (n, k, e).

(RC2) Delayed towage due to tugboat capacity shortage: The initial notice of a shortage in tugboat capacity depends on the information available to the tugboat planner with regard to demand for tugboats and the available tugboat capacity. Anticipated demand includes (a) the estimated number of tugboats, and (b) the estimated time of vessels at pilot station. The number of tugboats is indicated by the vessel agent or the pilot planner, and submitted to the tugboat planner (b, g, k). The VTS operator registers the pilot station time and the tugboat planner estimates the time that the tugboats need to meet the vessel. The *final* number of tugboats is decided when the pilot is on board the vessel, and is discussed and agreed with the vessel captain. The pilot shares the required number of tugboats with the tugboat planner (l), after which the latter deploys the tugboats, informing the tugboat captain (h). In cases where the tugboat planner notices that the available tugboat capacity is



insufficient to respond to tugboat demand, and will cause a delay, an update is submitted to HCC, pilot planning and boatmen planning departments (g, k, f).

(RC3) Delayed towage due to delays in the previously served vessel: The initial notice of a delayed towage due to delays in the previous assignment depends on information available to the tugboat planner, submitted by the tugboat captain, who receives information on delays in the current assignment from the pilot (m). The tugboat captain updates the tugboat planner on delays that occur during their assignment (h). When the tugboat planner is certain that not enough tugboats are available to meet demand at the requested time, he sends a request for an updated time to the pilot planners (k). Sometimes, the tugboat planner informs the pilot directly of the delayed tugboat arrival (l). Sometimes, when the tugboat does not arrive on time at the scheduled assignment, the pilot calls the tugboat planning (l). In case the tugboat is already in the proximity of the vessel, the tugboat captain directly contacts the pilot on board the vessel to inform the pilot about its delayed arrival (m).

(RC4) Berth unavailability due to occupancy by inland barge: The initial notice of berth occupancy by an inland waterways barge depends on the information available to the pilot, submitted by the VTS operator or the boatmen who are present at the quay waiting for the vessel's arrival (q or i). The pilot informs the tugboat captain (m). When the delay is certain, the pilot, the tugboat captain and the boatmen inform their planning departments accordingly (o, h, d).

(RC5) Berth unavailability due to occupancy by sea-going vessel: Either the pilot onboard or the VTS operator notice that there is a delay due to the berth being occupied by a vessel.

Whoever notices this first, notifies the other (q). The VTS informs the pilot of the incoming vessel regarding the delay so it can slow down if necessary (q). The pilot on-board the delayed vessel calls his pilot colleague on-board the incoming vessel to discuss the details of the delay and possibilities of passing each other by manoeuvring in the port. One of the pilots must update the VTS operator of the decisions that are being made (q). Next, the pilot updates the tugboat captain (m). When the delay is certain, the pilot, the tugboat captain and the boatmen crew inform their planning departments accordingly (o, h, d).

(RC6) Delayed terminal operations due to unfinished (un)loading activities: The initial notice of unfinished (un)loading activities depends on the information available to the pilot from the boatmen at the quay who receive information from terminal employees (i). When the pilot notices the delay of the departing vessel, he informs the VTS and the tugboat captain (q, m). If the occurrence of the delays is certain, the pilot, tugboat captain and boatmen inform their planning departments (o, h, d).

(RC7) Delayed departure due to unfinished bunkering activities: The initial notice of unfinished bunkering activities depends on information available to the pilot when he boards the vessel. When the pilot notices the delay, he informs the VTS, tugboat captain and boatmen (q, m, i). When the delay is certain, the pilot, tugboat captain and boatmen inform their planning departments (o, h, d).

(RC8) Congestion at the fairway due to peak demand: The VTS operator is the first to notice a delay because of fairway congestion. Depending on the traffic, the VTS operator can decide to delay an incoming or outgoing vessel. The VTS operator updates the pilot (q). Pilots of different vessels contact each other to discuss



the traffic situations and any possibilities to pass each other. To inform VTS with regard to the decision being made, one of the pilots updates the VTS (q), the tugboat captain and the boatmen (m, i). The pilot, tugboat captain and boatmen inform their planning departments (o, h, d).

(RC9) Congestion at the fairway due to passage of large vessels: The initial notice of delay depends on the information available to VTS regarding the current traffic in the port, and the planned arrivals and departures of the larger vessels (and possibly their delays). This information is shared with VTS by pilots (q). The tugboat captain and boatmen also notify the pilot when they notice congestion in a port sector (m, i). Pilots of vessels contact each other to discuss the traffic situation and the possibility of passing each other through manoeuvring. When it is certain there will be a delay, the pilot, tugboat captain and boatmen inform their planning departments (o, h, d).

The critical information sharing links (shown in brackets) allow delay mitigation for the frequently occurring root causes that meet with broad agreement from all the NC actors. We re-order the critical information sharing links in a number of distinct information sharing groups based on specific actors and information content (see Table 1 in Appendix). Together, these groups form the 'arrangement' for sharing critical information for delay mitigation. The arrangement further condenses and simplifies the required information sharing actions. The re-ordering of the critical information sharing links (see Table 1 in Appendix for the associations with each link) leads to the following groups:

- i. Sharing vessel information: Information sharing between the vessel agent and the planning departments (pilot planning, tugboat planning, HCC and terminal planning) regarding the voyage order details and specifications such as ETA, ETD, estimated number of tugboats and designated berth.
- ii. Sharing joint planning information: Information sharing between the pilot planning, tugboat planning, boatman planning departments and HCC regarding the updated ETA, ETD and their requests for delayed ETA and ETD.
- iii. Sharing deployment information: Information sharing between the pilot, tugboat captain and boatmen crew with their planning departments regarding the deployment information such as meeting point with the vessel, or estimated start and completion time of services.
- iv. Sharing assignment information: Information sharing between the VTS, pilot, tugboat captain and boatmen crew regarding traffic in port, (sailing speed and course) and the decisions and disrupting events that occur during the ongoing assignments.
- v. Peer-to-peer information sharing between the pilots: Information sharing between the pilots of different assignments regarding delays and status of scheduled or ongoing assignments.
- vi. Sharing information of shared resources: Information sharing from boatmen crew and VTS with the pilot of the assignment that shares a resource (berth, fairway, tugboat) with another assignment. Fig. 7 shows the parts of the information sharing arrangement and how they interact.



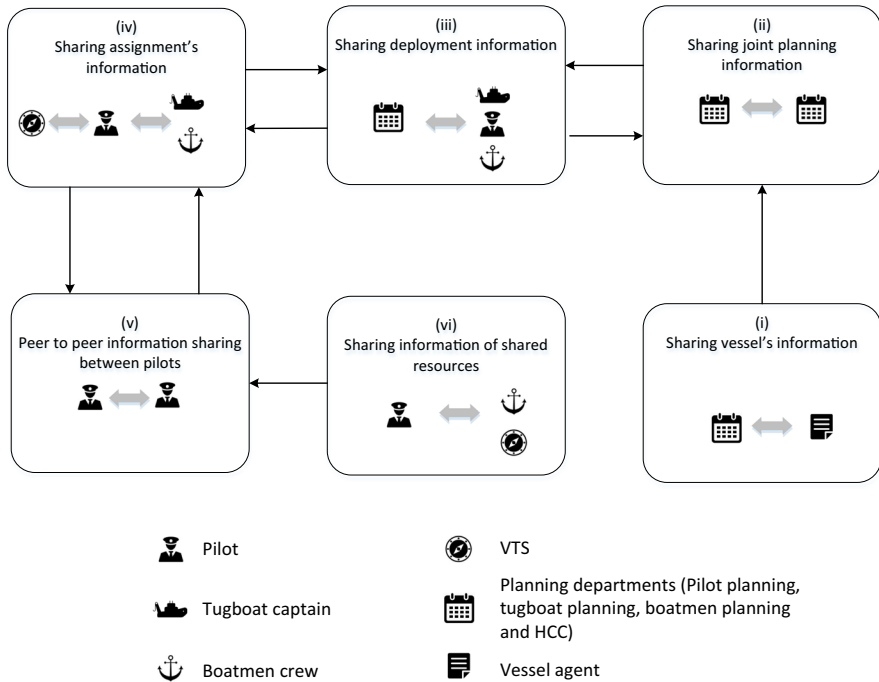


Fig. 7 Information sharing arrangement for delay mitigation

The information available to each of the groups may depend on the information being submitted by other groups. Each group is represented with a box. Arrows indicate that the information that is available to the receiving box depends on the information being submitted from a sending box. For example, the availability of information of group (ii) depends on the information sent from groups (i) and (iii). These results are a stepping stone towards the creation of information systems for advanced operational information sharing between the actors for delay mitigation. The structural relationships between information sharing arrangements and the main root causes of delays, ensure consistency and support effective information sharing. The findings of our case study give rise to the following discussions, based on existing literature; they also have practical implications. These are discussed in the next section.

6 Findings

We highlight a couple of salient findings from our case.

Firstly, the analysis of root causes of frequently occurring delays shows that most of the service delays are a result of the high level of utilization of port infrastructure and resources, such as the fairway, pilots, tugboats and berths, rather than technical issues or weather conditions. This appears to be the result of increased pressure on



ports by ever larger vessels, visiting ports more frequently. In this regard, our study supports the findings of earlier studies regarding the need for a proactive role of ports in the port call process (Paixão and Marlow 2003; Song and Panayides 2008; Carbone and De Martino 2003). As opposed to the current principle, whereby vessel visits are scheduled in fixed time windows, based on terminal planning only, and port actors have to react, ports can require vessels to call the port to arrange their just-in-time arrivals, considering the availability of all port resources (Lind 2019). Such arrangements can help ports to plan their resources (e.g. pilots, tugboats and infrastructure) optimally and operate more efficiently. However, this also requires an understanding of the inter-dependencies as well as a certain level of ‘partnership’ to work.

Secondly, the expert surveys showed a very close agreement among experts on the root causes of delays. This suggests a high shared awareness of delay situations among the actors of the PoR. Operational support with information systems for better transparency is, however, indispensable. Our results constitute only a framework for the contents of information shared, and do not provide details about the information sharing processes themselves. Different operators may want to operationalize the arrangement in different ways. For example, one pilot may prefer first to communicate a delay to the pilot planning department, and then expect the latter to notify the tugboat and boatmen planning departments, and next they inform the tugboat captain and boatmen crew. Another pilot, however, may first want to communicate the delay to the pilot on the other vessel and then inform the tugboat captain and boatmen crew, expecting them to update their own planning departments. Lack of distinct information sharing guidelines for each delay case makes it difficult to track the information. Furthermore, multiple calls involving the same delays can be labour intensive and confusing. Hence, one of the keys in mitigating port delays is designing specific information sharing guidelines for each delay case, so that each operator knows exactly what to do, who to contact and what information to share in each case. In designing such guidelines, we suggest paying particular attention to the needs of actors, because on-time information needs of different actors differ. For instance, in the Port of Rotterdam, on-time information for boatmen deployment can be inadequate for tugboat deployment, as the time needed for the tugboat dispatch is much longer than the time required for the boatmen crew. In addition, we suggest registering the necessary details in a delay database so that these causes are documented systematically and continuously and can be relied upon dynamically for studying the needs of the actors.

Thirdly, we find that, in many cases, the pilot is the one who notices the delay first. Therefore, strengthening information sharing links from other parties to the pilot and vice versa can contribute enormously in mitigating delays. The former facilitates early notice of delays, while the latter helps avoid the propagation of delays, by helping others to adapt their tasks and decisions. Consequently, we



suggest adoption of digital solutions, investing in ICT developments and trainings to further connect pilots to the other actors.

Fourthly, drawing conclusions about the responsibility of individual actors in the occurrence of delays is not easy. The statistics of the PoR showed that more than half of the delays are associated with delayed towage. We argue that this situation indicates the vulnerable position that the tugboat company finds itself in, with regard to information sharing within the NC, rather than issues with towage operations per se. Take, for instance, descriptions of 5.3 for the delayed towage due to a shortage in tugboat capacity (RC2). For the initial notice of tugboat capacity shortage, the tugboat planner depends on two pieces of information: the expected number of tugboats and the estimated arrival at the meeting point. These two pieces of information are submitted by two different actors, the pilot planner and the VTS. When either information is missing or delayed, that causes delays in the tugboat planning and hence their dispatch. The required number of tugboats for each assignment remains *estimated* until the pilot sends the final request for tugboats from the vessel, as agreed with the captain.¹ This disruption only leaves a small margin for the tugboat company to dispatch the required number of tugboats if the actual number deviates from the original estimate. Another case is when towage delays occur due to delays of the previous voyage (RC3). In this case, the tugboat planner depends on information submitted by the tugboat captain, while the tugboat captain must receive it from the pilot first. These examples show that depending on the timely submission of information from others increases the risk of towage being delayed.

Fifthly, our case findings show the minimal contribution made by the terminal of study in the NC's information sharing. In the PoR, boatmen on the quay or the VTS operator act on the terminal's behalf to update the NC actors on any disruptions or delays. This means that the information regarding the completion of terminal operations may be imprecise. Actively involving the terminal in information sharing with the NC can significantly help improve the distribution of updated quality information. Similarly, the terminal is not involved in the updates about delays and decisions made by the NC. Since the efficiency of the terminal is significantly affected by ETA uncertainty (Thoben and Wortmann 2013), linking the terminal to the NC's information can benefit the terminal. Considering the benefits of further involvement of the terminal in information sharing of the NC, we argue that there is a significant opportunity for the mutual benefit of both the terminal and the rest of the NC actors, that has so far not been fully exploited.

Finally, our results confirm and reinforce the existing literature on inter-dependencies in ports. Earlier studies reported that the processes which different port actors carry out are inter-dependent and these inter-dependencies impact the ways port actors interact (Vitsounis and Pallis 2012). The authors identified three types of inter-dependencies: serial (precedence of a process), reciprocal (mutual resource exchange among processes) and pooled inter-dependency (sharing a resource between processes). Our results show that these inter-dependencies not only exist in port processes, but also in information sharing for the provision of these processes. Take, for example, information sharing groups (i), (ii) and (iii), where there is a serial

¹ It should be clear that, in most ports, the pilot is just the transmitter of the request for tugboats, while the decision on the number of tugboats belongs solely to the ship's master.



inter-dependency. Sharing deployment information depends on the information being shared among the planning departments for joint planning. The information for the joint planning itself depends on the availability of vessel information. In other words, some information groups are antecedents to the subsequent information groups. Groups (iii) and (iv) provide an example of a reciprocal inter-dependency, where an information recipient processes the information, makes a decision and sends it back to the initial sender. For example, information on which planning departments base their decision depends on the information being shared with them by operational actors. Once a decision has been made, the information is sent back to the operational actors. Groups (iii), (iv) and (v) have pooled inter-dependency. In pooled inter-dependency, the information available to a group depends on the information shared from multiple groups. As such, the availability of information in group (iv) depends on information from two other groups (iii) and (iv). The existence of a variety of inter-dependencies complicates the identification of the actors' information needs. This complexity indicates that it is unlikely that the actors' information needs can be met in the absence of clear information guidelines. Therefore, it is necessary to design information sharing guidelines systemically. Moreover, we note that most information sharing links are inter-organizational, challenging information sharing even further by presenting organizational barriers. Our empirical findings substantiate the position of Talley et al. (2019, 2020) on the importance of these relationships. For facilitating information sharing practices in the ports, it may be interesting to investigate the actors' inter-organizational relationships as a pre-condition for information sharing.

7 Conclusions and future research directions

The paper proposes an approach that systematically studies information sharing in port to help mitigate delays in service times. It helps to identify which information is critical to be shared and with whom. We apply the approach to the case of PoR. The results provide insights into port delays and their relevance in terms of information sharing. Nine frequently occurring delays were identified. To facilitate early notice of delays and avoid their propagation, critical information sharing links were specified. Based on the approach and its application, we identified opportunities for improvements and suggested recommendations for practice. The main findings are the following:

- Delays occur mainly due to increased pressure on ports and the over-utilization of port resources. Managing this pressure requires proper planning of port resources by, first of all, ensuring the just-in-time arrival of ships, based on the port's resource availability. This means that ports need to adopt a more proactive role in the port call process, as opposed to the current principle in which ETAs are extremely inaccurate, time windows are based on terminal planning only and port resources cannot be planned until the vessels arrive at the port.
- Information sharing links are inter-dependent and inter-organizational. The sender of the information itself receives information from an earlier sender and often requires additional information from multiple senders to make decisions.



This inter-dependency creates complexity in identifying from whom to obtain the information and who to inform next. The presence of inter-organizational links complicates information sharing even more. These complexities imply that, for improving information sharing, ports have to design operational information sharing guidelines fitting into their specific context.

- Neither the causes of the delays nor the measures to mitigate them must be seen in isolation. The port services form a complex system that needs to be approached systematically. Accordingly, delays that are attributed to one actor may be mitigated by facilitating information sharing among the rest of the actors.
- Results showed the critical position of pilots, the vulnerable position of tugboat companies, and the minimal contribution of the terminal in information sharing. Considering these positions is essential for the effective design of information sharing guidelines. We identified a significant potential opportunity to improve information sharing that is as yet unexploited.

These findings provide input for addressing the key port management challenges regarding the facilitation of information sharing, currently on the agenda of port policymakers. Adoption of these recommendations can ultimately help port efficiency improvements. This also leads us to the following suggestions regarding the future extension of our work. Firstly, the scope of this paper is limited to the *'what and whom'* questions of information sharing, and does not include *how* and *when* the information must be shared; something that future research can look into. Future research can also investigate whether digital solutions can overcome practical challenges of information sharing. The question *'whether the actors would be willing to share information considering the unequal distribution of costs and benefits, risks involved, lack of trust, and unwillingness to invest in infrastructure?'* also merits further research. Secondly, our research can be extended by a further quantitative analysis of delays and their root causes. Here, we identified the frequently occurring causes of delays through expert interviews. The combined use of geographical position data and process logs of port actors could increase the accuracy of identifying root causes. Thirdly, we suggest measuring the impacts of improved information sharing on port delays and overall efficiency to help measure the magnitude of the impact. Finally, the approach presented here can and should be applied to other seaports. Repeated applications and their comparison can help generate generalized findings, noting that different ports in different contexts will undoubtedly affect the information sharing needs.

Appendix

The following Table 1 re-orders the information sharing links across the nine root causes of frequently occurring delays and provides distinct information sharing groups.



Table 1 Expert inputs on the frequency of delay causes

Root Causes of delays	Information Link	From	To	Information group	Information content
RC1	b	Vessel agent	HCC	i	Updated ETA and ETD, vessel's information, ordered nautical services
	n	HCC	Pilot planning		
	o	Pilot	Pilot planning	iii	Estimated completion time of the ongoing assignment
	q	VTS	Pilot	iv	Updated ETA
	n	Pilot planning	HCC	ii	Requests for a delayed ETA or ETD
	k	Pilot planning	Tugboat planning		
	e	Pilot planning	Boatmen planning		
RC2	b	Vessel agent	HCC	i	Updated ETA and ETD, vessel's information, the estimated number of tugs
	g	HCC	Tugboat planning		
	k	Pilot planning	Tugboat planning		
	l	Pilot	Tugboat planning	iv	Updated ETA, Final number of required tugboats
	h	Tugboat planning	Tugboat captain	iii	Deployment information
	g	Tugboat planning	HCC	ii	Requests for a delayed ETA or ETD
	k	Tugboat planning	Pilot planning		
RC3	f	Tugboat planning	Boatmen planning		
	m	Pilot	Tugboat captain	iv	Updates on the ongoing assignment, estimated completion time
	h	Tugboat captain	Tugboat planning	iii	Estimated completion time of the ongoing assignment, updates on delayed arrival
	l	Pilot	Tugboat Planning		
	k	Tugboat planning	Pilot planning	ii	Request for a delayed ETA and ETD
	q	VTS	Pilot	vi	Updates on berth unavailability and estimated availability time
	i	Boatmen	Pilot		
RC4	m	Pilot	Tugboat captain	iv	Updates on the ongoing assignment
	o	Pilot	Pilot Planning	iii	Updates on the ongoing assignment and estimated completion time
	h	Tugboat captain	Tugboat planning		
	d	Boatmen	Boatmen planning		



Table 1 (continued)

Root Causes of delays	Information Link	From	To	Information group	Information content
RC5	q	VTS	Pilot	vi	Traffic information, updated ETA and ETD
		Pilot	Pilot	v	Updates on sailing and manoeuvring information, possibility of overtaking
	m	Pilot	Tugboat captain	iv	Updates on the ongoing assignment
	o	Pilot	Pilot Planning	iii	Updates on the ongoing assignment and estimated completion time
	h	Tugboat captain	Tugboat planning		
RC6	d	Boatmen	Boatmen planning		
	i	Boatmen	Pilot	vi	Updates on the completion of time of terminal operations
	q	Pilot	VTS	iv	Updates on the ongoing assignment
	m	Pilot	Tugboat captain		
	i	Pilot	Boatmen		
RC7	o	Pilot	Pilot Planning	iii	Updates on the ongoing assignment and estimated completion time
	h	Tugboat captain	Tugboat planning		
	d	Boatmen	Boatmen planning		
	q	Pilot	VTS	vi	Updates on the completion time of bunkering operations
	m	Pilot	Tugboat captain		
	i	Pilot	Boatmen		
	o	Pilot	Pilot Planning	iii	Updates on the ongoing assignment and estimated completion time
	h	Tugboat captain	Tugboat planning		
	d	Boatmen	Boatmen planning		
	q	VTS	Pilot	vi	Traffic information, updated ETA and ETD
RC8		Pilot	Pilot	v	Updates on sailing and manoeuvring information



Table 1 (continued)

Root Causes of delays	Information Link	From	To	Information group	Information content
RC9	q	Pilot	VTS	iv	Updates on the ongoing assignment and decisions made by pilots
	m	Pilot	Tugboat captain		
	i	Pilot	Boatmen		
	o	Pilot	Pilot Planning	iii	Updates on the ongoing assignment and estimated completion time
	h	Tugboat captain	Tugboat planning		
	d	Boatmen	Boatmen planning		
	q	VTS	Pilot	iv	Traffic information, updated ETA and ETD
	m	Tugboat captain	Pilot		
	i	Boatmen	Pilot		
	o	Pilot	Pilot	v	Updates on sailing and manoeuvring information
	h	Tugboat captain	Pilot Planning	iii	Updates on the ongoing assignment and estimated completion time
	d	Boatmen	Tugboat planning Boatmen planning		



Acknowledgements We are thankful for the contributions of all who participated in the interviews, especially Raymond W.P. Seignette. We are also grateful to the anonymous reviewers of MEL and to Bart Wiegman for their constructive comments. This research was part of the SwarmPort project, number 439.16.108, and supported financially by The Dutch Research Council (NWO).

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