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Automatic information exchange between interoperable information systems: Potential improvement of access management in a seaport terminal

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ABSTRACT

The purpose of this paper is to explore how and when the most beneficial and cost effective information attributes can be automatically exchanged between interoperable information systems of a seaport terminal operator, a road haulier, and a rail operator to potentially improve their access management. The automatically exchange of the attributes is dependent on interoperability between information systems of the involved actors. The interoperability is achieved through a developed application programming interface in this study. This case study adds to prior research by developing a cost-benefits analysis that categorises the attributes (from low cost/low benefit to high cost/high benefit) involving four strategies: data farming, dedicated information exchange, opportunistic information exchange, and avoiding information exchange. These four strategies are important in identifying when to collect the information attributes automatically to facilitate real-time decision-making and in turn potentially improve the access management for the involved actors. is developed in this case study to enable interoperability between the information systems of involved actors. As a change management tool, the cost-benefit analysis can also be used to identify and support transformation of attributes from one category to another. The empirical study included nine workshops resulting in the identification of the most beneficial and cost effective information attributes: *deviation information, direction, driver ID, estimated time of arrival, goods priority information, intermodal transport unit (ITU) ID, ITU status, opening hours, shipment ID,* and *vehicle ID*. The attributes must be automatically exchanged according to three identified time phases: one week before, one day before, and two hours before the ITUs are to be picked up at the terminal. By exchanging these attributes between the interoperable actors´ information systems, there is potential for reducing the actors´ turnaround times, increasing their access reliability, access precision, and access flexibility. Finally, two propositions are formulated from the empirical findings and in relation to prior research results.

1. Introduction

Intermodal freight transportation is complicated due to its variety of modes of transportation (Marchet et al., 2012). Between the modes, intermodal transport units (ITUs)[1] are handled and moved, i.e. transhipment (Bontekoning et al., 2004)—for example, from long-distance transport (e.g., by sea or rail) to road transport (Lumsden, 2006). Transhipment of ITUs take place in intermodal freight terminals that can be classified into four different types: seaport terminals, railroad terminals, inland waterway terminals, and airports (Lowe, 2005; Roso et al., 2009). These terminals differ in terms of geographical coverage, volume, and capacity (Wiegmans et al., 1999). Seaport terminals are in focus in this paper since they can be characterized with higher volumes and capacity utilization compared to the other three terminal types, and since they play the most crucial role in logistics and supply chains (Lam and Su, 2015). Seaport terminals involve large number of different actors that make intermodal freight transportation even more complicated. Actors are people or organisations within business networks (Håkansson et al., 2009). In this case study, involved actors refer to industrial organisations and their decision makers (and not policy makers), and they are represented by one seaport terminal operator, one road haulier and one rail operator.

These actors are chosen since they face, as most other seaport terminal operators, road hauliers and rail operators do, accessibility issues such as slow modal shift (Woodburn, 2006), inefficient loading and unloading activities (Sternberg et al., 2012b); slow, unnecessary administration (Sternberg et al., 2014) and long turnaround times at terminals (Dekker et al., 2013). Turnaround time is the elapsed time

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[1] Intermodal transport units are standardised load units such as containers, semi-trailers, and swap bodies.

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from when a truck enters a terminal area to the time it exits (Islam et al., 2013), and is an important access service element, i.e., a performance measure, at terminals (Lubulwa, Malarz, & Wang, 2011) and depend heavily on how the daily operations and resources of terminals are planned. For example, poor management at terminal results in longer turnaround times with more bottlenecks (Islam et al., 2013; Motono et al., 2016), which in turn negatively affect access to the terminal (Phan and Kim, 2015). Other important access service elements are access reliability which measures whether access to terminals is correctly handled as negotiated between involved actors at the initiation of the transportation; access precision which measures whether access was gained on time as negotiated between involved actors at the initiation of the transportation; and access flexibility which measures whether involved actors can exchange information updates in real time when changes occur during transportation (Jacobsson et al., 2018).

These accessibility issues are related to that seaport terminals are decentralised in the way that involved actors make their own decisions independently of the others, although the trend is toward centralised transport planning and cloud computing (Sternberg and Andersson, 2014). For example, due to the independently decision making, vehicles arrive to seaports unnoticed (Covic, 2017; Motono et al., 2016; Wasesa et al., 2017). Without any pre-notifications, seaport terminal operators are not able to prepare the arrivals of vehicles that in turn has negative impact on the accessibility issues. Additionally, the decentralisation of seaport terminals might also have come about due to lack of information exchange among involved actors (Buijs and Wortmann, 2014), who state that information exchange between actors is critical for efficient operations. Another reason for the poor information exchange could be lack of high quality real-time data. Without such data, actors are forced to make decisions based on 'old' data, previous experiences, or incomplete data (SteadieSeifi, Dellaert, Nuijten, Van Woensel, & Raoufi, 2014). Many studies have pointed out that good information exchange between actors is a key success factor in improving efficiency at seaport terminals (Bisogno et al., 2015; Sternberg et al., 2012a). Such information exchange becomes even more important when disturbances such as accidents and weather changes occur in seaport terminals.

To establish better information exchange among involved actors, and in turn reduce the identified accessibility issues, the actors´ access management need to be improved. In this paper, access management is defined according to Jacobsson et al. (2017) as *the management of the process of actors accessing resources for certain activities in intermodal freight transportation*. Resources refer to material or immaterial resources, whether mutually dependent, physical, human or heterogeneous, that are owned by actors (Håkansson and Snehota, 2006). Resources in this paper are trucks, ITUs, personnel, terminal equipment and information. Activities refer to actions conducted by actors based on specific resources (Gadde et al., 2003). Activities in this paper are transhipment, road and rail haulage. To improve the access management, there are five information services, referred to 'access management services´ in this paper, identified in the literature: information access services (Tseng and Liao, 2015), automated gate services (Dekker et al., 2013), pre-notification and appointment services (Covic, 2017), real-time information exchange platform services (Carlan et al., 2016), and dedicated access services (Boile and Sdoukopoulos, 2014). These services have different capabilities in exchanging or sharing information in real time. According to Jacobsson et al. (2018), real-time information exchange platform services and dedicated access services have higher capabilities in exchanging information in real time compared to the other three identified access management services. Therefore, this case study focuses mainly on the real-time information exchange platform services and dedicated access services. With these two services the access management can be improved and the identified accessibility issues can be reduced that in turn can lead to more efficient intermodal freight transportation (European Commission, 2011; Mondragon et al., 2017).

The access management services are based on interoperable information systems that include various information communication technologies (ICTs) (Lu, 2017; Mondragon et al., 2017; Panetto, 2007). Interoperable information systems enable actors to integrate and coordinate their intra- and interorganisational business processes (Romero and Vernadat, 2016). Interoperability is defined according to Chen et al. (2008) as 'the ability of two systems to understand each other and to use functionality of one another'. To be more precise, interoperability is the exchange of information in an effective, meaningful, and useful manner between different types of information systems, computers, networks, and ICTs (Panetto, 2007). Moreover, interoperable information systems impact automatic information exchange between the systems (Romero and Vernadat, 2016). Automatic exchange means that the information is exchanged by itself with no or little direct human intervention (Görmer-Redding, 2018). Automatic information exchange between interoperable information systems can in turn facilitate improved communication in real time between involved actors since the information will be on time and of good quality. The information content, i.e. the actual message, that is exchanged is referred to 'information attributes' in this study according to the object-orientation paradigm (Booch, 1991; Yourdon, 1993). Object orientation is powerful when modelling the complexity of transport systems (Arnäs, 2007). Objects can be related to actors, resources, and activities, which in turn can transmit the actual messages, i.e., the information attributes, among the actors. Consequently, through the usage of interoperable information systems and ICTs, more high-quality information attributes can be automatically exchanged in real time among the involved actors (Dürr and Giannopoulos, 2003).

However, although prior research has identified the crucial role of applying information systems, ICTs and access management services to improve the four access service elements (turnaround time, access reliability, access precision, and access flexibility), little research has focused on selecting the most beneficial and cost effective information attributes, exploring how they can be automatically exchanged and when these attributes are required to be exchanged between interoperable actors' information systems. To examine what information attributes are most beneficial and cost effective, a cost-benefit analysis is developed and applied in this study. Moreover, there is a need of more automatic information exchange between actors´ interoperable information systems since prior studies show that manual handling of the exchange of information attributes contributes to more error and more stress for involved actors (Jacobsson, 2019). Therefore, the purpose of this paper is to explore how and when the most beneficial and cost effective information attributes can be automatically exchanged between interoperable information systems of a seaport terminal operator, a road haulier, and a rail operator for more effective access management. To fulfil the purpose, three research questions (RQs) need to be answered:

RQ1 - How can information attributes be automatically exchanged between the interoperable information systems of involved actors?

RQ2 - What information attributes are most beneficial and cost effective to be automatically exchanged between the interoperable information systems of involved actors?

RQ3 - When are the most beneficial and cost effective information attributes required to be most cost effectively and automatically exchanged between the interoperable information systems of involved actors?

This case study was conducted through literature reviews and empirical studies. The empirical studies were conducted through nine workshops that resulted in the identification of the most beneficial and cost effective information attributes to be automatically exchanged between the interoperable information systems of involved actors. Moreover, this case study adds to prior research by exploring how and when these information attributes need to be automatically exchanged to have the greatest effect on the four access service elements.

2. Review of relevant literature

2.1. Interoperable information systems

As stated previously and according to prior research, e.g. Heilig and Voß (2017); Jacobsson et al. (2017, 2018); Phan and Kim (2015), real-time information exchange platform services and dedicated access services have the most potential in improving the access management for involved actors. These services are based on different information systems. Information systems are composed of people and computers that produce, collect, process, filter, distribute, and interpret information (Kroenke et al., 2013), and consist of three this paper, the physical components are, except for the already mentioned involved actors and resource, truck and ITU flows. The decision sub-system is composed by decision support systems (DSSs) that supply information to decision makers, and the information sub-system is composed by real-time systems (RTSs) and transaction processing systems (TPSs) (Wortmann et al., 2013). RTSs operate in real time to monitor physical variables (e.g., text, numbers, audio, and video) via sensors, store the variables in log files, and update TPSs with these variables (Buijs and Wortmann, 2014). TPS are transport management systems that can record changes when certain events occur, such as transhipment of ITUs, changes in transportation plans, and/or arrivals at destinations (Wortmann et al., 2013). These changes are uploaded to DSSs and can be communicated via EDI (electronic data interchange) or XML-based (Extensible Markup Language) connections to other TPSs in other organisations (Buijs and Wortmann, 2014). In other words, when TPSs implemented in one organisation can communicate with TPSs implemented in other organisation, an interoperable information system is created.

2.2. Information communication technology applications

Interoperable information systems typically include various information communication technology (ICT) applications to enable and improve collaboration among involved actors in freight transport (Dürr and Giannopoulos, 2003). One common topology developed by Marchet et al. (2009), (2012) where four important ICT-application domains are described: 1) transport management (TM), 2) supply chain execution (SCE), 3) field force automation (FFA), and 4) fleet and freight management (FFM). TM can help, except for support decisions makers with transportation planning, optimization and execution (Mason et al., 2003), transport planners to coordinate actor shipments, manage freight consolidation activities and choose the transportation modes. SCE applications are powerful to respond in real time when unforeseen events occur along the transportation of ITUs (Meyr et al., 2015), and to increase opportunities to exchange information in real time among different SCEs installed at different actors. FFA applications can enable wireless communication between front line operators (e.g. truck drivers) access to back-office information (e.g. information at actors´ information systems) by sending requests from wireless devices to the back-office. FFM applications offer real time monitoring of vehicle travel times, service times, delivery points, and ITU temperature (Zeimpekis and Giaglis, 2006), and dynamic and efficient management of fleets of vehicles by using electronic maps, order-handling systems, vehicle tracking systems, and other communication systems (Harris et al., 2015). For road transportation, automatic vehicle location systems use global positioning system (GPS) devices to calculate real-time locations of vehicles and radio frequency identifications to transmit identities (such as a unique serial number) of objects through radio waves (Graham and Rogers, 2012).

Table 1 shows an overview of the TM, SCE, FFA and FFM applications with respective topic, functions, technologies and benefits. For more detailed overview of the ICT-technologies, the authors refer to Harris et al. (2015); (Heilig and Voß, 2017); Muñuzuri, Onieva, Cortés, & Guadix, 2019.

In addition, FFM involves real-time monitoring of parameters such

Table 1
Four ICT application domains classified by Marchet et al. (2009), (2012).

	Transport management (TM)	Supply chain execution (SCE)	Field force automation (FFA)	Fleet and freight management (FFM)
Topic	Decision support tools	Real-time management	Wireless communication	Reporting tools
ICT applications	Transportation planning; optimization execution; carrier load tendering; routing and scheduling; shipment tracking and tracing; freight payment and auditing.	Supervision and automation of activities; distribution scheduling; information exchange	Supporting integration between remote workforce and corporate business processes	Access control; vehicle tracking and tracing; parameters monitoring; management of fleets of vehicles
ICT technology	Internet technology	Internet technology	Mobile technology	Positioning technology; communication technology
Benefits	Improved efficiencies;reduced costs; reduced lead-time variability; the higher the integration level;the higher the related benefits	Increased operations efficiency, reduced number of errors during data entry procedures and service level enhancement	Higher connectivity and location awareness;better flexibility; enhanced interactivity; increased efficiency and effectiveness	Improving port terminal operations; reduced administration and waiting times; optimize the use of resources

as travel times, service times, and waiting times. Such information, together with vehicle speed, total fuel used, axle weight, and vehicle identification number, can be provided by a fleet management system (FMS) and is important for decision makers (Marchet et al., 2009). For example, Dynafleet is a web-based fleet management tool developed by Volvo Trucks that can streamline the planning and delivery of transport assignments, manage fuel consumption, view the location of trucks in real time, and monitor driver times (Dynafleet, 2019). From an infrastructure point of view, the Swedish Transport Administration supplies application programming interfaces (APIs) that provide different status information on roads (e.g., when accidents and roadwork occur).

2.3. Available information attributes

Jacobsson et al. (2017) identified information attributes, which they define as the actual transmitted information and exist for terminal operators and road hauliers, and their corresponding activities and resources perform and control, respectively. In other words, involved actors with their activities and resources are producers of information attributes. Additionally, in their study they also identified what of the existing information attributes are required to be exchanged among those actors improve their access management. Moreover, their study also classified the information attributes into static, historical and dynamic categories. Static information attributes are persistent and do not change over time (Giannopoulos, 2004). Historical information attributes are important when making future predictions or forecasts (Bhatt and Zaveri, 2002; Burstein et al., 2008). Dynamic information attributes can be changed over time, accessed and exchanged in real-time (Giannopoulos, 2004). Of these categories, the dynamic ones (but also the historical ones for future predictions) are of interest in this study since the focus is on performing automatic information exchange in real time and on maintaining the historical data to be able to make informed real-time decisions as well as predictions. Therefore, this study has selected from both these existing and required information attributes the most suitable ones that are interesting for automatic information exchange. The suitable information attributes are shown in Table 2.

2.4. Structuring suitable information attributes

The information attributes in Table 2 might have different characteristics when it comes to how difficult it is to collect them and how well they can fulfil the aim of automatic information exchange. To sort out and to structure these attributes, the matrix of Kraljic (1983) is useful since it is a tool and a model for categorisation. Also, in using this matrix together with a cost-benefit analysis such as the one from Mishan and Quah (2007), it is possible to see how worthy these attributes are for the system under study as they are sorted and structured according to their costs and benefits for automatic information exchange.

2.5. Synthesis: automatic information exchange between interoperable information systems

Interoperable information exchange must be horizontal, inter-organizational, bi-directional, digital, and structured (Jacobsson et al., 2017). TPSs from different actors are able to exchange the structured suitable information attributes via EDI or XML-based connections, shown as the bidirectional arrow in Fig. 1. The figure also illustrates how TPSs, DSSs, and RTSs interact with each other internally within each organisations, and how these systems defined by Buijs and Wortmann (2014) are related to the ICT applications defined by Marchet et al. (2009), (2012). The ICT applications are marked in *italics*.

The TPS applications include SCE applications to enable the structured exchange of suitable information attributes among involved actors´ information systems. The TPS implemented at each actor's information system, can then upload the suitable information attributes to the DSS applications where the decision makers can then act upon these exchanged suitable information attributes. The DSS applications include the TM applications that update the RTS applications. The RTS applications include the FFA and FFM applications to enable real-time monitoring of different information.

3. Methodology

When investigating contemporary phenomenon in real-life situations, case studies are the preferred approach (Yin, 2013) as they aim to explore situations in which an intervention has multiple outcomes, to describe an intervention, to explain a causal relationship, and to generate a meta-evaluation study of evaluation. Moreover, regarding theory generation, case studies are established and well-known research methods. Furthermore, case studies are useful to better

Table 2
Suitable information attributes [selected from Jacobsson et al., 2017] for automatic information exchange.

Sources	Categories	
1. Actors	**Historical**	**Dynamic (real time)**
1.1 Haulier	*Earlier interactions*	*Support back office*
1.2 Terminal operator	*Occupancy rate history; Opening hours*	*Opening hours*
2. Resources	**Historical**	**Dynamic (real time)**
2.1 Terminal with equipment	*Occupancy rate; Queuing status; Traffic history*	*Actual departure time; Actual return load; Availability of the terminal; ITU status; Occupancy rate; Queuing status*
2.2 Drivers	*Behaviours; Driver ID; Ignition interlock; Intelligent speed adaption; Rest/break schedules; Safety belt usage*	*Driver's behaviours; Driving times; Intelligent speed adaption; Schedule status; Safety belt usage*
2.3 Vehicles	*Emissions; Fuel consumption; Route; Speed limits; Vehicle ID*	*Breaking status; Direction; Fuel consumption; Position; Speed; Startability; Tyre contact area*
2.4 Haulier's transport planners	*Deviation information; Estimated delivery time; Estimated pick-up time; Time of delivery*	*Actual pick-up time; Actual time of delivery; Deviation information; Estimated delivery time; Estimated pick-up time; Proof of delivery*
2.5 Terminal's personnel	*Deviation information; Estimated pick-up time; Estimated pick-up time; Planned return load; Time of delivery*	*Actual pick-up time; Actual time of delivery; Deviation information; Time of delivery*
2.6 Goods	*Bill of lading; Dangerous goods declaration; Goods priority information; ITU ID; ITU status; Temperature*	*Bill of lading; Dangerous goods declaration; Deviation information; Goods priority information; ITU ID; ITU status; Temperature*
2.7 Infrastructure	*Road conditions; Road status; Situations*	*Dynamic speed limits; Road conditions; Road status; Situations of the infrastructure*
3. Activities	**Historical**	**Dynamic (real-time)**
3.1 Road haulage	*Deviation information; ETA; Route; Shipping ID*	*Deviation information; ETA; Terminal's loading point; Terminal's unloading point; Loading instructions; Loading status; Route; Unloading instructions; Unloading status*
3.2 Transhipment	*Arrival time of ITU; Confirmation of arriving ITU; Deviation information; Pick-up location; Shipping ID*	*Deviation information; Handling of ITU; Terminal's loading point; Terminal's unloading point; Loading instructions; Loading status; Unloading instructions; Unloading status*

Note: ID = Identification; ITU = Intermodal transport unit; ETA = Estimated time of arrival.

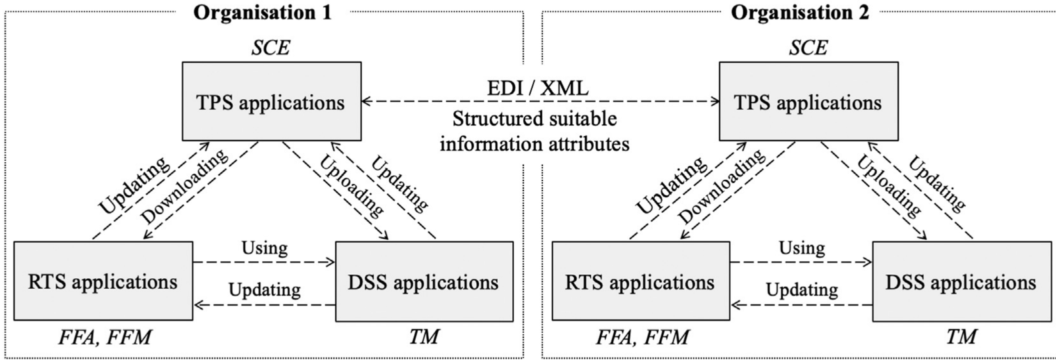

Fig. 1. Interoperable information systems with included sub-systems and ICT applications as adopted from Buijs and Wortmann (2014); Marchet et al. (2009), (2012); Perego et al. (2011).

understand the collected data and to provide explanations for 'best practices' (Eisenhardt, 1989; Ellram, 1996). Finally, there are different empirical data collection methods in case studies that can be combined such as questionnaires, archives, interviews, and observations (Eisenhardt, 1989).

3.1. Case selection

The selection of the involved actors, i.e., the participants, was performed as follows. First, a seaport terminal operator (named here 'Seaport terminal operator') was selected due to that they operate the largest terminal in Scandinavia was selected, and that the operator is associated with problems such as poor accessibility, lack of communication among actors, and long turnaround times for trucks, as identified by other research studies such as Buijs and Wortmann (2014); Dekker et al. (2013); SteadieSeifi, Dellaert, Nuijten, Van Woensel, & Raoufi, 2014; Sternberg et al. (2014), (2012b); Woodburn (2006). Second, after discussions with the Seaport terminal operator, the road haulier (named here 'Road haulier'), and the rail operator (named here 'Rail operator') were selected on the premise that they transport ITUs to and from the seaport terminal on a daily basis. The information system supplier was selected due to their expertise in designing and developing information systems in the field of intermodal freight transportation. The participants are described in Table 3.

The columns in Table 3 describes the characteristics of the participants. The second and third columns cover the number of employees and vehicles for each participant. The fourth column identifies the information systems that the participants have implemented and are in use. None of the participants have implemented or are applying a transaction processing system (TPS) in that sense that can record changes when certain events occur and upon these changes automatically exchange the most beneficial and cost-effective information attributes to other TPSs implemented at other actors. To bridge this gap and fulfil the purpose of this case study, and to be able to answer the three RQs, the participants designed and developed TPSs for each participant that controls application programming interfaces (APIs). The APIs can enable that information from information systems implemented at one actor can be exchanged to information systems implemented at another actor, and vice versa using electronic data interchange (EDI) messages in a similar way as illustrated in Fig. 1. The fifth column indicates weekly volume of ITUs for each participant.

3.2. Data collection

The empirical studies included nine workshops that resulted in the identification of the most beneficial and cost effective information attributes as well as how and when they are required to be exchanged to improve access management for participants. All nine workshops, the participants, and the objectives of each workshop are shown in Table 4. Also, the time is shown when each workshop took place with respect to the time period of this case study. For example, M1 represents the first month, and M3 represents the third month of this study.

Furthermore, the addressed RQs for each workshop is shown in the fifth column in Table 4. As can be seen, in some workshops more than one RQ are addressed.

3.3. Data analysis

For the analysis, a 2 × 2 matrix inspired by the model of supplier relations by Kraljic (1983) is used. The dimensions of the matrix in this case are, instead of the original ones by Kraljic, taken from cost-benefit analysis adopted from Mishan and Quah (2007). The identified information attributes are partitioned into four categories, from high cost/high benefit to low cost/low benefit. Each category requires a certain information exchange strategy:

Category: Low cost – High benefit: **Data farming** strategy – Collect as much data as possible. The strategy needs to focus on efficient high-volume information exchange.

Table 3
Participants.

Participants	Number of employees	Number of vehicles	Information systems (IS)	Weekly volume (ITUs per week)
Seaport terminal operator	438	8 ITU cranes; 2 railway cranes; 40 straddle carriers	TPS: None; RTS: Navis; DSS: Navis	10,000
Road haulier	60	40 semi-trailers; 15 side lifters	TPS: None; RTS: Dynafleet, Samsung note with K2-app; DSS: K2 Fleet101	600
Rail operator	6	2 trains	TPS: None; RTS: Swedish Transport Administration; DSS: Hogia	1400
Information system supplier	5	N/A	TPS and API developer	N/A

Note: ITU = Intermodal transport unit, TPS = Transaction processing system, RTS = Real-time system, DSS = Decision support system

Table 4
Workshops.

Workshop number	Month	Participants	Workshop objectives	Addressed RQ
Workshop 1	M1	One yard planner, one dispatcher, and one planning manager (Seaport terminal operator)	Identifying the Seaport terminal operator's needs to receive the most beneficial and cost effective information attributes from the road hauliers. The workshop resulted in the three time phrases: one week before, one day before, and two hours before.	RQ2, RQ3
Workshop 2	M3	One planning manager, one yard planner, and one dispatcher (Seaport terminal operator)	Discussions of how the most beneficial and cost effective information attributes need to be received (e.g., through emails, through the information system, etc.).	RQ1
Workshop 3	M4	One planning manager, one yard planner, one rail planner, one planning manager, and one dispatcher (Seaport terminal operator)	Discussions of how the implementation of the receipt of the beneficial and cost effective information attributes can be conducted in the information system of the Seaport terminal operators and how this implementation fits with all other implementation plans of the Seaport terminal operator. Additionally, the rail planner was involved to raise the needs of beneficial and cost effective information attributes from the rail operators.	RQ1
Workshop 4	M4	One head of department (Road haulier) and one head of department (Rail operator)	Identifying the needs of Road haulier and Rail operators to receive beneficial and cost effective information attributes from Seaport terminal operator. According to them, it is of great importance for their planning to receive beneficial and cost effective information attributes from Seaport terminal operator.	RQ2
Workshop 5	M4	One planning manager, one yard planner, one rail planner (Seaport terminal operator); one head of department (Road haulier); and one head of department (Rail operator)	Connecting Seaport terminal operator with Road haulier and Rail operator. Discussing what information attributes are most beneficial and cost effective, when they need to be exchanged, and how they should be exchanged automatically. Both organisations were given homework to investigate how this technically is to be solved. Additionally, the need of an information system supplier was raised.	RQ1, RQ2, RQ3
Workshop 6	M5	One head of department (Road hauliers); one head of department (Rail operator); and one CEO and one software developer (Information system supplier)	Technically focused discussions of how the Seaport terminal operator's, the road haulier's and rail operator's information systems can become interoperable through the implementation of APIs.	RQ1
Workshop 7	M5	One planning manager, one yard planner, one rail planner (Seaport terminal operator); one head of department (Road haulier); one head of department (Rail operator); one CEO, and one developer (Information system supplier)	Follow-up discussions regarding the technical implementation to achieve the interoperability between the actors´ information systems. The information system supplier gave a demo on how this exchange could be implemented.	RQ1
Workshop 8	M5	Three software developers (Seaport terminal operator, Road haulier, and Rail operator)	Technical discussions on how to implement the APIs according to the demo shown in the previously workshop.	RQ1
Workshop 9	M8	One head of operations and one head of IT (Seaport terminal operator); one head of department (Road haulier); one head of department (Rail operator); and one CEO (Information system supplier)	Final discussions of implementation and decision-making to kick off the implementation.	RQ1, RQ2, RQ3

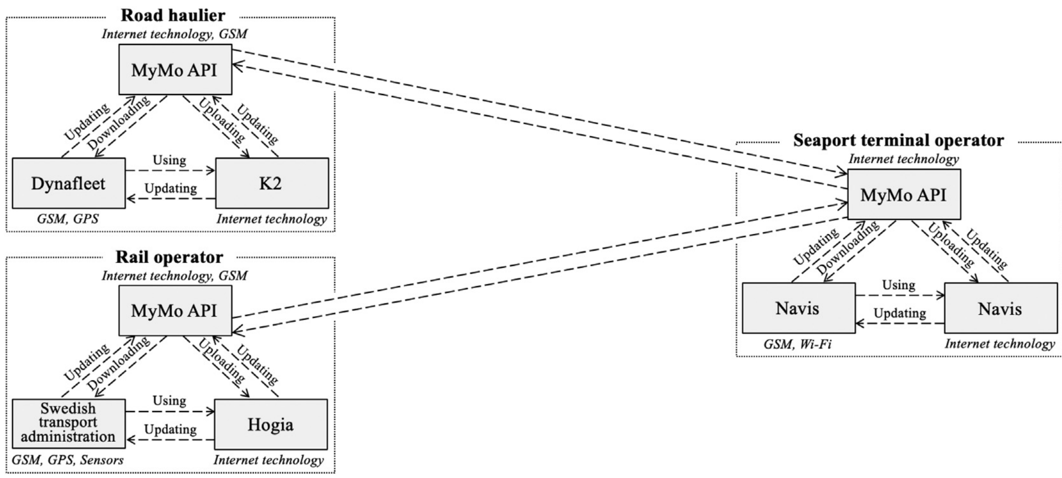

Fig. 2. The setup of the interoperable information systems of participants.

Category: High cost – High benefit: **Dedicated information exchange** strategy – Attributes that are crucial and difficult to collect. The information exchange strategy needs to be focused on getting these data as accurately and efficiently as possible, even if costs are high.

Category: Low cost – Low benefit: **Opportunistic information exchange** strategy – Collect data from this category if it can be done without negative side effects.

Category: High cost – Low benefit: **Avoid information exchange** – Information attributes in this category should not be collected.

4. Results

In the following sub-sections, the results and the answers to the three research questions are described and analysed.

4.1. Automatic information exchange between the interoperable information systems of participants

Below, the setup of the information systems of participants to achieve an automatic information exchange between the interoperable information systems of participants is described, see Fig. 2. This setup answers RQ1 (How can information attributes be automatically exchanged between the interoperable information systems of involved actors?) and is developed with respect to how information systems can become interoperable according to the section where the review of relevant literature is described and according to Fig. 1. The information systems at the road hauliers (K2) can now automatically exchange information with the information system at the Seaport terminal operator (Navis) and vice versa. In the same way, information can now be exchanged between the information system at the rail operators (Hogia) and Navis.

However, in this setup, no information exchange is possible between K2 and Hogia since there is no need of such exchange between the road hauliers and rail operators. The exchanges of information among the information systems are triggered by different EDI request messages. The requests are either triggered by changed status of information attributes or triggered on a regular basis as further described in the sections below. To be able to execute the requests upon receipt of these triggers, the API buffers the most beneficial and cost effective information attributes.

4.2. Most beneficial and cost effective information attributes for automatic information exchange

This section answers RQ2 (What information attributes are most beneficial and cost effective to be automatically exchanged between the interoperable information systems of involved actors?) and is built upon the answers of RQ1. By applying a cost-benefit analysis, the most beneficial and cost effective information attributes to be automatically exchanged between the interoperable information systems of participants can be identified.

As can be seen in Fig. 3, the information attributes listed in Table 2 are structured and sorted according to these four categories. Additionally, the categories have been filled in with different shades of grey to make it easier to see what information attributes should be automatically collected. For example, the lighter the grey colour, the better the fit, and the darker the grey, the worse the fit. Accordingly, the automatic information exchange strategy should be as follows: the information attributes that are located in the farming quadrant should be automatically collected; then, the focus should be on those in the dedicated information exchange, followed by those in the opportunistic quadrant. The attributes in the 'Avoided information exchange' quadrant should not be automatically collected.

The automatic information exchange should be conducted by analysing the different sources of information attributes using the technologies discussed previously. For example, Table 5 shows how the information attributes in the green quadrant can be collected.

4.3. Required triggers for automatic information exchange

This section answers RQ3 (When are the most beneficial and cost effective information attributes required to be most cost effectively and automatically exchanged between the interoperable information systems of involved actors?) and is built upon the answers of RQ1 and RQ2.

As previously discussed, the request messages from the most beneficial and cost effective information attributes are either triggered by changes in their status (e.g., the ITU status changes from 'not ready' to 'ready' for pick up) or by triggers that occur on a regular basis. The API solution continuously polls changes of ITU status in Navis. As soon as the ITU status changes, the K2 and Hogia systems are notified of the status change. The transport planners at the road hauliers and rail operators are then able to schedule or re-schedule certain ITUs for pick up.

The triggers are implemented in three different time phases with respect to the requirements of the participants. The three required time phases are shown in Fig. 4. By exchanging information accordingly, the Seaport terminal operator wishes to get the information from the hauliers one week before to plan the reloading from the vessel of the ITUs that the hauliers and the road hauliers are to pick up, one day before to plan the ITUs to be picked up by the hauliers the following day, and two hours before arrival of the trucks to make final adjustments and redeploy resources if necessary.

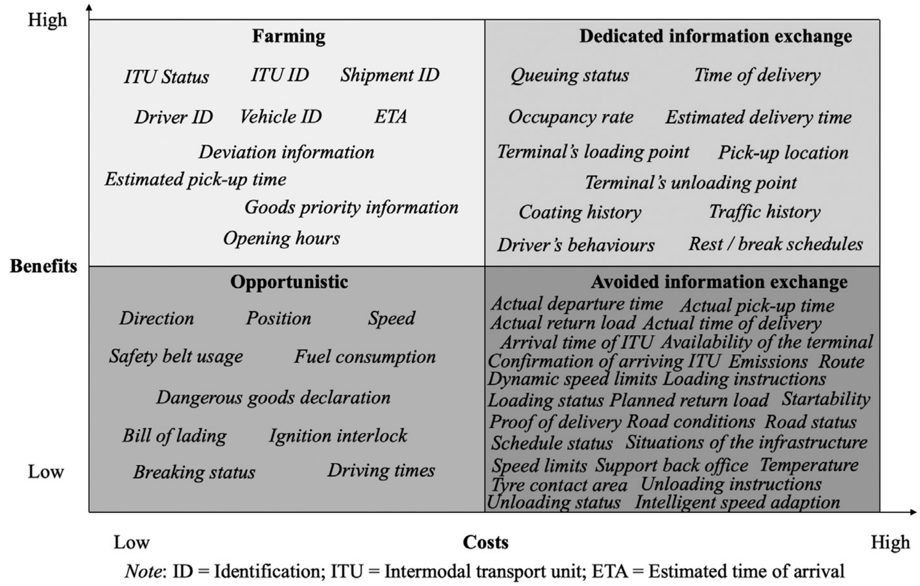

Fig. 3. Cost-benefit analysis of identified information attributes.

Figs. 5, 6, and 7 show in more detail how and what information attributes need to be exchanged at the different phases. In the first phase, the Seaport terminal operator needs to get a list of the ITU IDs that the hauliers intend to pick up the following week, as shown in Fig. 5. The list must contain the ITU IDs as well as which day each ITU is supposed to be picked up. The straddle carrier drivers are marked in grey as they will need this information when the yard planners or dispatchers involve the straddle carrier drivers in such early planning.

Fig. 6 shows how the information exchange should be handled one day before of the arrival of the trucks. What differs from the previous phase, i.e., one week before, is that the hauliers send a list the day before with the ITU IDs and corresponding time slots, on an hourly basis, of what they plan to pick up the following day. As in the last phase, the straddle carrier drivers are marked in grey since they will not be directly involved in the information exchange.

Finally, Fig. 7 shows how the information exchange should be handled two hours before of the trucks' arrival at the terminal. This information exchange is important to be able to follow up and to recognize any changes from the plans made in the two previous phases and thus be able to act based on that information by possibly redistributing resources in the terminal. As illustrated in Fig. 7, the transport planners and drivers are not only able to update the information with ITU ID and ETA, but also to receive an estimated queue time in the marshalling area.

5. Discussion

To fulfil the purpose of this study, which is to explore how and when the most beneficial and cost effective information attributes can be automatically exchanged between interoperable information systems of a seaport terminal operator, a road haulier, and a rail operator to potentially improve their access management, three research questions are answered, and two propositions are drawn from the results. The research questions are answered in the results section, and the motivation and formulation of the two propositions are described below. The two propositions and the results from this case study are only based upon one case and cannot be transferred to other terminals that do not have the same characteristics as the terminal under study in this case.

There are many information sources on intermodal freight transportation that can be used to collect information attributes (Jacobsson et al., 2017; PBS, 2015; Sternberg, 2008; Trafikanalys, 2014). By collecting, analysing, and visualizing a large amount of information, advantages such as improved decision-making and prediction of the future can be gained (Chen & Zhang, 2014). To gain such advantage, a number of resources are required such as skilled analytics, powerful computers, and a large bandwidth (Chen et al., 2012). However, these resources are often lacking at small organisations (Coleman et al., 2016), whereas over 80% of road hauliers in the EU and the US are small organisations (Sternberg et al., 2013). Therefore, for these small organisations, the exchange of beneficial and cost effective information is more important than the exchange of a large amount of information. Additionally, prior research has indicated that the exchange of beneficial and cost effective information attributes, and not the exchange of all available information attributes, can improve access management for actors in intermodal freight transportation (Jacobsson, 2019; Jacobsson et al., 2017). Hence, the first proposition is stated as:

Table 5
Technologies and sources for collecting the most beneficial and cost-effective information attributes.

Information attribute	Technology	Source of information
Deviation information	Navis; FMS (e.g., CIS Spedition, Hogia, K2)	Transport planners, truck drivers (CIS Spedition, 2019; Hogia, 2019; K2, 2019; Navis, 2019)
Direction	GPS; FMS (e.g., Dynafleet, K2)	(Dynafleet, 2019; K2, 2019)
Driver ID	N/A	Truck drivers
ETA	FMS (e.g., Dynafleet)	Truck drivers, (Dynafleet, 2019)
Goods priority information	FMS (e.g., CIS Spedition, Hogia, K2)	Transport planners, truck drivers (CIS Spedition, 2019;Hogia, 2019; K2, 2019)
ITU ID	Navis; FMS (e.g., CIS Spedition, Hogia, K2)	Transport planners, truck drivers (CIS Spedition, 2019; Hogia, 2019; K2, 2019; Navis, 2019)
ITU Status	Navis	(Navis, 2019)
Opening hours	Web page service	Terminal's home page
Shipment ID	Navis; FMS (e.g., CIS Spedition, Hogia, K2)	Truck drivers, transport planners (CIS Spedition, 2019; Hogia, 2019; K2, 2019; Navis, 2019)
Vehicle ID	FMS (e.g., Hogia, K2)	Truck drivers (Hogia, 2019; K2, 2019)

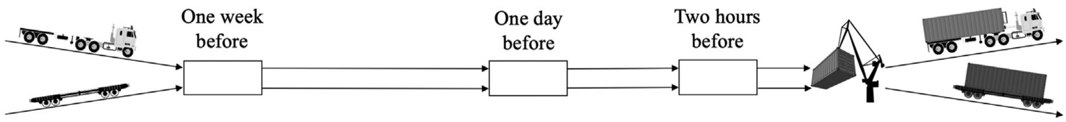

Fig. 4. Three phases of information exchange.

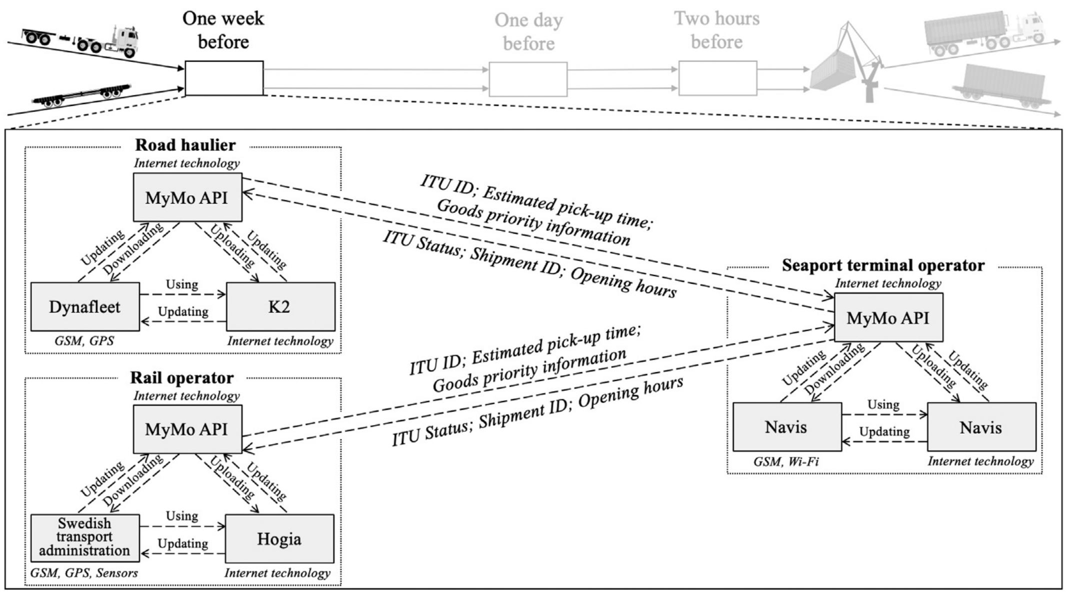

Fig. 5. Information exchange one week before.

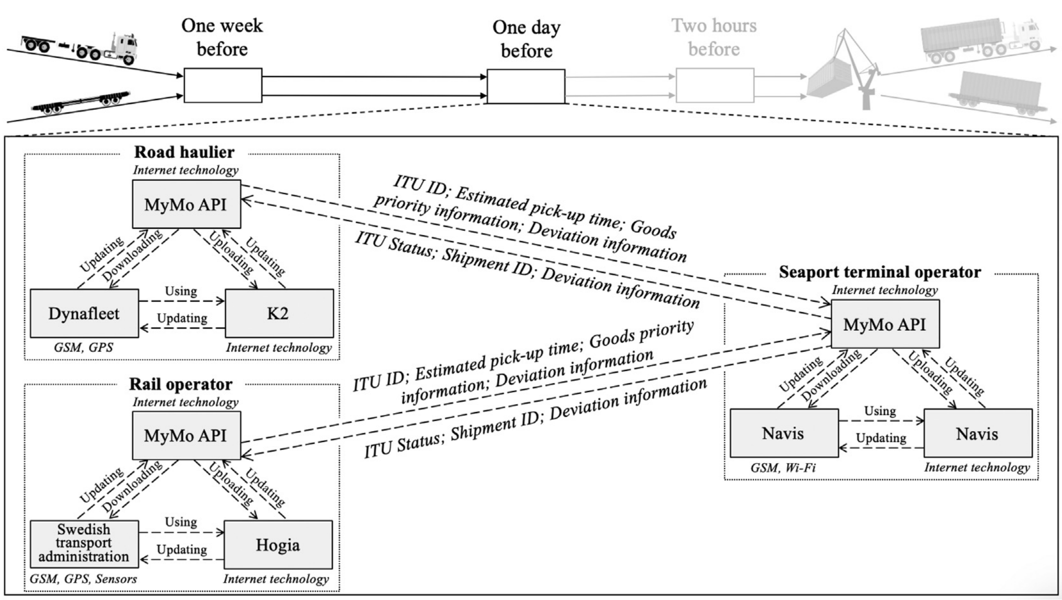

Fig. 6. Information exchange one day before.

Proposition 1. Only the most beneficial and cost effective information attributes (and not all available information attributes) are necessary to be exchanged automatically between the interoperable information systems of involved actors to improve their access service elements.

By exchanging the most beneficial and cost effective information attributes according to the three required time phases (one week before, one day before, and two hours before), there is a potential to improve the access service elements (turnaround time, access reliability, access precision, and access flexibility) and in turn improve access management for involved hauliers and the Seaport terminal operator. Prior research has indicated similar results where there is a potential to affect the access service elements positively when using different access management services (Jacobsson et al., 2018). For example, by using real-time information exchange platform services, the turnaround time for trucks in terminals can be decreased (Carlan et al., 2016), and access reliability, access precision, and access flexibility can be increased. Thus, the second proposition is formulated as:

Proposition 2. Access service elements are improved when the most beneficial and cost effective information attributes are exchanged automatically (one week before, one day before, two hours before,

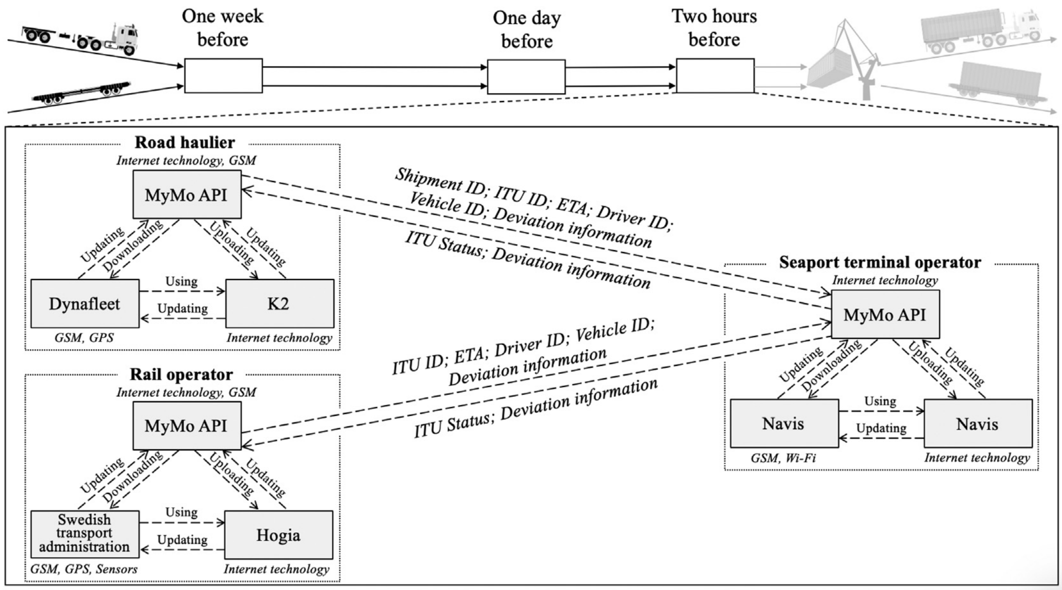

Fig. 7. Information exchange two hours before.

and by status changes of the information attributes) between involved actors´ interoperable information systems.

6. Conclusions

The main finding of this case study is that the access management of the participants, i.e. one seaport terminal operator, one road haulier, and one rail operator, can be improved when they exchange the most beneficial and cost effective information attributes. These attributes are identified through a cost-benefit analysis of collected empirical data to be *deviation information, direction, driver ID, estimated time of arrival, goods priority information, intermodal transport unit (ITU) ID, ITU status, opening hours, shipment ID,* and *vehicle ID*. These attributes are required to be exchanged according to three identified time phases: one week before, one day before, and two hours before the ITUs are to be picked up at the terminal. To automatically exchange these information attributes according to the three time phases, an interoperable information systems setup is developed. The setup uses APIs to connect the information systems of the participants with one another. From these findings and in relation to prior research results, two propositions are formulated.

This study contributes with new knowledge regarding intermodal freight transportation and information systems as it explores how and when the most beneficial and cost effective information attributes need to be exchanged automatically between participants´ interoperable information systems to improve the access service elements. For example, by exchanging these attributes in an automatic manner, there is a potential for reducing turnaround times for trucks and increasing access reliability, access precision, and access flexibility for the participants. Additionally, contributions for management include new knowledge for decision makers about what information needs to be considered and what technologies are available for performing automatic information exchange.

This study also contributes new theoretical knowledge by developing a cost-benefit analysis model to identify and structure required information attributes into different categories, from low cost/low benefit to high cost/high benefit. The model involves four strategies—data farming, dedicated information exchange, opportunistic information exchange, and avoiding information exchange—that are important in determining when to collect data automatically to facilitate real-time decision-making and in turn potentially improve resource efficiency in the interface between terminals and land-based transportation. Additionally, the developed cost-benefit analysis model can be used to classify data sources to ensure that sufficient resources are deployed for automatic information exchange and that unnecessary collection is avoided. As a change management tool, the model can also be used to identify and support transformation of attributes from one category to another, especially from high cost to low cost and from low benefit to high benefit, as data processing tools and techniques evolve over time.

A major limitation in this case study is that only one seaport terminal has been studied. Therefore, further research is needed to investigate how the developed cost-benefit analysis model may be further developed and adjusted to also cover the differences in geographical coverage, volume, and capacity of other seaports and other intermodal freight terminal types, such as other railroad terminals, inland waterway terminals, and airports. And, due to the differences of these terminals, other information attributes, compared to the ones identified in this case study, may also be identified as ‘low-cost/high-benefits’. To further generalise the findings, the two formulated propositions should be transferred into hypothesis to be statistically tested. Furthermore, the cost-benefit analysis model should also be developed to include sea transportation. Another limitation is that this study only mentioned some of the available technologies for collecting data automatically. Therefore, future research should investigate other potential methods to incorporate new technologies for automatic information gathering. Additionally, little research has been conducted when it comes to how empirical information exchange of real-life measurements in terminals can be performed automatically. Therefore, further investigation needs to be conducted to gain better knowledge and understanding about automatic data exchange in real-life scenarios. Finally, policy makers should also be included in future research since the research presented in the paper is primarily aimed at decision makers in industry, not policy makers.

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