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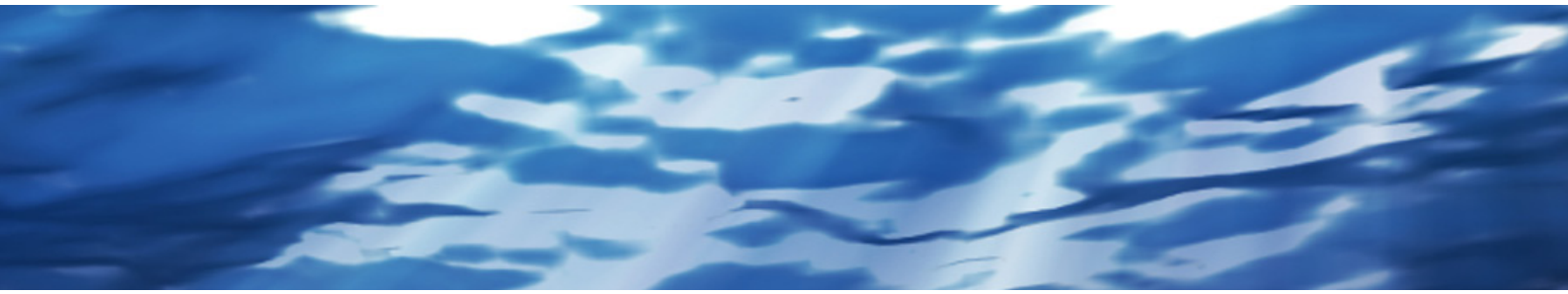

LIGHTHOUSE REPORTS

Digitalisation and automation in small and medium sized Swedish ports (SMPs)

En förstudie utförd inom Trafikverkets branschprogram Hållbar sjöfart som drivs av Lighthouse

TRAFIKVERKET

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HÅLLBAR SJÖFART

Digitalisation and automation in small and medium sized Swedish ports (SMPs)

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I samarbete med
Hallands Hamnar
Kvarken Ports (Umeå)
Karlskrona Hamn
Karlshamns Hamn
Landskrona Hamn

Detta projekt har genomförts inom Trafikverkets branschprogram Hållbar sjöfart, som drivs av Lighthouse.

Summary

Large pressure is now put upon Swedish small and medium sized ports (SMPs) due to an increased demand of goods expected to be transported, a strong desire to make a modal shift from road to sea, and also the introduction of new regulations on reporting formalities. This also means that the same requirements on supply visibility are now put upon each means of transport from the transport buyers' point of view.

In the transport chain, ports provide the important link between land-based and sea-based transports. This also concerns small and medium sized ports (SMPs), being an important part of the infrastructure catering for the distribution of people and goods within national and international transportation processes. Most often SMPs have a role in feeding goods to larger transportation hubs, and they offer a gateway towards sustainable transport modes.

The ongoing process of digitalisation and automation is something that SMPs cannot ignore. As SMPs often rely on scarce personnel resources, there is a need to seek opportunities, why it is of great importance to find ways to share knowledge and possibly co-utilize diverse solutions.

This report concludes the conducted pre-study seeking challenges and opportunities related to digitalisation and automation that are acknowledged by the ports of HallandsHamnar (Varberg and Halmstad ports), Karlshamn, Karlskrona, Kvarken Ports (Umeå), and Landskrona. The pre-study has resulted in identification of areas of collaboration regarding digitalisation, automation, and electrification in a larger innovation project gathering SMPs in Sweden.

Sammanfattning

Det finns höga förväntningar på att svenska små och medelstora hamnar (SMP) ska utvecklas och bli en integrerad del i ett hållbart transportsystem. Det baserar sig bland annat på den ständigt ökande efterfrågan på varor som förväntas transporteras, en uttalad ambition att flytta över allt fler transporter från land till sjö, samt införandet av nya lagkrav avseende rapportering. Transportköparna ställer också allt högre krav avseende transparens genom samtliga steg i förädlingskedjan, där hamnarna är en viktig nod.

I transportkedjan utgör hamnarna den viktiga länken mellan landbaserade och sjöbaserade transporter. Detta gäller även svenska små och medelstora hamnar (SMP) som är en viktig del av infrastrukturen för förflyttning av människor och varor i den nationella distributionen, och många gånger med en koppling till internationella transportkorridorer. Små och medelstora hamnar har även en viktig roll när det gäller att förse större transportnoder med gods, och de utgör därför en viktig länk till hållbara transporter för gods och resenärer.

Den pågående trenden med digitalisering och automatisering som nu starkt påverkar världens hamnar är något som SMP inte kan ignorera. Eftersom SMP ofta förlitar sig på knappa personalresurser finns det ett behov av att söka möjligheter att dela kunskap och eventuellt samutnyttja olika lösningar. Denna rapport sammanfattar den genomförda förstudien om utmaningar och möjligheter relaterade till digitalisering och automatisering som identifierats av hamnarna i HallandsHamnar (Varberg och Halmstad hamnar), Karlshamn, Karlskrona, Kvarken (Umeå) och Landskrona. Förstudien har resulterat i identifierade områden att samarbeta kring inom digitalisering, automatisering och elektrifiering i ett större innovationsprojekt som samlar svenska små och medelstora hamnar.

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1 Background

Small and medium sized ports (SMPs) constitute an important part of the infrastructure catering for the distribution of people and goods within national and international transportation processes. Most often SMPs have a role in feeding goods to larger transportation hubs and they offer a gateway towards a sustainable transport mode.

On the national and international arena, a lot of efforts are now being brought into making the port becoming integrated in the transportation system, by connecting what happens at sea with what happens at shore, contributing to efficiency and sustainability in transhipments and inter-modal shifts. This has driven the need for ports to upgrade its capabilities in connectivity and automation. The business landscape of port operations is also highly characterised by competition.

Large ports most often have substantial resources to respond to the contemporary developments while SMPs are building its capabilities on scarce resources to contribute to this development. Most often multiple responsibilities are built into the same human resource at the same time, as it is expected that SMPs follow the same developments as the larger players do. A natural way forward is therefore to gather SMPs for joint learning on digitalisation and automation.

The ongoing process of digitalisation has caused a lot of efforts to be pursued by the different players engaged in the maritime transports due to a lot of pressure on regulations, forcing each of the actors to upgrade its capabilities within digitalisation and automation. In other words, there is both regulative pressure as well as business pressure being put upon the ports of the world. This increases the need for knowledge sharing and possible co-utilisations of diverse solutions.

This pre-study, conducted during 2019 within the framework of Sustainable Shipping, the Swedish Transport Administration's industry programme run by Lighthouse, is looking into the challenges and opportunities related to digitalisation and automation associated to SMPs. In this pre-study HallandsHamnar (Varberg and Halmstad ports), Port of Karlshamn, Port of Karlskrona, Kvarken ports (Umeå), and Port of Landskrona have participated.

The conduction of this pre-study has also provided the basis for the establishment of a three-year innovation project within the same industry programme. RISE, University of Gothenburg, and Chalmers University of Technology will, as independent and neutral actors, orchestrate this effort. Building upon the participants in the pre-study, the innovation project captures a larger cluster of SMPs in Sweden to join forces regarding digitalisation, automation, and electrification.

1.1 Procedure, Participants and Data Collection Method

1.1.1 Procedure

The pre-study was conducted over 10 months, from March to December 2019. The first activity was to prepare basis for interviews and defining the scope of the study. During the following month, interviews were conducted with representatives from participating ports. During summer the interviews were analysed and use cases derived. After summer the ports were gathered for a two-day workshop hosted by Port of Varberg. During the workshop the identified use cases were described, discussed and prioritized to qualify as innovation themes in the upcoming innovation project.

1.1.2 Swedish transport infrastructure and selection of ports

Port infrastructure is a crucial factor in the development of the Swedish economy. According to the Ports of Sweden (2019), almost 90 % of Sweden's global trade is transported by maritime carriers. Specifically, the most important trading regions on other continents are the US for exports and China for imports while, the most significant regional trading partner is the European Union (Bergqvist and Cullinane, 2017). In terms of cargo, nearly 50% of Swedish maritime traffic is bulk cargo, followed by ro-ro traffic, with containers constituting only 7% of the total amount goods transported.

In terms of the governance system in Sweden, almost 70% of the 52 seaports are owned by municipal councils, called Integrated Port Companies[1], and have a public operational and ownership system (ISL, 2006). From a customer's point of view, this system offers some advantages allowing them to negotiate with one single organisation.

In fact, the municipal port administration system has a propensity for keeping these ports in operation as they are considered a source of local revenue (OECD, 2016). Consequently, there is intense competition among ports whose hinterlands overlap (ISL, 2006). In an intense political context, there are only three container terminals (Gävle, Gothenburg and Stockholm) that have been privatised (by concession agreements) in Sweden (Bergqvist & Cullinane, 2017).

Additionally, of the municipal port authorities, the Swedish port system is based on two main entities. On the one hand, the employers' association, Ports of

[1] Regional infrastructure connections of road and railway are financed by national government (ISL, 2006).

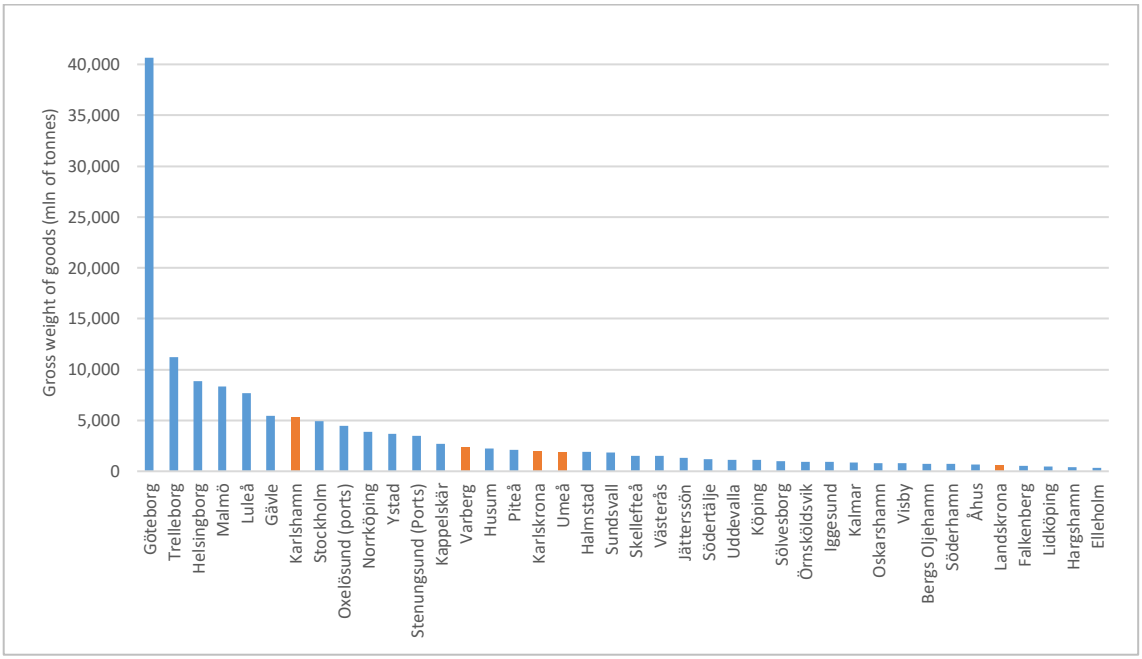
Sweden (Sveriges Hamnar - Transportföretagen[2]), includes 60 ports, with a membership of almost 4 000 employees (Bergqvist & Cullinane, 2017). On the other hand, the Swedish Maritime Administration (SMA) is a public entity that implements national transport policies and is responsible for maintaining maritime access outside the port area, for which it collects fairway dues[3] (ISL, 2006).

For long, the transport system in Sweden was based on an extensive intermodal transport network with road-rail transhipment terminals in some 30 cities, and the Swedish State Railways operated trains between most terminals wholesaling the service to forwarders and road hauliers. However, after first unbundling and partly privatising into Rail Combi in 1992, then merging with the Norwegian state-owned freight railways forming CargoNet in 2002, the Swedish State subsequently sold its shares in CargoNet in 2010. CargoNet, which built up the backbone of the Swedish intermodal road-rail network ceased to operate in 2012 causing a turmoil in the domestic transport market as analysed by Flodén and Woxenius (2017). In addition to the domestic road-rail intermodal network, a system of dry port shuttles connecting the seaports to the hinterland area has emerged, predominantly serving Port of Gothenburg (Bergqvist and Woxenius, 2011). Based on Almotairi et al. (2011), the information systems supporting the flow of containers is comparatively rudimentary.

This study has selected five SMPs to identify opportunities and barriers to digitalisation and automation of the sustainable port as a basis for establishing research, development, and demonstration initiatives in Sweden. Electrification was also added, since this was of great importance to the ports.

Figure 1 shows the 40 largest representative ports in Sweden. As the figure demonstrates, the Port of Gothenburg handled almost 42 million tons of cargo in 2018, followed by the Port of Trelleborg with almost 12 million tons, and the Port of Helsingborg with around nine million tons. In orange are marked the ports selected for this study, which are representative of SMPs in the total sample.

[2] The Swedish Confederation of Transport Enterprises is an organization for firms in the transport sector in Sweden. This confederation is focuses on consultation in labour law area (Transportföretagen, 2019)
[3] Fairway dues are based on the vessel's gross tonnage and they are differentiated according to the type of vessels and their air emissions (ISL, 2006)



Source: Own elaboration based on the data from European Commission (2019)

Figure 1. The 40 largest ports in Sweden in 2018

1.1.3 Selection of ports in the pre-study

The ports involved in the pre-study are characterised in the next section and their geographical location is visualised in figure 2 below. The selected ports are qualified as SMPs and were considered suitable for the study because of their distribution regarding geographical location and type of goods.

Figure 2. Location of the seaports selected for our analysis

1.1.4 Port description

This section aims to determinate the main characteristics of the five ports selected for this study based on general aspects, environmental features, hinterland (the land area within the coast) which is the inland market area a port serves, characteristics and future challenges.

1.1.1.1 Karlshamns Hamn

a.) General characteristics

This port is located on the south-eastern coast of Sweden in the municipality of Karlshamn, with approximately 32 000 inhabitants in 2018 (Karlshamn municipality, 2019). The area of the port is 75 ha with a total of 3 kilometres of quay berthing, around 45 000 m2 of warehouse storage for dry goods, and 500.000-m3 storage capacity for liquid bulk. As a result, this seaport is able to

handle all types of cargo, mainly energy products, dry cargo as forestry products, and ferries (Port of Karlshamn, 2019). Furthermore, in terms of passengers, the Port of Karlshamn has ferry liner connections to surrounding areas like Russia, Lithuania, and Germany. From a regional perspective, the port offers logistics services to its customers through its logistical location.

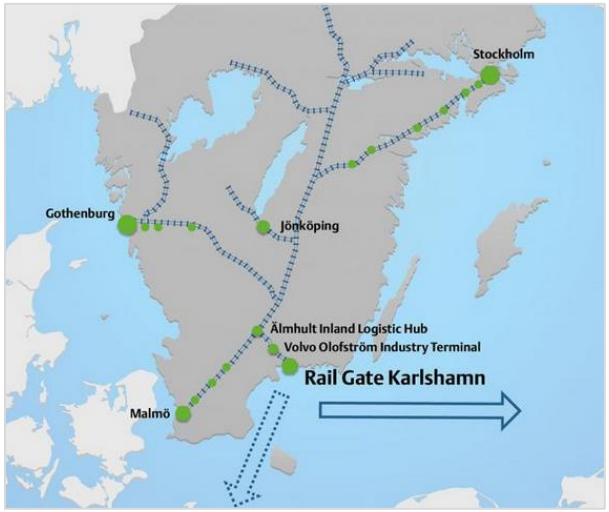
b.) Environmental aspects

As part of its logistics plan, the port has applied environmental programmes like treatment of sludge (i.e. controlling oil spills from vessels' engine rooms). According to the port website, its location far from the city helps to minimise negative environmental effects on residential areas. In the port area, the seaport has an efficient system for reception and treatment of sludge from vessels' engine rooms. Finally, the port maintains a power supply for vessels (Port of Karlshamn, 2019).

c.) Hinterland area

The port has developed a logistical capacity to provide competitive logistics services as well as to become an efficient intermodal node for the region. In this regard, the port is well connected to the region by rail and road.

Regarding railways, the port area has track connections that facilitate the movement of cargo between the seaside, quays and warehouses. Specifically, the Port of Karlshamn has two rail terminals. Furthermore, the port is two kilometres from the electrified railway system that moves cargo from and to the hinterland. Figure 3 shows the railway network in the Port of Karlshamn.



Source: Port of Karlshamn (2019)

Figure 3. Railway network on the Port of Karlshamn

Finally, in the case of road transportation, ro-ro traffic can easily reach the main motorways. The port is two kilometres from the E22 highway to Malmö and the R29 highway to Växjö (Port of Karlshamn, 2019).

d.) Future challenges

The port will be part of a development plan to increase the port area with over 100 ha during the next few years. Thus, the municipality that manages this port authority expects to increase port traffic and logistics services.

1.1.1.2 Karlskrona Hamn

a.) General characteristics

This port aims to connect Sweden to eastern European regions with routes to Poland, Russia and, indirectly, also to Asia. Karlskrona is an industrial port at Verkö with more than 100 000 m2 of goods storage.

Furthermore, the Stena Line operates in the Port of Karlskrona as a hub for its ferry traffic and applies environmental initiatives on reloading and storing goods.

b.) Environmental aspects

This port has terminal facilities to connect vessels to onshore power and reduce air emissions at the berth.

c.) Hinterland area

The port area has railway facilities that permit the handling of goods in trains of up to 600 m in length. Since 2014, the intermodal terminal offers efficient transhipments between vessels, rails, and roads with its electrified railway. Nevertheless, the rail connection has not yet found a wide commercial use.

In the case of roads, the port has good access roads to the E22 highway.

Furthermore, the Port of Karlskrona is part of the Trans-European Transport Network (TEN-T) which connects all European regions by an efficient transport network. Thus, Karlskrona is part of the transport corridor, Baltic Link (Port of Karlskrona, 2019).

d.) Future challenges

The port and logistics areas aim to expand and establish new logistics companies.

1.1.4.1 Landskrona Hamn

a.) General characteristics

This port on the southwest coast of Sweden is mainly focused on bulk products. Specifically, according to the Port of Landskrona (2019), this seaport provides cargo and storage services to its clients.

With a geostrategic historical background, this seaport helped to develop the production of mineral fertilisers in the area. The manufacturing of fertilisers has

decreased since the beginning of the nineties; therefore, the port has diversified its traffic and increased its facilities.

b.) Environmental aspects

According to the Port of Landskrona (2019), the port aims to reduce environmental impacts in the port area. Thus, the port strategy is based on educational programmes for employees, environmentally friendly business practices, technological developments, and environmental legislation requirements.

c.) Hinterland area

There are connections to/from the port to the hinterland via road and rail. There are big dry ports (logistic areas) located near Landskrona.

d.) Future challenges

Keep up and develop the quality of port operations. Find possible future ways to allow co-existence with the expanding city.

1.1.4.4 Umeå Hamn (Kvarken ports)

a.) General characteristics

The Port of Umeå is located in the north of Sweden close to Finland and has an annual cargo handling rate of around 2.3 million tonnes consisting mainly of forest industry products.

Since 2014 Umeå Hamn AB has been a subsidiary of INAB (Infrastruktur i Umeå AB) and the organisation Kvarkenhamnar AB (Kvarken Ports), that operates both Umeå and Vasa ports (the Port of Umeå, 2019)

b.) Environmental aspects

According to the Harbour Master, they are working on a new environmental strategy and also with applications for environmental permits for the necessary construction work, due to the ongoing work of the re-building of older parts of the port and the construction of the new parts of the port. The new environmental strategy is expected to be finalised during 2020.

c.) Hinterland area

In the case of railway, the Port of Umeå has a total of 12 500 m of rail tracks, of which 4 500 m are electrified. Since 2013, the Port of Umeå has had a direct connection with Holmsund and the Botniabanan in Gimonäs (the Port of Umeå, 2019).

From 2015 to 2017 the Port of Umeå expanded its storage area to handle container cargo (the Port of Umeå, 2019).

d.) Future challenges

The Port of Umeå is about to undergo major construction works in the near future as they are going to re-build the port for about 1.7 billion SEK. The energy berth will be moved, a new berth be built, and adjustments will be made such as reinforcements on existing berths and enlarging the Southern berth.

Due to the newbuilding of a Ro-Pax ferry, Wasaline, which is planned to begin its operations in April 2021 and replace the existing ferry, the port needs to adjust the ferry terminal and the berth to the new ferry. The new ferry aims to operate with hydroelectric propulsion (the Port of Umeå, 2019).

1.1.1.5 Varberg Hamn (HallandsHamnar AB)

a.) General characteristics

Since 2003, the port companies of Varberg and Halmstad have run HallandsHamnar (Port of Halland) together. This port has diversified traffic with liquid bulk, containers, cars, and mainly forest products (Port of Halland, 2019).

b.) Environmental aspects

According to the Port of Halland (2019), the port is focused on increasing its sustainable development and reducing the company's environmental impact on air, water, and land.

c.) Hinterland area

The location of the port on the Swedish west coast allows it to become an important logistics hub for the region. In terms of road transport, the port is close to the European highway (E6) and several national roads, while in terms of railway connections, the port has daily departures to the Småland region, Mälardalen, and Norrland (Port of Halland, 2019).

d.) Future challenges

In the upcoming 5 years, a large-scale urban development is taking place in the City of Varberg. The port will be affected due to the fact that parts of the land in where the port area is situated today, will become a new city district with residential and service facilities. Therefore, parts of the port will be moved to a new location (Farehamnen) and some of the existing parts will be rebuilt. The process to rebuild and phasing out operations is of course challenging, but at the same time an opportunity to build for future demands and adopt new technologies and innovations.

1.1.5 Summary table

In the table below the involved ports' figures regarding goods, liquid bulk-oil, TEUs and Passengers, for 2017 and 2018 are visualised.

Table 1: Summary table

		Goods (thousand tons)		**Liquid bulk – oil (thousand tons)**		**TEU**		**Passengers**	
Port	**Region**	**2017**	**2018**	**2017**	**2018**	**2017**	**2018**	**2017**	**2018**
Karlshamns Hamn	Blekinge	4497	5268	1148	1142	9801	9702	151786	169880
Karlskrona Hamn	Blekinge	1986	1965	-	-		81673	654582	683230
Landskrona Hamn	Skåne	556	548	-	-	-	-	316157	357192
Kvarken Ports, Umeå	Västerbotten	1957	1907	312	344	29334	27054	199641	212111
Hallands Hamnar, Varberg	Halland	3989	4228	452	423	71753	57845	155278	159914

Source: Own elaboration based on Port Authorities websites and Sveriges Hamnar

2 Trends in port developments – a global overview

To determine current trends in the use of technology by ports, this section includes a review of different port initiatives worldwide.

During recent years, port infrastructure has become fundamental as competitive advantage. Consequently, any unexpected situation illustrates just how sensitive ports are to external actions, such as seasonal-demand fluctuations, changes in regulations (Galvao et al., 2016; Taylor, 2017) and innovations. Port authorities have to guarantee their hinterland connectivity in order to enhance their traffic and their competitive position (Zhang, 2008; UNECE, 2010; Bergqvist, 2015). Thus, real-time information systems via digital technologies have transformed the ways cargo moves, and, consequently, transport actors have initiated the development of various programmes to improve their performance.

Based on different cases around the world, port information systems are implemented across vessels, trucks, and terminals (for instance, the e-maritime initiative, the e-seal system to reduce documentation, or the gate terminal automation system).

Considering port-initiated incentives for using technologies (electronic devices and computing platforms), it seems that, at the present time, digitalisation is more common and basically relevant for the trucking industry. However, it seems that there is a tendency for new technology to focus on automation and electrification to increase the efficiency of container transport and reduce operating time. Table 2 summarises a total of 58 initiatives worldwide.

Port Authority	Name of the programme	Initiative	Mode of transport	Implementation	Brief description	Reference
Amsterdam	*Intermodal Planner*	Digitalisation	Vessel, truck and rail	2015	Digital platform between transport operators and container terminals.	PA Website
	Walstroom	Electrification	Vessel	2008	Facilitate the processes of shore electric power.	Bestfact case
Antwerp	*Central Booking Platform*	Digitalisation	Vessel, truck and rail	2016	Booking system for transport customers.	Bestfact case
	Intermodal Solution and Connectivity Platform	Digitalisation	Vessel, truck and rail	n.a.	Connectivity platform that provides information about intermodal alternatives	OECD Round Table Report
Auckland	*Vehicle Booking System*	Digitalisation	Truck	2007	Trucks book slots in advance for picking up and dropping off containers. Encouraging off-peak truck travel and improving travel predictability	PA Website and Private Firm Website
	Best Available Unit	Digitalisation	Truck	n.a.	Cooperation between different agents to reduce unnecessary travels in and out the port (only 20%-30% of the trucks visiting the port are carrying full loads)	PA Website
Barcelona	*EcoCalculator*	Digitalisation	Vessel, truck and rail	2012	Website for calculating the CO2 emissions associated with a particular intermodal transport route	PA Website
Botany	*Terminal Appointment system*	Digitalisation	Truck	2011	Digital platform for appointment between truck drivers and terminal operator.	Motono, et al., IAME 2017
	RFID	Digitalisation	Truck	2011	The cost of monitoring was recouped by a newly introduced port wharfage of AUS$10 per TEU for both import and export containers	Motono, et al., IAME 2017
	Trailer parking slot	Digitalisation	Truck	2011	Trailer parking slot in order to prevent early or late arrivals at the gate	Motono, et al., IAME 2017
Brisbane	*Vehicle Booking System*	Digitalisation	Truck	2007	Appointment system used by truck drivers (to deliver/collect containers) Encouraging off-peak truck travel and improving travel predictability.	Private Firm Website
Busan	*Gate Automation System*	Automation	Truck	n.a.	An automatic gateway management system for entrance/exit the terminal.	OECD Report

Drechtstede n	*Walstroom*	Electrification	Vessel	2008	Facilitate the processes of shore electric power, increasing its usage rate instead of diesel generators.	Bestfact case
Felixstowe	*Vehicle Booking System*	Digitalisation	Truck	2007	Appointment system used by truck drivers (to deliver/collect containers) Encouraging off-peak truck travel and improving travel predictability.	PA Website
	RHIDES	Digitalisation	Truck	2004	An identity card for haulers at the port entrance.	PA Website
	PARIS-HPH	Digitalisation	Vessel, truck and rail	2013	A digital transport plan to reduce the number of empty containers being transported.	PA Website
	Terminal Appointment system	Digitalisation	Truck	2007	Digital platform for appointment between truck drivers and terminal operator.	Motono, et al., IAME 2017
Freemantle	*Vehicle Booking System*	Digitalisation	Truck	2007	Appointment system used by truck drivers (to deliver/collect containers) Encouraging off-peak truck travel and improving travel predictability.	Private Firm Website
Genoa	*Port Single window*	Digitalisation	Vessel, truck and rail	2010	Digital platform to facilitate electronic documentation	PA Report
Guangzhou	*Green truck project*	Innovation	Truck	2010	Skirts (panels between rear wheels) reduce the amount of wind underneath the trailer and can improve fuel economy by up to 5 %.	World Bank Report
Haifa	*New cargo gateway*	Automation	Truck	2016	A truck passing system by automatic sensors on the terminal area	PA Website
Hakata	*Hakata Port Logistics IT system*	Digitalisation	Truck	2000	Digital registration for all trucks and their containers in the HiTS	Motono, et al., IAME 2017
Hamburg	*Smart Port Logistics*	Digitalisation	Truck	2011	Logistics IT solutions for traffic management system	Bestfact case
	EVE program	Digitalisation	Truck	n.a.	Digital data analysis to determine the traffic situation for road traffic in the port	PA Website
	Parking Space Management	Digitalisation	Truck	2015	The mobile app of smartPORT logistics will inform truck drivers about capacities on the individual car parks and allow them to "book" parking bays.	PA Website
	Port Road Management Centre	Digitalisation	Truck	2011	Port Road management system to make the existing road network more efficient traffic flows.	PA Website
	The Intelligent Railway Point	Digitalisation	Rail	pilot project (since 2015)	The Port Railway's network equipped with multi-sensor technology.	PA Website

	The mobile all-purpose sensor	Digitalisation	Truck	n.a.	The sensor transmits its position and ID to a central system that collects this information.	PA Website
	Smart Road	Digitalisation	Truck	pilot project (since 2014)	Implement information technology systems in monitoring a road section in the Port.	PA Website
	Lärmtelefon	Digitalisation	Truck	2014	Telephone connection between the staff of the terminal operator and the residents.	IAPH case
Kaohsiung	*Automatic Gate System*	Automation	Truck	n.a.	An automatic gateway management system for entrance/exit the terminal.	PA Website
	License plate recognition System	Digitalisation	Truck	n.a.	A vehicle license plate recognition system	PA Website
Los Angeles and Long Beach	*CAAP - Clean Truck Fee*	Digitalisation	Truck	2009	Truck registration using data from electric gate access.	Program Website
	CAAP - Air quality monitoring	Digitalisation	n.a.	2008	Data collection regarding to air and weather in the harbour area	Program Website
	Zero Emission Technology	Electrification	Truck	2006	The Port is testing electric plug-in yard tractors. Electric heavy-duty on-road trucks and battery-electric heavy-duty trucks.	PA Website
	AB 2650	Digitalisation	Truck	2003	Digital gate system to control truck idling times at terminal gates.	OECD Round Table Report
Melbourne	*Vehicle Booking System*	Digitalisation	Truck	2007	Appointment system used by truck drivers (to deliver/collect containers) Encouraging off-peak truck travel and improving travel predictability.	Private Firm Website
Miami	*Electronic security gates*	Digitalisation	Truck	n.a.	Digital gate system to reduce truck idling times	PA Website
Montreal	*new track entry portal*	Digitalisation	Truck	2011	New digital truck entry portal to reduce transaction times by 80% and waiting times by 50%.	PA Website
Nagoya	*Nagoya United Terminal System (NUTS)*	Digitalisation	Truck	2005	Digital gate system to reduce service time	Motono, et al., IAME 2017
	Screening center system	Digitalisation	Truck	2011	Digital tool to control containers and truck documentation.	Motono, et al., IAME 2017
Napier	*Vehicle Booking System*	Digitalisation	Truck	2007	Appointment system used by truck drivers (to deliver/collect containers) Encouraging off-peak truck travel and improving travel predictability.	PA Website

Oakland	*CTMP- Clean Trucks*	Digitalisation	Truck	2010	Digital truck registration to control engine conditions.	PA Website
	AB 2650	Digitalisation	Truck	2003	Digital gate system to control truck idling times at terminal gates.	OECD Round Table Report
Port Metro Vancouver	*Traffic Management Centre*	Digitalisation	Truck	2013	Real time monitoring of traffic conditions.	PA Website
	Truck Licensing System	Digitalisation	Truck	2013	Digital registration of different transport modes: fleet size, truck age, safety and environmental aspects.	PA Website
	Truck Clean Program	Digitalisation	Truck	2008	Radio Frequency Identification (RFID) to control trucks in the Port.	PA Website
	Terminal Appointment system	Digitalisation	Truck	1999	Appointment system used by truck drivers to reduce port access congestion.	Motono, et al., IAME 2017
Rotterdam	*Walstroom*	Electrification	Vessel	2008	Facilitate the processes of shore electric power.	Bestfact case
Seattle	*Truck Clean Program*		Truck	2008	Radio Frequency Identification (RFID) to control trucks in the Port.	PA Website
Sines	*Port Single window*	Digitalisation	Vessel, truck and rail	2009	Digital information system through a single window wants to avoid "double transhipping" in the port terminal.	PA Website
South Carolina-Charleston	*Clean Truck certification*	Digitalisation	Truck	2014	Digital registration and certification for truck drivers considering their truck engine	PA Website
Southampton	*Terminal Appointment system*	Digitalisation	Truck	2006	Digital platform for appointment between truck drivers and terminal operator.	Motono, et al., IAME 2017
St. Petersburg	*Sea Port of Saint-Petersburg*	Digitalisation	Truck	2016	Real time monitoring of traffic conditions.	PA Website
Stockton	*The Port's Truck Traffic Control Plan*	Digitalisation	Truck	2008	Real time monitoring of traffic conditions.	PA Website
Sydney	*Vehicle Booking System*	Digitalisation	Truck	2007	Appointment system used by truck drivers (to deliver/collect containers) Encouraging off-peak truck travel and improving travel predictability.	Private Firm Website
	Truck Clean Program	Digitalisation	Truck	2008	Radio Frequency Identification (RFID) to control trucks in the Port.	PA Website
Taiwan Inter. Port Corp	*Automatic Gate System*	Automation	Truck	2015	An automatic gateway management system (RFID) for entrance/exit the terminal.	PA Website

Tanger Med	*Gateway management system*	Digitalisation	electric vehicles	Until 2017	Digital registration of trucks	PA Website

Source: Own elaboration based on different sources of information

For additional initiatives confer Lind et al. (2020) which provides an overview of contemporary initiatives associated to digitalisation on port call operations.

3 Towards a model for positioning SMPs in a transport system context

Digital and autonomous innovations are seen as enablers to increase the competitiveness of sea transports. The new technology enables enhanced coordination and optimal transhipment operations through information transparency among involved actors in the transport system. A port as a hub consists of a large number of actors, all producing a vital component of value for the "common" customer. There is a need to consider port operations as part of the larger transport system, revealing the specific role of the port, and ensuring an optimal coordination of the port as a hub. Ports as well-coordinated hubs are key to ensure a high level of attractiveness for sea transports as transport alternative and to create incentives for cargo owners to choose sea transports over other transport means (when applicable) and thereby contribute to the realisation of the 2030 United Nations Agenda for Sustainable Development. The system context has been taken into consideration in the pre-study as depicted in the figure 4 below.

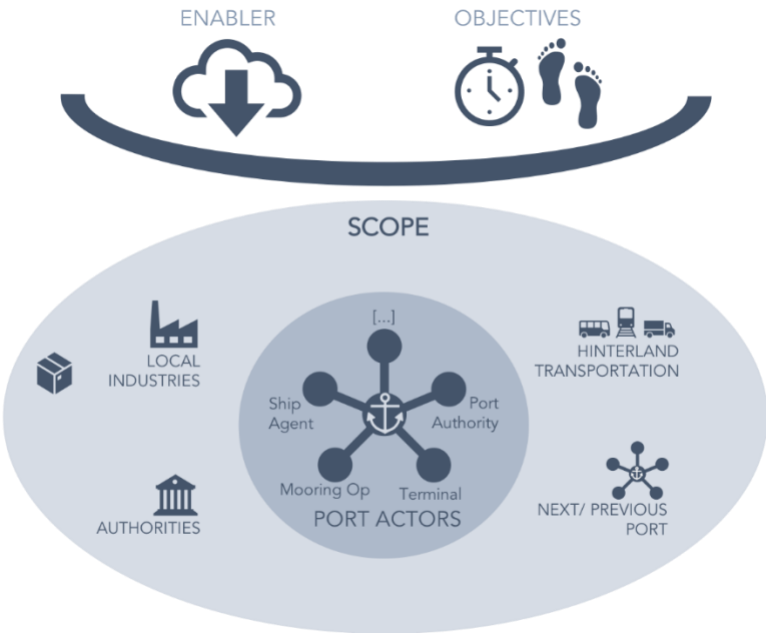


Figure 4: Scope in pre-study

In this pre-study, focus has been on SMPs and the challenges that are related to their characteristics. Often the port organisation lacks a dedicated IT-role and the responsibility for IT is instead given to someone interested in technology but having another primary role in the organisation.

Through collaborative processes port organisations can support each other in joint efforts in knowledge development and sharing experiences on technical solutions.

Barriers also exist to investing in and implementing technology due to the investment cost. SMPs have limited budgets for investing in new technology, why collaborative initiatives for investment purposes are needed. Most often the investments need to be based on specific customer requirements, otherwise the port lacks incentives for making the investment. A collaboration arena, bringing SMPs together, and enabling joint procurement processes and co-investments, is one enabler identified through this pre-study. Such co-investments might bring opportunities of co-utilisation.

Another enabler identified in the pre-study, is digital collaboration to enable information transparency for port optimisation through common situational awareness. To optimise the port as a hub and ensure that involved actors are well coordinated in their efforts, sharing of data about progress and intentions for critical events are crucial.

Yet another enabler that was identified is related to a test arena, to enable suppliers of technical solutions to display/demonstrate their products in a real port environment. Such a test arena allows future users of new innovations to try out and understand the benefits of future solutions before making the investment.

Examples of such innovations, which were also discussed in the pre-study are auto-mooring systems, use of autonomous vehicles and equipment for efficient cargo operations, digital dashboards for situational awareness, the next generation of Port VTS, interfaces for autonomous shipping, control rooms for remote pilotage and surveillance of movements within the port area (on ground) based on digitally twinned infrastructure. Such a display/demonstration environment, spanning over several ports, has been coined as a *Port*LivingLab.

Ports are highly competitive businesses, and shipping companies can relatively easy change port of call if the price-tag, service or any other aspect are better with a competitor. Therefore, the port's ability to be competitive is of highest concern in the process of optimising port operations. However, for SMPs it is a necessity to go beyond competition and apply a collaborative strategy, in order to gain the benefits from digitalisation and technology driven development.

The industry has transformed due to the digital era and ports will be forced to accept innovation through automation and digitalisation. For SMPs to adapt to the rapid development, collaboration is needed. Figure 5 depicts the areas of co-operation and collaboration identified in the pre-study as enablers to facilitate SMPs to gain benefits from digitalisation. Technology is also a driver for more sustainable solutions and SMPs will need to join forces to adopt sustainable innovations in their operations.

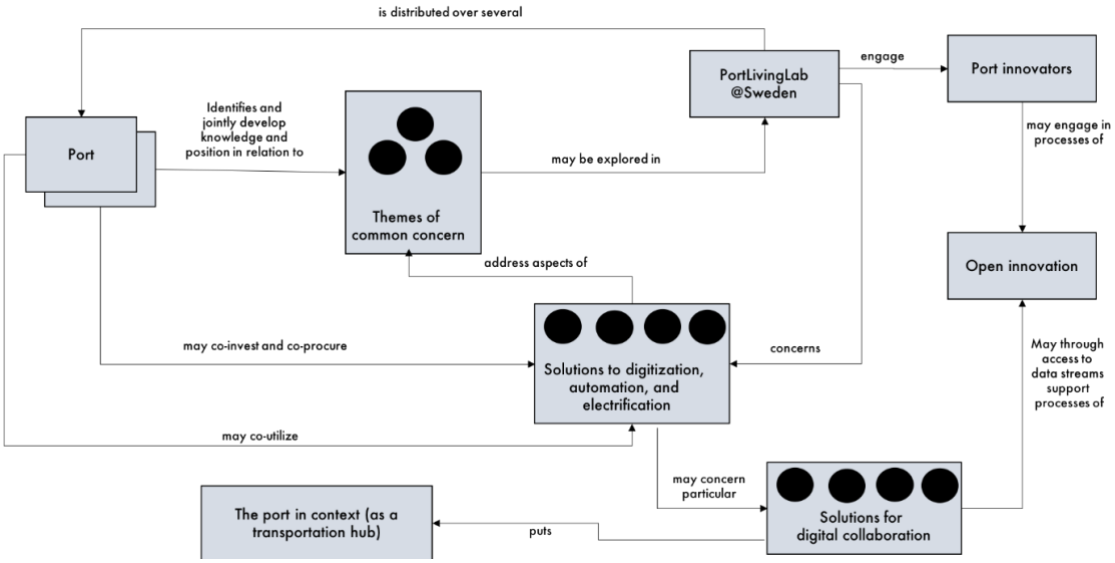


Figure 5: Identified arenas of co-operation and collaboration

4 Development trends identified at participating SMPs

4.1 Digitalisation – an enabler for an integrated practice of port operations in context

In this pre-study the participating ports revealed that they would appreciate support to overcome barriers when it comes to digitalisation. The SMPs do not see problems with collaboration with other ports when it comes to technology and operations, since they are aware of not having the same capabilities as larger ports which often have their own IT-department. For the SMPs it is not rare that their "IT-guy-/girl" is someone who got that responsibility due to an interest in IT but not having it as their main duty, and not having the time and competence to ensure that the SMP can follow the rapid changes in digitalisation.

During the project workshop in the city of Varberg where all ports in the pre study were represented, it was expressed by the ports that it would be beneficial if some kind of forum existed where they could discuss digitalisation and especially implementation of new digital solutions, since it is often hard to introduce those in the ports.

One of the examples that was brought forward during the workshop was when one of the ports implemented a new system to help the truck drivers to inform them about which unit they should pick up next, the response from the truck drivers were: *"I'm hired to drive a truck not to work with IT"*. But after some training and discussions, the truck drivers could see the benefits of the new system for their work, how it improved and reduced uncertainties since the system informed them which unit to pick up next and where to deliver it. This example highlights the fact that digitalisation almost always changes the work tasks and the known

procedures for the personnel, meaning that part of the digitalisation process should be focused on change management.

All of the ports see digitalisation as an important component for their business and they are at different stages when it comes to digitalisation. Some of the ports uses a Port Community System (PCS) for planning of their port calls and/-or operations and some are using Excel spread sheets. They all see digitalisation as a possibility to improve the work flow for their personnel, such as the possibility to follow positions, look into common reports instead of having personnel working with different spreadsheets, and a way to eliminate errors when data is transferred digitally instead of typing in from different paper reports.

The ports also expressed a wish for support of when it comes to analysing new initiatives and sharing of experience when it comes to new digital solutions. Not only for the port as a domain itself but also for when it comes to putting the new services into a larger perspective such as transport buyers, shippers and other ports. They also showed an interest in the possibility to potential co-utilisation of digital support when it comes to upgrading to new solutions and, hence, they don't have the same capabilities as larger ports.

When it comes to digitalisation it varies how far they have come, depending of what type of cargo they handle in the port, since it also depends on which of the stakeholders that pushes the technology. In some categories of goods such as sawn timber or dry bulk, it is often the port that pushes for digitalisation but when it comes to the container side, it is the container shipping companies that pushes digitalisation. Also, those different types of cargo, e.g. dry bulk and container, often have different planning horizons depending on different sensitivity when it comes to loading and discharging, e.g. container shipping is not weather sensitive but dry bulk such as grain is extremely weather sensitive and the loading/discharging needs to be stopped when bad weather is ahead.

4.2 Automation – taking part in the challenges of becoming more automised

There is a political will to transfer goods transport from road to sea along the Swedish coast. More costal shipping and shortsea shipping will be a key action to meet the increasing transport needs and to reach the environmental goals. A number of challenges needs to be solved, one is the cost of transferring goods from ship to land and vice versa. The use of automation could help reducing cost for transhipment.

The ports are looking into and working with automation in various ways, some have invested in automatic gates with imaging technology and/or have gate access with codes or tags, where drivers report themselves at gates, get access to the port and instructions where to drive. Some of the ports have automated some of their data flow in the port. Automation is a complex issue with the potential of saving money for the port and make some tasks more efficient. At the same time, it is

hard to discuss internally in the port since some personnel might feel threatened, and that their job is in jeopardy.

When it comes to automation, there is also the question of where to start. One of the ports is thinking of installing a photo gate for inspection of the cargo that comes in and leaves the port, instead of having personnel that physically inspects each trailer/container and then fills in a report. Another port is looking into how they can utilise an autonomous ferry to transport goods between one of the productions facilities that uses their port for further shipment, instead of having more than 30 plus trucks going back and forth between the two locations every day. These rubber-based transports do also have environmental effects in the city where the port is located.

The participating ports express similar wishes when it comes to automations as when discussing digitalisation, that they would like to have a forum to discuss this with other ports and experts, since they don't have the competence and resources themselves to evaluate different initiatives or solutions and it is easy to be convinced by different product companies pushing for their own solution. The SMPs don't see any problems when it comes to collaboration about different solutions or initiatives in automation. Where should they start looking into where they can start the automation process, on the shore to shore side, shore to ship side or on different cargo handling solutions? How can automation help the ports and make them more efficient and competitive?

4.3 Electrification – a mean for providing port services aiming at enhanced sustainability

This pre-study was in the beginning about digitalisation and automation but when starting the work, we realised that also electrification is an important topic for the ports. Electrification of port operations can roughly be divided in two segments where one is the service of providing an electrical connection to berthed ships as well as to waiting trucks. The other segment is how to electrify the port's own operations, such as electrically powered mobile cranes and trucks. With regards to change management, electrification can be easier to implement than digitalisation and automation, since it doesn't challenge jobs and has potential of saving money and reduce emissions including noise.

Electrification is also a topic where the ports would appreciate to have an arena where they could discuss different solutions that exist and exchange experiences of introduced initiatives. What operations could benefit from electrification? What are the current challenges with onshore power supply for berthed ships? How can the port operations become more energy efficient? Is it possible to produce and store energy within the port? Can the port be an energy provider both to ships and to other means of transports operating in connection to the port?

For example, if trucks are idling due to waiting time, it might be possible to provide an electrical connection to reduce the emissions and still maintain a good working environment for the driver. Another issue is that there are several

different manufacturers of port handling equipment producing electrified trucks and cranes, which could be useful for the ports to invest in. However, the port then needs to investigate how this will affect operations with regards to for example operational time, charging time, possibilities to change batteries, or operating while connected to electric infrastructure and backup system in case of power failure. Moreover, the business case has to be analysed, what is the cost to buy those things compared to traditional equipment and is it cheaper to charge them compared to cost of fuel and when do you reach break-even?

The need for city and port to be able to co-exist in the same geographical area is an issue that needs to be addressed, as many cities have plans to expand towards the waterfront. The more specific concerns are related to noise and air emissions. Both these issues can benefit from electrification, as it replaces combustion engines and lowers noise.

4.4 Summary table on themes within digitalisation, automation and electrification.

In the table below some different themes within the areas of digitalisation, automation, and electrification are surfaced that would form the agenda for arranging the collaborative work within the forthcoming innovation project.

Table 3: Identified Themes

Themes within Digitalisation	**Themes within Automation**	**Themes within Electrification**
Digital collaboration for enhanced coordination of port operations.	Automation for improving and monitoring port operations (e.g. gate systems, detection entrance solutions)	Sustainable operations through electrification (e.g. less emissions and noise reduction)
Digitalisation for improving port operations and decrease manual errors	Automations as a cost reducer	Techniques and business models for producing and storing energy
Energy savings through digitalisation	Use of drones in port operations surveillance.	Onshore power supply for ships
Contributions to reduced emissions through digitalised port call operations	Energy savings through IoT that makes it possible to control and automate energy usage	Shore based power supply for trucks waiting to board ships
Sensors, e.g. wind, current and water depth) that provides data to makes operations more efficient	Sensors, e.g. wind, current and water depth) that provides data to makes operations more efficient	

RLTestbed (*port*LivingLab) for display and test of digital innovations.	RLTestbed (*port*LivingLab) for display and test of innovations (automation).	RLTestbed (*port*LivingLab) for display and test of innovations (electrification).

5 Next steps – towards a collaborative innovation project on port development for Swedish small and medium-sized ports

A proposal for an innovation project was developed as a result of the findings in this pre-study, following on the results from interviews and the workshop. The initial proposal was merged with other port-centric project proposals to the industry programme Sustainable shipping, in order to form a wider and more general innovation project but still with digitalisation and automation of SMPs at the core. In particular, electrification is added since this was a finding in this pre-study as well as included one of the project proposals, namely electric connections to avoid idling lorries and reefer units in ferry ports.

The Swedish Transport Administration approved the funding of the innovation project, I.Hamn, as part of the industry programme Sustainable Shipping. This project started in January 2020. Appendix A contains an extracted description of the innovation project.

Lighthouse has also progressed the plans for a focus group gathering ports for joint knowledge dissemination and learning. The focus group will be established during 2020 and the activities will be firmly coordinated with the actions in the innovation programme.

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Appendix A – Innovation project description

This appendix is a separate document (project proposal description).

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