Recommendation report on methods, actions, and ICT solutions linked to enhanced information visibility and transmission processes for improving the cargo flow efficiency of the BSR maritime transportation and port operations

Final report

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Published: September 2020

European Union
European Regional Development Fund

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By Yiran Chen and Irina Wahlström

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1 Background and introduction

The project *Baltic Loop* focuses on solutions to improve and smooth the transport flows of both people and goods in three selected corridors running in the West-East direction (Northern, Middle and Southern) within the Central Baltic Region, namely Örebro – Turku/Tallinn/Riga – St. Petersburg. The project seeks to minimise the impact of traffic hindrances and bottlenecks. The overall aim is to minimise travelling and cargo time in the corridors and reduce CO_2-emissions.

Against this background, this report looks at how the integration of digital solutions can improve the efficiency of sea logistics and port operations on a general level and from a shortsea shipping point of view. The report will lay out the common challenges ports and maritime actors typically face, look at different ICT solutions and measures alleviating these lock-ins and inefficiencies and, finally, present the benefits gained in operational efficiency and business performance.

We introduce Baltic Sea short sea shipping and port operations in this chapter. As the regular sea connections in the Baltic Loop corridors mainly represents ro-ro traffic, this sub-trade will be of particular focus, but attention will also be put on dry bulk traffic.

1.1 Characteristics of Maritime Trade in the Baltic Sea

A number of international and European Union (EU) level policies affect and guide the development of the maritime industry. The Trans-European Transport Network (TEN-T) policy is put together to develop and implement measures to improve the connectivity of a Europe-wide network of all transport modes. The overall policy objective is to close gaps, remove bottlenecks and technical barriers, as well as to strengthen social, economic and territorial cohesion in the EU. Besides the construction of new physical infrastructure, the TEN-T policy supports innovation, new technologies and digital solutions. The objective is to make better use of infrastructure, reduce the environmental impact of transport, enhance energy efficiency and increase safety.

The Motorways of the Seas (MoS) is a horizontal priority and the maritime dimension of the TEN-T, whose aim is to integrate maritime links with the hinterlands and the EU's Member States. It embodies short-sea routes, ports, associated maritime infrastructures, equipment, facilities and relevant administrative formalities.

The EU's Maritime Transport Policy up to 2020 [1] prioritises decarbonisation, competitiveness and digitalisation, an effective internal market and a world-class maritime cluster, through which the EU wants to ensure global connectivity and the functioning of an efficient internal market.

These are only two examples of the maritime regulatory framework policies that set targets for the maritime industry.

According to the International Maritime Organization (IMO), over 90% of the global trade is carried by sea, and it is, by far, the most cost-effective way to move goods and raw materials around the world[2]. In the European Union (EU), almost 90% of the external freight trade is seaborne, of which short-sea shipping (SSS) covers a significant share. SSS is maritime transportation of goods over relatively short distances and a typical duration of 1-3 days, as opposed to the intercontinental deep-sea shipping.

Figure 1-1 illustrates the national level of the gross weight percentage of goods transported by SSS to and from main ports among EU countries in 2018[3]. The average share of cargo transported by SSS on the EU level amounts to 58.6% (dotted line). A comparison between the EU countries shows that SSS is particularly relevant for the countries within the Baltic Sea region (marked in blue columns). Of all EU countries, Finland has the highest SSS transport percentage of 92%. Sweden (89%), Estonia (78%) and Latvia (77%) also rank high.

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[1] European Commission -Priorities for the EU's Maritime Transport Policy until 2020 (2017)

[2] IMO, 'IMO Profile - Overview', *IMO (International Maritime Organization)*, 2020 <https://business.un.org/en/entities/13> [accessed 24 March 2020].

[3] Statistics Explained and Eurostat, 'Maritime Transport Statistics - Short Sea Shipping of Goods - Statistics Explained', 2018 <http://ec.europa.eu/eurostat/statistics-explained/index.php/Maritime_transport_statistics_-_short_sea_shipping_of_goods#Total_short_sea_shipping> [accessed 7 February 2018].

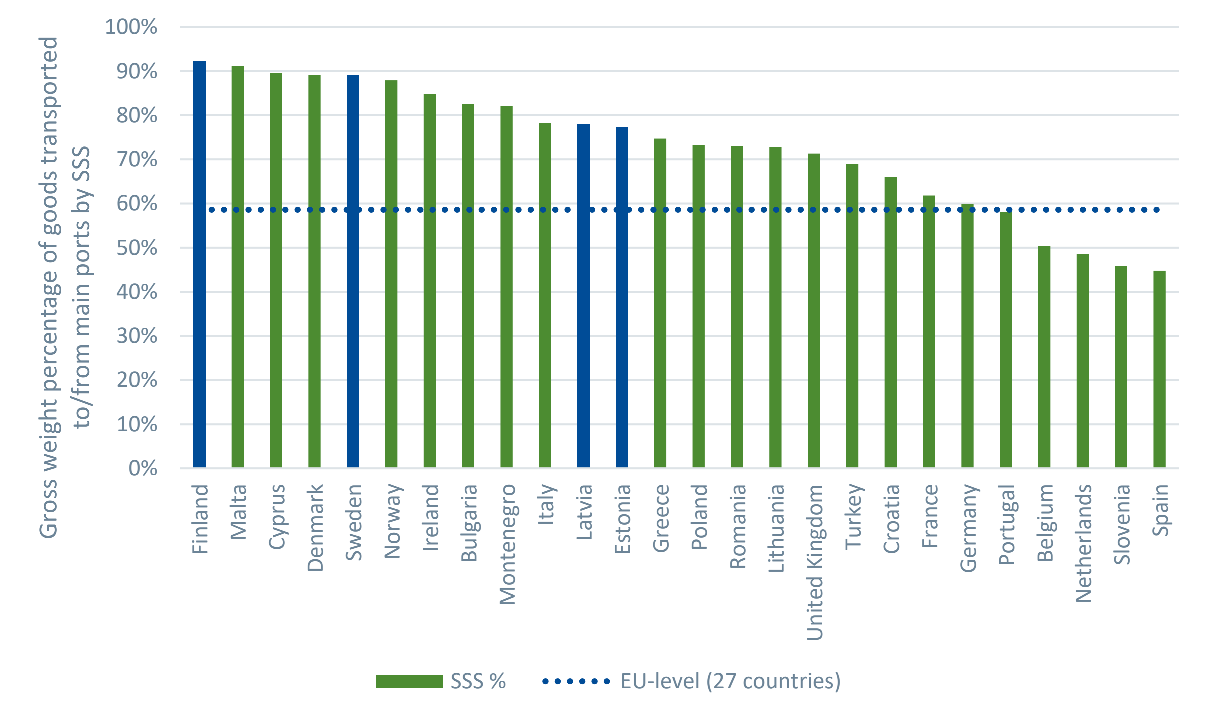

Figure 1-1 Share of SSS in maritime freight transportation per country in 2018.

The sea legs of the Baltic Loop corridors all represent short sea shipping connections and cover the ports of Stockholm, Kapellskär and Nynäshamn, all representing a combined transport concept serving both Ro-Ro cargo and passenger traffic (Table 1-1). Stockholm dominates in the traffic to/from Finland, although the services from Kapellskär to Naantali (Finland) and Tallinn (Estonia) also form significant cargo routes. The ferry lines to Estonia operate from Kapellskär and Stockholm, while Latvia is operated from Stockholm and Nynäshamn.

Table 1-1 Connectivity among Baltic Loop partner cities

Corridor	Departure port	Arrival port	Duration (h)	Dist (nm)
Northern	Stockholm (via Åland)	Turku	11	170
	Kapellskär (via Åland)	Naantali	7	113
Middle	Stockholm (via Åland)	Tallinn	17	237
	Kapellskär	Paldiski South	9.5-11	156

Southern	Nynäshamn	Ventspils	8.5-10	171
	Stockholm	Riga	17	276

Internationally, the IMO's ambition is to reduce 50% of the shipping-generated greenhouse gas emissions by the year 2050 compared to the reference year of 2008[4]. The goal on the EU level is to achieve a 60% reduction in transport-generated greenhouse gas emissions by 2050. Moreover, the goal is to shift 30% of road freight to SSS by 2030[5]. Hence, SSS plays a significant role in reducing the overall transport emissions.

[4] IMO, 'Adoption Of The Initial Imo Strategy On Reduction Of Ghg Emissions From Ships And Existing Imo Activity Related To Reducing Ghg Emissions In The Shipping Sector', 2018.

[5] COMM/TREN, 'Short Sea Shipping - Mobility and Transport - European Commission', 2016 <https://ec.europa.eu/transport/modes/maritime/short_sea_shipping_en> [accessed 30 March 2020].

1.2 Ports' role and function in supply chains

Ports function as important transport nodes linking land and maritime transportation and different transport modes within logistics chains. Therefore, overall transport efficiency is affected by the port's connectivity and operational efficiency, amongst other factors.

However, ports are frequently recognised as forming a discontinuation point in the maritime logistics and supply chain, because they exhibit low information transparency and coordination of processes and procedures inside the port. Additionally, the information flow is fragmented and compartmentalised into silos that do not enable real-time tracking; for instance, varied data formats are transmitted through several communication channels among organisations.

Most ports today are publicly-owned privatised companies[6] that are responsible for the port area's development and operate with financial and decision-making autonomy. The port authority acts as the landlord of the port area, providing and maintaining the port infrastructure: quays, port storage and warehousing facilities, cranes and immediate traffic connections. The ports' primary revenue comes from port-calling dues and goods-handling fees.

Port operators or stevedoring companies are in charge of cargo handling and port operations. They typically rent the facilities and infrastructure from the port authorities and provide their machinery, workforce and other operational resources.

The nature of the port operations is complex and requires orchestration and coordination of activities between different actors that involve numerous activities, machinery, and documentation processes. Figure 1-2 displays the steps of cargo flow between consignor and consignee when maritime transportation is involved, whose activities are mostly carried out in the port area[7].

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[6] Jussi Rönty, Marko Nokkala, and Kaisa Finnilä, *Port Ownership and Governance Models in Finland Development Needs & Future Challenges*, *VTT Technical Research Centre of Finland*, 2011.

[7] Yiran Chen, 'An Ecosystem Approach towards Port Operation in Finland' (Åbo Akademi University, 2018).

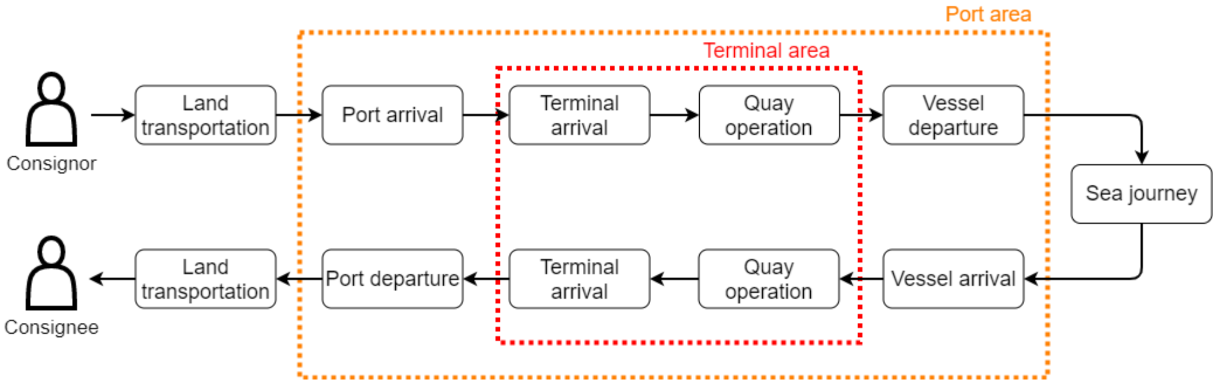

Figure 1-2 Cargo flow stages of the logistic chain when maritime transport is involved.

This report focuses on solutions that can enhance the overall cargo flow efficiency in the selected Baltic Sea region ports as part of the Baltic Loop project. Ro-Ro traffic occupies a high percentage in most of the corridors' ports, although some ports also function as mixed ports that handle bulk cargos. Ferry and Ropax services play an essential role in connecting neighbouring countries within the Baltic Sea area.

1.3 Ro-Ro and dry bulk operations in focal ports

Maritime transportation in the Baltic Sea Region consists of a high degree of short sea shipping, whose transport time typically takes 1-3 days. The ports of the Baltic Loop corridors handle all commodity types (liquid bulk, dry bulk and general cargo), but this report concentrates mainly on sea logistics in conjunction with Ro-Ro and dry bulk operations.

In Ro-Ro maritime transportation, ferries and ro-pax vessels carry wheeled cargo such as trucks, trailers and cars that are driven on and off the vessel (roll-on, roll-off) or use a mobile loading platform (mafi trailers) pulled by a tug master. Ro-Ro ships have built-in or shore-based rampsthat enable easily manageable and efficient loading and unloading procedures in ports[8].

Ro-Ro traffic in the Baltic Loop partner countries of Sweden, Finland, Estonia and Latvia occupied around 29% of the total EU Ro-Ro traffic in 2018. Ro-Ro traffic represents a

[8] European Commission, *Motorways of the Sea: An Ex-Post Evaluation on the Development of the Concept from 2001 and Possible Ways Forward*, 2017 <https://ec.europa.eu/transport/themes/infrastructure/motorways-sea_en>.

dominant or marked share of the total cargo throughput in several of the project corridors ports such as Kapellskär (99%), Stockholm (50%), and Turku (71%).

Ro-Ro transportation offers regular, scheduled and punctual services combining both passenger and freight transportation (trucks, trailers). Therefore, the ship schedule and speed can better be optimised with regard to vessel design, operated routes and fuel economy compared to dry bulk shipping. From an environmental perspective, Ro-Ro transport could contribute significantly to emissions reduction if the loading factor is high enough (over 70%) and the operational speed is optimised[9].

Traffic pulses of arriving and departing ships require efficient traffic management within and outside the port, in city areas and connecting infrastructure. Today, the lack of real-time traffic information and a slot system for trucks prior to ship departures cause traffic peaks and unnecessary waiting times in ports, hours before the actual departure.

Dry bulk traffic represented a dominant or marked share of the total cargo throughput in Latvian partner ports in 2018: 57% of the total cargo in Riga and 38% in Ventspils.

The nature and efficiency of dry bulk and Ro-Ro operations vary to a great extent. Dry bulk shipping typically serves industries with regular consignments and those with more random shipment needs and less stringent timetable requirements.

Dry bulk shipping presents a number of challenges regarding transport efficiency. Dry bulk ships are usually served by ports using the "first come, first served" principle. This means that vessels speed up during their voyage expecting an early arrival, exhibiting inefficient fuel economy, just to realise that a queue of waiting for ships outside the destination port has built up. Waiting outside the port can take up to several days, during which the auxiliary engines are running, simultaneously generating unnecessary

[9] Harald M. Hjelle, 'The Double Load Factor Problem of Ro-Ro Shipping', *Maritime Policy & Management*, 38.3 (2011), 235–49 <https://doi.org/10.1080/03088839.2011.572697>.

emissions. Additionally, vessels often sail only partially loaded or even in ballast when cargo has not been found for both legs of the roundtrip[10].

Dry bulk traffic is also more prone to being affected by weather conditions such as rain that cause delays in loading and unloading procedures due to commodities' moisture sensitivity. Low temperatures and icing can complicate and obstruct the opening/closing of weatherproof hatch covers of cargo holds during loading and unloading procedures (Figure 1-3).

Figure 1-3 Weather conditions' influence on dry bulk cargo transportation[11].

[10] Magnus Gustafsson and others, 'Revolutionizing Short Sea Shipping', 2016, 26 <http://www.abo.fi/fakultet/media/9465/anastasia9feb2016.pdf>.

[11] Chen.

A need exists to consider both administrative and technological solutions to enhance Ro-Ro and dry bulk traffic efficiency; those solutions when coordinated can enhance the overall operation and communication efficiency[12]. Section 3 presents these.

[12] European Commission.

2 Material and Methods

This study's analytic process and methodologies were desktop study, semistructured interviews, and online thematic surveys directed to relevant stakeholders.

2.1 Desktop Study

The desktop study reviewed recently published reports related to cargo transportation, digitalisation and ICT (information and communications technology) solutions.

It also studied recent projects related to multimodal transportation on the EU level and those covering Baltic Loop corridor sections. Special attention was paid to digital solutions within maritime transportation and port operations.

This report investigated the current status and level of digitalisation in port operations and multimodal transportation, technological implementation strategies, successful cases of information flow improvement measures, and potential challenges or bottlenecks faced.

2.2 Semistructured Interviews

Eighteen interviews were carried out during November 2019 and July 2020. The interviewed parties were carefully chosen to establish an understanding of corridor performance efficiency. The different transportation stakeholders -- actors, authorities and academia -- that operate in the three project-defined corridors were interviewed. Table 2-1 summarises this study's interviewed parties.

The interviews' duration was typically 60 to 90 minutes and incorporated questions related to current transport challenges and the solution portfolio. Some interviews were recorded and transcribed, whilst notes were taken for nonrecorded interviews. The names of the interviewed companies and persons will remain confidential in this context.

The thematic interview analysis provided new insights for the report content. Interview questions were adjusted to reflect newly discovered aspects and solution novelties. Hence, the open-ended questions provided an efficient method to build a contextual understanding of the current state. The formulation of these questions was based on relevant project reports and discoveries during interactions with stakeholders.

Table 2-1 Transport Stakeholders Interviewed in this Study

Interviewed party	Number of interviews
City authority	3
Specialist associations	2
Digital solution provider	4
Academia	1
Maritime infrastructure provider	1
Maritime transport / stevedoring company	2
Port authority	2
Transport technology provider	2
Transportati consultancy	1
Total	**18**

2.3 Online Thematic Survey

The online thematic survey was carried out during November and December 2019. Stakeholders from the project partner countries -- Estonia, Finland, Latvia, and Sweden -- were invited to answer the questionnaire.

The contacted stakeholders represented both public and private actors within the transport infrastructure, cargo, or passenger transportation areas; 93 answers were received altogether. Table 2-2 classifies the number and share of answers according to each stakeholder's operational area and function.

This report focuses on the analysis of cargo and maritime transport actors' opinions regarding innovative digital solutions.

The survey questions were predominantly quantitative multiple-choice questions. Optional open-ended complementary questions were posed for more detailed opinions. The survey aimed to establish a preliminary view of smooth cargo flow hindrances and drivers in the various Baltic Loop-defined transport corridors,\.

Furthermore, cargo flow hindrances and drivers have also been identified and discussed at Baltic Loop stakeholder days, kick-off events, and other relevant seminars arranged by third party actors.

Table 2-2 Stakeholders' Answers Classified by Area of Operation

Operation area	Number of answers	%
Planner (public authorities/urban designers)	41.00	44%
Cargo international (freight related actors)	34.00	37%
Cargo national/regional (freight related actors)	9.00	10%
Other (interdisciplinary firms, e.g. NGOs, expert associstions)	9.00	10%
Total	**93.00**	**100%**

Appendix I displays the key survey questions and the respondents' locations.

A further quantitative parametrisation was performed to enhance visualisation of the qualitative results. Most questions contained four-scale answer options, such as not relevant, insignificant, relatively significant, and significant. A numerical coefficient from 0 to 1 was applied for these options: 0 for not relevant, 0.25 for insignificant, 0.5 for relatively significant, and 1 for significant. A median value was calculated for each hindrance and driver for a general comparison (see Eq. 2-1). A similar method was established by Rohdin et al. for questionnaire analysis[13].

$$Final\ value = \frac{\sum counts * corresponding\ answer\ values}{number\ of\ total\ answers} \qquad \textit{Eq. 2-1}$$

For instance, if a factor contains five answers of significant, two of relatively important, one of insignificant, and three answers of not relevant, the final result would be 0.57 (see Eq. 2-2).

[13] Patrik Rohdin, Patrik Thollander, and Petter Solding, 'Barriers to and Drivers for Energy Efficiency in the Swedish Foundry Industry', 35 (2007), 672–77 <https://doi.org/10.1016/j.enpol.2006.01.010>.

$$\frac{5 * 1 + 2 * 0.5 + 0.25 * 1 + 3 * 0}{5 + 2 + 1 + 3} = 0.57 \qquad \text{Eq. 2-2}$$

Alternative approaches were used to compare results. Firstly, different transportation modes -- inland (rail and road) and maritime transport -- were compared with each other. Secondly, different operational areas -- transport infrastructure, freight, and passenger transportation -- were compared. This report focuses on the results related to cargo actors and cargo transportation.

Results range between values 0 – 1, while below 0.25 stands for not relevant, between 0.25 - 0.5 for somewhat significant, 0.5 – 0.75 for relatively, and 0.75 – 1 significant or very important.

A thematic content analysis was carried out for the qualitative answers. Conclusions were made based on each respondent's operational field and type of organisation.

Several aspects were identified using the just-mentioned materials, and corresponding recommendations for enhanced information visibility and transmission were provided.

3 Transport flows and port operation efficiency

This section summarises the results obtained from the online survey and interviews, followed by a short corresponding discussion. The more detailed survey results are presented in two Appendices: Qualitative Questionnaire Results in Appendix II and Quantitative Questionnaire Results in Appendix III.

3.1 Bottlenecks

Cargo flow hindrances and drivers, as stated by the respondents, were collected and identified. The total number of answers was 43, of which five represented stakeholders within maritime transport; the rest represented inland transport actors. There is also a small input percentage represented by intermodal transport and infrastructure-related stakeholders. The latter two were excluded for the accuracy of the analysis.

Certain factors, identified both in the questionnaire and interview answers, are technologically directly interdependent, such as the lack of digital infrastructure and services and timely information. Moreover, other factors, such as limited interorganisational collaboration and sluggish border control procedures, could be partly solved by implementing an optimised application of information exchange technology.

The analysis identified the bottlenecks that hinder efficient communication. Bottlenecks refer to critical phases or activities that should be carried out to improve the overall transportation efficiency. Based on the analysis method and results presented in the previous section, the hindrances were grouped thematically:

- institutional: lack of communication and collaboration among relevant stakeholders
- operational: capacity limitations, infrastructure conditions and limited or lacking interoperability
- technological: challenges related to current digital tools and implementation of new innovative ones

Table 3-1 summarises the bottlenecks.

Table 3-1 Bottlenecks Related to Communication Efficiency in Cargo Transportation

Bottleneck	Description
Introduction of new technologies	The solution providers do not acknowledge the ports' individual requirements, needs and challenges, whereby the value proposition does not attract the port.
Unwillingness to experiment, behavioral resistance	The lack of willingness to experiment or collaborate using new products and solutions.
Open feedback loop	Challenging to improve the functionality of new (digital) solutions due to lack of/limited user feedback.
Authority commitment	Public or transport project piloting opportunities are provided in some cases, but those are granted too short implementation and execution periods.
Need for advanced traffic data collection	Intelligent traffic data collection systems do not exist in places; tracking real-time traffic requires infrastructural readiness.
Unification of APIs for improved data sharing and interoperability	Different organisations have their own customised application programming interfaces (APIs), such as software packages. Most of these APIs are rudimentary. Even if companies are willing to share data, data sharing still remains a problem without a unified API.
Data security-related regulative/normative support for the transport sector	Data security-related standards exist, but each sector collects different data. Even though most of the service providers build their own database and operate using ISO data security standards, they still need one more specified for the transport sector.
Development of a policy and framework standards for intermodal transport	Policy and framework standard exist for individual transport modes, e.g., rail, maritime, land logistics, but not for multimodal and intermodal transport.
Lack of open data sharing	Many private companies do not want to share information, because they lack knowledge on technologies, trust or security.

Solving the bottlenecks necessitates a cocreative and collaborative process among stakeholders. Bottlenecks can be characterised as individual or interdependent. The latter could be tackled in parallel and simultaneously through the establishment of a standardised policy and traffic management framework, enabling improved data sharing between different transport modes, for example, through unified APIs. However, the key to initiating all these changes is the stakeholders' willingness and motivation to collaborate and be open towards new ideas or practices being introduced. Solution-providing companies should also introduce their value propositions based on customers' individual requirements and needs.

Bottlenecks may arise from different sources and constellations. They can be related to the existing infrastructure and the lack of traffic data collection.

Operational Bottlenecks

Meteorological-natural conditions invariably affect the prerequisites of transport infrastructure, transport modes, terminal and port functions and operations. Weather conditions are critical for dry bulk operations. The handling, loading and unloading of dry bulk cargo can be slowed down or brought to a standstill because of precipitation, therefore, increasing the vessel's turnaround time in ports.

Ro-Ro traffic, however, is affected by weather conditions mainly on land-based sections, i.e., the roads ultimately will slow down traffic flows and impair traffic safety through low visibility, winter conditions, and reduced maintenance. Shortage of road maintenance, especially in winter time, was considered a challenge and an effect of insufficient maintenance budgets. These aspects could be avoided by real-time weather predictions and predictive weather modelling digital solutions.

Insufficient transport infrastructure capacity not meeting the actual demand and causing congestion and delays is regarded as constituting a significant bottleneck, especially on the roads and approaches to big port cities during rush hours. This capacity issue could be tackled through improved transport flow flexibility, aided by real-time traffic management systems.

Low system interoperability and varied communication channels constitute further challenges. Digital clearance processes, for example, are partially implemented for certain transport modes, while others still rely on physical paper documents.

Institutional bottlenecks

The planning and execution of a functional transport infrastructure is a multilevel process affecting the entire society and involving a number of stakeholders, including not only national authorities, regional planners, public and private transport providers but also the actual users within passenger and cargo transportation. This requires a holistic and long-term vision and approach to transport infrastructure planning, land use and funding.

Shortage of funding resources, fragmented transport chain collaboration, and limited stakeholder alignment were, however, regarded as constituting one of the most relevant bottlenecks affecting transport flows and transport system development, as evidenced by the questionnaire responses and interviews.

Hence, the respective stakeholders should be encouraged to encourage multilateral discussions, cooperation and coordination within the planning process, whose current settings are still characterised by established hierarchical and bureaucratic practices in many cases.

The feedback loop is incomplete between the infrastructure planning bodies and the end users; hence, the functionality, needs and requirements do not necessarily meet. The communication between planners and users is limited and slow, whether it concerns physical or digital transport infrastructure, thus potentially resulting in unoptimal and malfunctioning solutions.

The information flows in ports remain scattered and complex due to a lack of coordination and limited data integration. The digital solution providers approach the ports with a variety of high-ended technologies and solutions that do not necessarily take into account the port's actual individual requirements, needs and challenges. Hence, the actual cost-benefits and value propositions remain unclear, resulting in an unwillingness to experiment and invest in these solutions. Many ports also wait for standardised data management solutions before being encouraged enough to make a positive investment decision.

Institutional challenges, such as lack of trust in data sharing or in experimenting with new solutions, significantly influence the implementation of ICT (information and communications technology) solutions.

Technological bottlenecks

The *low interoperability of ICT systems* within and between organisations hampers seamless information transmission. Information verification, standard data formats and unified communication channels could reduce the administrative burden of various port operations[14]. Limited collaboration among the port community is the typical obstacle to introducing new technologies.

The communication and data exchange between various maritime supply chain actors and organisations are still often characterised by manual inputs and a lack of interoperable systems. The main bottleneck is the dependence on traditional communication channels, such as telephones or faxes, that are still used frequently. Furthermore, the clearance processes are carried out on different, unconnected platforms; thus, manual typing or even paper documents are needed to fulfil mandatory legislative reporting processes.

Unification of application programming interfaces (APIs) for better data sharing demands the following conditions: unified data format, collection and management protocols. Most of these APIs are rudimentary. Data sharing still remains a problem without a unified API even if companies are willing to share data.

However, the keys to initiating all these changes are a willingness and motivation to collaborate and share data and openness towards any new ideas or practices being introduced. At the same time, solution providers should also introduce their value propositions in an attractive way that is understandable and targeted.

[14] Brian Dixon, 'BIMCO Proposes New Ship-to-Port Data Exchange', *Fathom World*, 2019 <https://fathom.world/bimco-proposes-new-ship-to-port-data-exchange/> [accessed 10 July 2020].

Partner countries should communicate and unify further the frameworks for a seamless implementation of new technologies for better corridor traffic-flow performance. One example can be the sharing of information management standards in the transport sector or the best available practices for different information transmission-related processes. Ports and their stakeholders, including operators, digital tool developers, users and authorities, should collaborate to identify and enable key levers for improving port operational efficiency, productivity, and profitability.

Furthermore, holistic *regulative support* is needed. The introduction of new technologies also requires compliance with regulatory policies and standards. Collection and management protocols are needed to ensure data security and traffic safety, laws and standards related to data formats. Consequently, data sharing and exchange through unified communication channels should also be facilitated.

3.2 Drivers

Based on the analysis method of answers mentioned in the previous section, the following drivers were identified:

- introduction of new contractual models for increased sectorial competition
- public-private partnerships (PPP) to enhance collaboration and investment planning
- standardised communication channels and information management protocols in corridors to collect, integrate and manage similar data sets to optimise traffic flows.

Some of the listed drivers are institutional, while others are technological. Some drivers could similarly be considered the consequence of others, such as data standardisation requiring regional PPP and innovative contractual models.

Increasing sectorial competition could increase innovation and research among stakeholders, based on inputs from questionnaire respondents and the interview contributions. Protected markets with low competition hinder the entrance of new companies and solutions. A highly competitive business environment forces companies to reflect more on opportunities and innovations and, hence, to consider experimenting with new business models.

The shipping industry is often characterised by long-term, exclusive contracts, which lead to operational inflexibility and inefficiency. Renewal of contractual models and terms could shorten the contract duration and, thus, encourage companies to innovate and compete.

More implementation of public-private partnerships (PPP) is needed. Several PPP projects were reviewed, and financial input by private partners in public investment and constructions projects have proven to result in fruitful collaboration, as evidenced by the FinEst project that aims to improve and integrate the passenger services of the Ports of Helsinki and Tallinn through a smart mobility concept. These cities collaborated with different transport hubs and innovative companies; the problems were not immediately solved due to the project's short term, but that transportation sector is more collaborative than before.

Stakeholders within the shipping industry demonstrated insecurity and lack of knowledge regarding different technological solutions as drivers. Innovative technologies are considered costly, amongst other things, and environmentally friendly technologies are not necessarily in line with business profitability. Lack of proper technical understanding may cause this kind of prejudice. The uncertainty of the benefits that digital investments can bring to operations was one of the main concerns, along with the time-consuming and resource-binding training process. PPPs could facilitate the fusion of knowledge residing in the cocreative building process of digital solutions.

A demand is emerging for a standardised data collection and management procedures in the corridors that could, hence, improve the overall information exchange. The lack of interoperable digital systems hinders smooth communication among the actors, especially when international traffic occurs. The digital transport infrastructure (connecting all actors and transport modes) should be the first to be standardised to connect the corridor sections. The digital infrastructure consists of a standardised management protocol, integrated sensor systems, and communication channels.

A management protocol should be built based upon agreement by the relevant stakeholders, as each country has a customised, national single window. The standardisation also applies to the integration of traffic sensors in the partner countries. It is challenging to track traffic demands and flows without suitable sensors. Improving digital infrastructure does not necessarily require high investments in new hardware or software for some stakeholders; it could merely require efficient management of the created information and data. Information could be transmitted automatically and would no longer require manual retranscription when communication channels of communication are harmonised and integrated.

These recommendations rely on stakeholders' statements about the cargo flows in the current supply chains. From a scientific or facilitator's perspective, suitable suggestions should be provided based on a global analysis of technological and economical solutions and their social impact. Thus, detailed solutions or suggestions related to the questionnaire results are explained in more detail in later project deliverables.

4 Digitalisation of maritime transportation and port operations

The shipping industry, including port operations, is known to be a traditional and conservative industry that has functioned more or less as an isolated function within the maritime supply chain and is characterised by a variety of operational inefficiencies, lock-ins and poor data collaboration[15].

4.1 Current state

Only 49 of the 171 IMO Member States in shipping, for example, have digital port community systems (PCS). PCS is a neutral and open electronic platform enabling the intelligent and secure exchange of information between public and private stakeholders in order to improve the competitive position of maritime logistics through a single window[16].

The maritime transport industry has, nevertheless, gradually started to undergo a profound transformation catalysed mainly by digital disruption, an expanding environmental agenda and a growing competitive landscape. Ports and terminals need to re-evaluate their role in maritime logistics and integrate digitalisation-driven innovations and technologies provide significant transformational potential. However, fundamental challenges emerge when digital solutions are being implemented: Institutional or market resistance, together with financial shortages and user behavioural resistance, amongst others, can be recognised as such challenges.

The degree of digital infrastructure readiness, integration and adaption vary between countries and industries. The European Union (EU) maintains a Digital Transformation Scoreboard[17] to analyse the prerequisites and the actual digitalisation integration level of its member states. These are measured as the Digital Transformation Enablers' Index (DTEI) and the Digital Technology Integration Index (DTII). Sweden and Finland both rank high and above the EU28 averages (37.3 in DTII and 49.2 in DTEI). Latvia, however,

[15] Magnus Gustafsson, *Positioning Report: Analysis of the Current Shipping Industry Structureand a Vision for a Renewed Shipping Industry Ecosystem* (Åbo: Åbo Akademi, 2015).

[16] Patrick Verhoeven at *'BPO Webinar: The new reality of the ports sector'*, 2020.

[17] European Commission – Digital Transformation Scorecard (2018)

lags behind in both indexes, whilst Estonia exceeds the DTEI average but fails to reach the DTII.

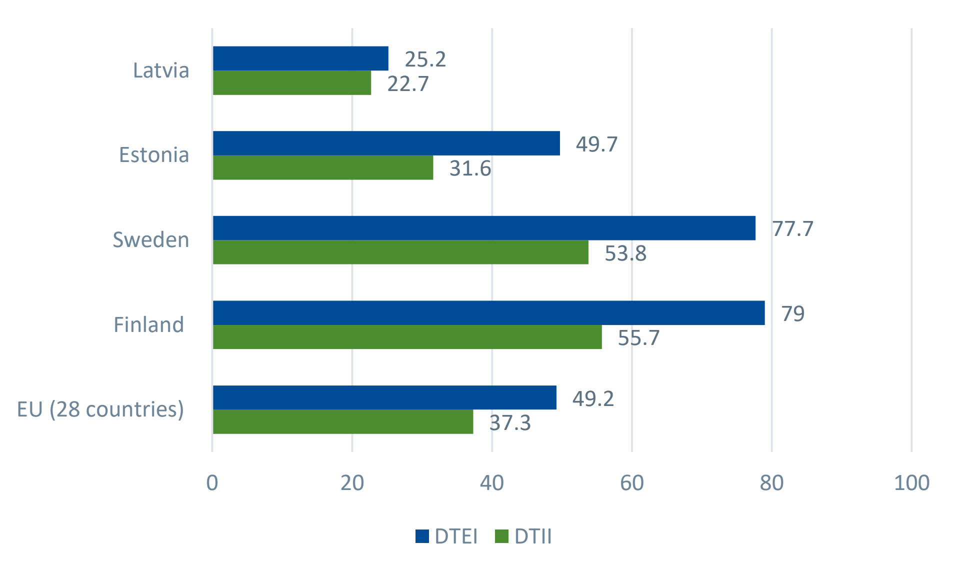

Figure 4-1 DTII and DTEI in EU (2018). [18]

The European Maritime Single Window (EMSW) was prototyped in 2015 by the EU Commission, as Figure 4-2 illustrates[19]. The objective was to test procedures that would simplify the information submission required at port calls by maritime and customs authorities for maritime cargo formalities and to facilitate the reporting procedure for ship data providers (masters, ship agents, ship operators) through the development of a harmonised eManifest. The approach was taken through unifying administrative procedures on a website for the relevant actors, such as ship data providers, national authorities, via SafeSeaNet[20].

[18] Laurent Probst and others, *Digital Transformation Scoreboard 2018 - EU Businesses Go Digital: Opportunities, Outcomes and Uptake*, 2018 <https://doi.org/10.2826/691861>.

[19] EMSA, 'Operational Projects - European Maritime Single Window Prototype - EMSA - European Maritime Safety Agency', 2020 <http://www.emsa.europa.eu/related-projects/emsw.html> [accessed 30 March 2020].

[20] European Maritime Safety Agency, *National Single Window Prototype an Electronic Solution for Simplifying Administrative Procedures*, 2015.

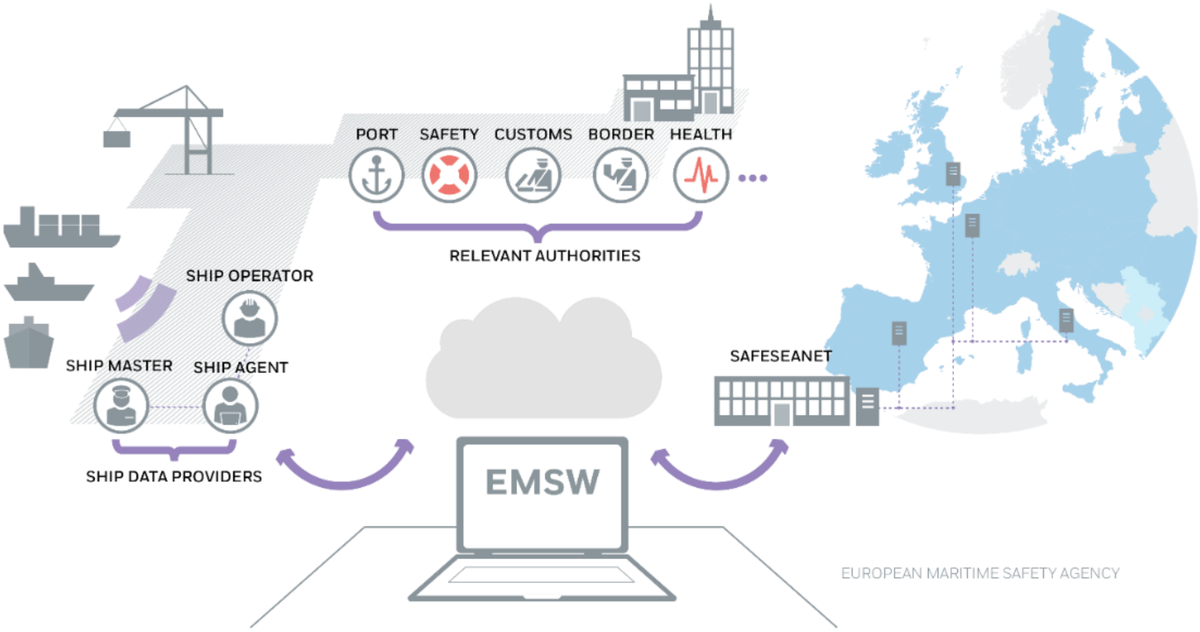

Figure 4-2 European Maritime Single Window (EMSW) prototype.[21]

The prototyping of EMSW successfully proved its potential to reduce administrative procedures through simplified and harmonised electronic reporting. The submitted information could be re-used by the shipping actors, which saves time by avoiding typing and other potential input errors. The data quality is improved for authorities and becomes more traceable as information is consolidated. Other EU member countries consequently started developing national single windows based on the given prototype[22]: Finland employs Portnet[23], Estonia uses the Electronic Maritime Information system (EMDE)[24], Sweden employs the Maritime Single Window (MSW)[25],

[21] EMSA.

[22] European Maritime Safety Agency.

[23] Liikennevirasto, *Portnet – National Single Window Implementation in Finland Portnet – National Single Window (NSW)*, 2017.

[24] Veeteede Amet, 'Electronic Maritime Information System', 2020 <https://veeteedeamet.ee/en/elektronical-maritime-information-system> [accessed 13 July 2020].

[25] Linda Hedlund, 'Uppgifter Att Lämna via MSW' (Tullverket).

and Latvia uses the Electronic Customs Data Processing Systems (EMDAS)[26]. These systems are currently maintained and optimised by each country, and there is limited operational information flow between public and private actors.

4.2 Emerging digital tools and solutions

The EU identifies nine key technologies for digitalisation: social media, mobile services, cloud technologies, the Internet of Things (IoT), cybersecurity solutions, robotics and automated machinery, big data and data analytics, artificial intelligence (AI) and 3D printing[27].

Different approaches exist for improving port operation efficiency: enhancing the connectivity of transport modes, managing traffic management, organising asset and resource management, and improving infrastructure or facility conditions.

Real-time truck queueing systems for trucks can be implemented and used by ports and cross-border stations for land-based transport flows. The system suggests a just-in-time arrival to the port for truck drivers based on a driving-time prediction. Intelligent Traffic Systems (ITS) are also emerging that improve overall traffic management in ports and cities. However, this requires extensive communication network coverage and agreement on data sharing among various actors.

AI-enabled port call optimisation and virtual port calls are emerging in ports; these predict more accurate arrival and departure times for vessels. The exact time of arrival is known, so ship operators can sail at optimal speed with regard to the actual arrival time, which also translates to higher onboard operational energy efficiency. At the same time, ports can better plan and coordinate functions and services, because ships arrive as an even and optimised flow. Furthermore, the solution could provide a space for information exchange among the collaborators, enhancing the overall communication efficiency. The Port Community System (PCS) is another approach that could provide a standard information flow, an improvement in data quality, and

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[26] State Revenue Service of the Republic of latvia, 'How to Become E-Customs Systems' User | Valsts Ieņēmumu Dienests', 2018 <https://www.vid.gov.lv/en/how-become-e-customs-systems-user> [accessed 10 September 2020].

[27] Probst and others.

integrity and transparency between private and public stakeholders within a supply chain. Furthermore, PCS also improves the traceability of goods and operations in the entire supply chain[28].

The road transport infrastructure is innovating its maintenance measures through the use of artificial intelligence. Damaged road sections can be registered and repaired before the road conditions worsen.

The market transparency on cargo transport availability is also increasing because the price of a shared container for shippers is already visible. The integration of transport demands can improve the current inefficiency in maritime transportation.

Enhancing security and safety is also part of the digitalisation agenda, through which technologies such as blockchain are aiming to secure transactions, data privacy and exchange.

[28] Patrick Verhoeven at *'BPO Webinar: The new reality of the ports sector'*, 2020.

5 Conclusion

The demands for and on transport infrastructures are bound to increase with today's increasing trade and cargo volumes. However, the overall efficiency can be improved by employing digital infrastructure and suitable communication channels during cargo transportation. The objective is to achieve an optimal or maximum utilisation rate of transport units and modes, infrastructure, technology, and resources. It is essential to integrate different transport modes and coordinate operations through efficient information exchange to achieve better connections in the corridors.

A continued and coherent introduction and implementation of technological solutions will facilitate efficient transport flow in the Baltic Loop corridors, which also translate into less transport-generated emissions regardless of transport mode. However, this requires collaboration between different actors in the transport chain, such as public authorities and companies, to align their strategic plans and pursue an ongoing discussion and collaboration.

Different strategic agendas exist on a country level for improving the communication and information flows within transport systems and cargo logistics. Nevertheless, many challenges will become apparent at the implementation stage, because the roots of the bottlenecks are sometimes more complex than initially was thought.

Tentative paths and operational processes should be given more attention compared to the implementation of individual technologies in order to improve communication efficiency along with the logistics and supply chains. Existing bottlenecks can be of different types; thus, the overall change requires systematic collaboration by all stakeholders. Furthermore, the improvement of cargo transport efficiency and, hence, the advances in improvement paths are a more coherent suggestion than are individual solutions. These paths could be designed and implemented by employing strategic methods and numerical modelling.

Finally, a robust and well functioning digital infrastructure enables ports to manage and maintain their physical infrastructure and collaborate with other actors. Digital solutions can improve situational awareness and scheduling of critical, just-in-time processes, providing more flexibility to operations. Both the actual port operations and the prediction and decision process regarding future maintence and investment needs can be made more efficent. The digital transformation lays the foundation for improved competitiveness and for safe, secure and sustainable maritime logistics services.

A. Appendix I – Questions on the questionnaire

Table A-1 Key Survey Questions and Question Types

Question		***Question type***
2. Please indicate the legal form of your organisation		*Multiple choice*
3. Please indicate on which level your unit operates organisation level		*Multiple choice*
4. Please indicate on which sections of the given corridors you operate		*Check box*
5. Please indicate what transport services you provide		*Check box*
6. Please indicate in which transport sub-sector you operate		*Check box*
7. Direction of trade and transport you primarily deal with (Cargo)		*Check box*
8. On which level do you primarily operate in passenger traffic (Passenger)		*Multiple choice*
9. How often do you experience delays in the scheduled or expected delivery/arrival time on the transport corridor?		*Multiple choice*
In which corridor sections have you experienced delays?		*Long answer text*
10. What are (or could be) the major causes of delays in transport corridors?	The current capacity (e.g. traffic network and fairway dimensions, road load limits) does not meet the traffic demand	*Multiple choice grid*
	Conflicting interest of capacity usage (passenger traffic vs. cargo traffic)	*Multiple choice grid*
	Concentration of people and traffic to certain busy routes/corridors (Increasing future traffic development)	*Multiple choice grid*
	Constrained accessibility to traffic nodes or main traffic routes	*Multiple choice grid*
	Lack of timely information	*Multiple choice grid*
	Poor connectivity in transport and travel chain	*Multiple choice grid*
	Low frequency of service	*Multiple choice grid*
	Customs and border services	*Multiple choice grid*
	Lack of communication, co-operation and coordination between public authorities and other stakeholders	*Multiple choice grid*

	Weather conditions	*Multiple choice grid*
	Other, please indicate	*Long answer text*
11. How important for your organisation are the following criteria to ensure your transport operations/services on the corridor?	Physical condition of transport infrastructure you use	*Multiple choice grid*
	Service speed	*Multiple choice grid*
	Good accessibility to the main traffic nodes	*Multiple choice grid*
	Adequate infrastructure capacity to avoid traffic jams or delays	*Multiple choice grid*
	Traffic safety and security	*Multiple choice grid*
	Price of service	*Multiple choice grid*
	Communication, co-operation and coordination between public authorities and other stakeholders	*Multiple choice grid*
	Availability of information technology systems	*Multiple choice grid*
	Timely exchange of information	*Multiple choice grid*
	Environmentally friendly transport modes	*Multiple choice grid*
	Quick custom/border services	*Multiple choice grid*
	Green technologies / use of renewable energy resources	*Multiple choice grid*
	Other criteria, please indicate	*Long answer text*
12. What are the main hindrances of transport infrastructure development?	Lack of long-term vision in transport infrastructure planning	*Multiple choice grid*
	Expensive innovative technologies	*Multiple choice grid*
	High investment cost	*Multiple choice grid*
	Lack of communication, co-operation and coordination between public authorities and other stakeholders	*Multiple choice grid*
	Lack of digital infrastructure and digital service	*Multiple choice grid*
	Lack of funding for infrastructure investments	*Multiple choice grid*
	Existing legislation	*Multiple choice grid*

	Please indicate other main hindrances of transport infrastructure development per corridor	*Long answer text*
13. What (and to what extent) could improve traffic flows in the international traffic corridors?	Digitalisation of services	*Multiple choice grid*
	Increased infrastructure capacity to avoid traffic jams or delays	*Multiple choice grid*
	Improved accessibility to the main terminals and traffic routes	*Multiple choice grid*
	Timely exchange of information	*Multiple choice grid*
	Increased traffic safety and security	*Multiple choice grid*
	Different pricing policy	*Multiple choice grid*
	Communication, co-operation and coordination between public authorities and other stakeholders	*Multiple choice grid*
	Increased use of information technology systems	*Multiple choice grid*
	Improved custom/border services	*Multiple choice grid*
	Innovative technologies	*Multiple choice grid*
	Increased competition among transport service providers	*Multiple choice grid*
	Other, please indicate	*Long answer text*

B. Appendix II – Qualitative Questionnaire Results

The three specified transport corridors represent a set of specific characteristics and distinct challenges. These challenges could relate to various factors, such as cultural-institutional issues, meteorological factors or infrastructure conditions.

Corridor endpoints: Norwegian and Russian borders.

There are high traffic volumes in relation to existing infrastructure capacity from Oslo to Stockholm.The road and railway infrastructure capacity no longer meet the actual traffic demand due to the increasing passenger transportation flows.

Long queueing time at the Estonia-Russian and Latvia-Russian borders has been reported as a bottleneck. This situation might be caused by undermanning of the border authorities and potential cultural-institutional differences. Additionally, it was mentioned that E-visa is in use for ferry and road but not for rail transport.

The Northern Corridor

The Northern Corridor's challenges relate mainly to oversized, heavyweight vehicle (OHV) traffic. Limited information about roads that oversized trucks can use on lower road networks was mentioned.

The ferry connection between Sweden and Finland and its efficiency forms a crucial transport link between Finland and the Nordic markets. A cargo operator respondent remarked on the ferries' limited capacity. Despite the high ferry service frequency between Stockholm and Turku, the car deck space for OHV transport is limited or nonexistent. Moreover, there is a conflicting capacity demand between passenger and freight transportation during holiday seasons.

Road-haulage respondents represented a significant percentage of all responses received; hence, road transport conditions are accentuated. Frequently recurring congestions were reported on Turku and Helsinki's ring roads. Turku's ring road also suffers from an uneven sectional infrastructure capacity that affects road haulage. For instance, four-lane roads sectionally narrow into two-lane roads. These discontinuation points negatively affect traffic safety and security. The Turku ring road is currently undergoing improvement measures.

It was also stated that better communication and coordination is needed between relevant stakeholders in transport infrastructure planning. However, this is a complex process in which relevant stakeholders and users should collaborate and cooperate more dynamically and with long-term visioning and planning to achieve holistic and well functioning overall solutions.

The Middle Corridor

The Middle Corridor's challenges consist of conflicting user and stakeholder interests. For instance, there is a conflict between freight and passenger transportation on the Paldiski-Ülemiste railway section. The nightly railway freight transportation causes noise and disturbs the residents in the Old Town. Shipping companies are operating with business models that combine passenger and freight transport, although there is a desire by the City of Tallinn to minimise/remove the freight traffic (trucks) out of the historical city.

Additionally, challenges related to different transport modes are also mentioned, for example, low connectivity between Tallinn airport and Old City Harbor and potential collision with wildlife on the Tallinn-St. Petersburg section.

The Southern Corridor

The Southern Corridor faces limitations in infrastructure condition and capacity, mainly because of the lack of digital infrastructure, transport infrastructure funding and maintenance.

Industrial production and businesses are increasingly moving out of the Riga city centre, causing growing transportation between Riga and suburban areas. The traffic safety is impaired to some extent due to the lack of wild-life fencing along the road on some sections, e.g., Riga-Minsk (although not part of the actual corridor).

C. Appendix III – Quantitative Questionnaire Results

From the quantitative survey results:

Table C-1 contains the ranking of the mentioned hindrances based on the median of the answers. The results are valued between 0 – 1: Below 0.25 stands for not relevant, between 0.25 - 0.5 for somewhat significant, 0.5 – 0.75 for relatively significant, and 0.75 – 1 significant or very important.

Drivers for Improving Corridor Transport Flow Efficiency Identified by Different Stakeholders

Ranked priorities for improving the corridors' efficiency are similar among different stakeholders. The average rating of these drivers is higher than that of hindrances.

However, it is observed that infrastructure planners more often register and highlight the significance of environmentally friendly and innovative technologies than others.

However, infrastructure users, as opposed to infrastructure planners, emphasise improved traffic safety and security more, together with increased infrastructure flexibility as priorities.

The views are largely unanimous among both international and national cargo operators. In contrast, the needs for digital improvements, environmentally friendly technologies and further collaboration among relevant stakeholders are stressed more among international cargo operators. National cargo operators emphasise more those aspects related to traffic safety and security, improved infrastructure flexibility and physical transport infrastructure conditions.

Hindrances Affecting Corridor Transport Flow Efficiency Identified by Different Stakeholders

A number of hindrances are shared and prioritised by all stakeholders, such as the lack of digital infrastructure and service, of customs and border service, of expensive innovative technologies and of a regulatory framework affecting the infrastructure development.

Infrastructure planners' views and knowledge about the current or future infrastructure demands could be better acknowledged and capitalised on. They also consider that organisational collaboration and information transmission could be better handled. Challenges related to infrastructure funding were also pointed out.

Among cargo operators, the importance of infrastructure adaptability is emphasised more on the national level; however, the impact of weather conditions is recognised, especially in international operations. It is also observed that national operators generally identify more challenges than international operators do. For instance, national operators would desire more timely traffic information, better connectivity and service frequency.

Table C-1 Drivers and Hindrances for Different Parties

Drivers	All	Planner (n=41)	Cargo (n=43)	Cargo (int) (n=34)	Cargo (n/r) (n=9)	Others
Environmental-friendly technologies	0.39	0.45	0.35	0.37	0.25	0.35
Further collaboration among relevant stakeholders	0.46	0.45	0.47	0.52	0.31	0.39
Increased competition among transport service providers	0.58	0.57	0.59	0.62	0.47	0.61
Innovative technologies	0.59	0.62	0.56	0.57	0.53	0.58
Digital improvements	0.60	0.59	0.60	0.61	0.47	0.61
Improved custom/border services	0.61	0.60	0.62	0.65	0.50	0.64
Traffic safety and security	0.69	0.67	0.74	0.70	0.86	0.57
Improved infrastructure flexibility and physical conditions.	0.70	0.62	0.70	0.67	0.83	0.47

Hindrances	All	Planner	Cargo	Cargo (int)	Cargo (n/r)	Others
Lack of digital infrastructure and digital service	0.26	0.26	0.24	0.24	0.28	0.39
Customs and border services	0.49	0.41	0.27	0.29	0.19	0.33
Expensive innovative technologies	0.34	0.35	0.33	0.32	0.33	0.39
Legislative factors hindering infrastructure development	0.33	0.34	0.32	0.28	0.47	0.31
Lack of timely information	0.38	0.43	0.23	0.19	0.36	0.38
Inadequate service frequency and connectivity in transport chain	0.36	0.51	0.22	0.18	0.38	0.35
Fragmented organisational collaboration	0.49	0.47	0.37	0.36	0.39	0.47
Current infrastructure inadaptive to growing demand	0.35	0.64	0.34	0.26	0.67	0.36
Weather conditions	0.47	0.43	0.60	0.60	0.61	0.47
Shortage of infrastructure investment funding	0.62	0.76	0.46	0.43	0.56	0.71