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FINAL REPORT 1/2023

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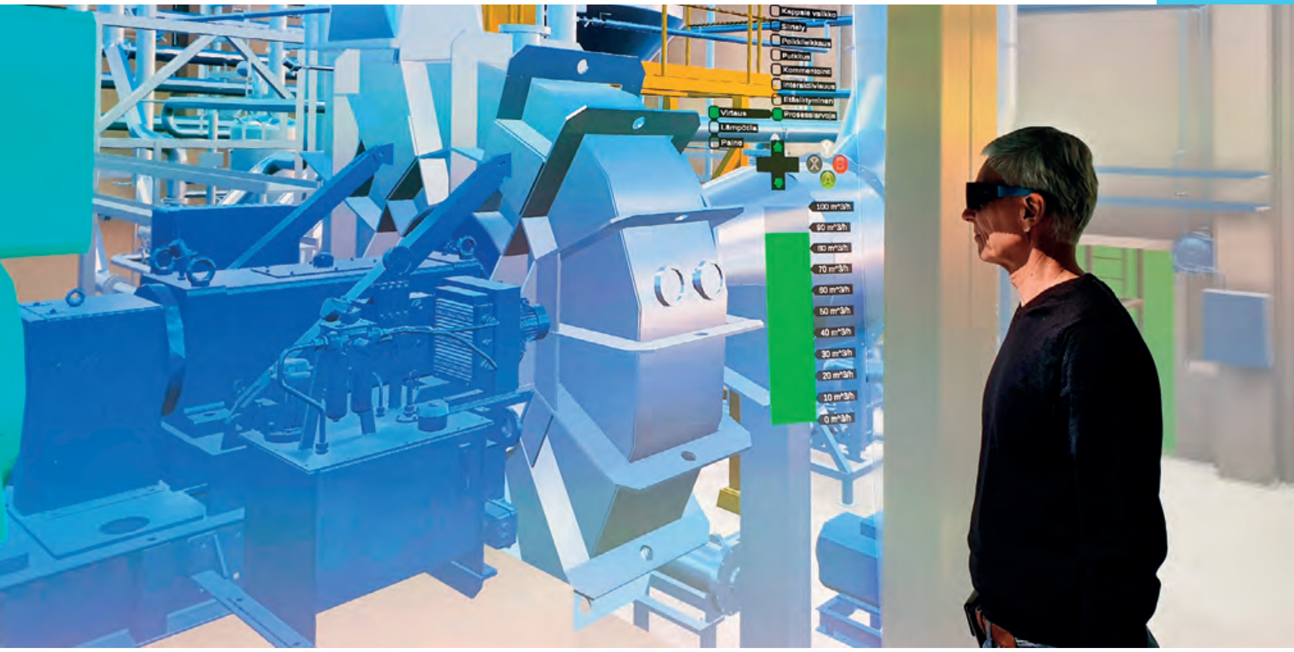
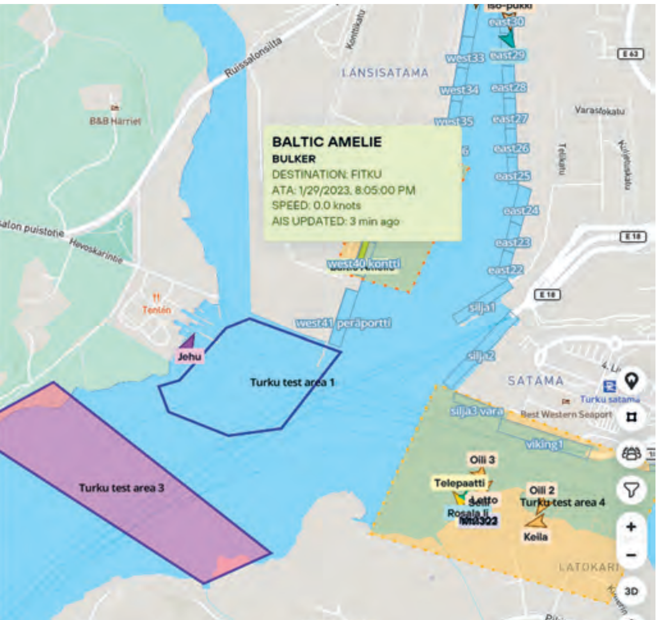
Sea4Value – Smart Terminals

2021 – 2023





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Ferry terminal, Port of Turku, Finland.
Photo: Mikhail Markovskiy

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FOREWORDS

The shipping industry is at the forefront of global trade and commerce, connecting economies and facilitating the movement of goods around the world. However, the traditional operations of sea terminals can be complex, time-consuming, and resource-intensive, with significant environmental impacts. With the global economy changing at an unprecedented pace, there is a growing need for sea terminals to become more efficient, sustainable, and responsive to the needs of the industry. Maritime port digitalization provides a critical solution to these challenges, helping ports to reduce their environmental impact and meet the demands of a rapidly changing world. Reducing emissions in ports is becoming increasingly important due to the growing concern about the environmental impact of shipping and the need to address climate change.

Preparation for the Sea4Value (S4V) program began already in 2018. DIMECC's Design for Value (D4V) project was going to end soon, and Rolls-Royce had just demonstrated the world's first fully autonomous road ferry. Therefore, it was quite understandable that the focus was on a digital and autonomous transport system. However, this concept was so broad that, in early 2019, it was decided that it was better to divide this program into three different projects, focusing on port activities, the fairway part, and finally open sea voyages. In 2020, S4V Fairway was the first of these to start, followed by S4V SMARTER in 2021.

Sea4Value SMARTER (smart terminals) is a collaborative project among multiple organizations, such as companies and research institutions, which aims to develop innovative solutions and bring them to market. The project has two main objectives: the reduction of emissions and the exceptional flow and experience of passengers and cargo. These objectives were taken into consideration in three use cases, which are ship turnaround, truck traffic, and passenger flow. The project is supported by Business Finland, a Finnish government agency responsible for promoting the innovation and competitiveness of Finnish businesses. In this report, we take an in-depth look at the various ways in which terminals can be made smarter. From the deployment of smart technologies such as Internet of Things (IoT) sensors and artificial intelligence (AI) algorithms, to the automation of processes such as truck entry into the port area and yard management, we explore the benefits and best practices for adopting these technologies.

Overall, the importance of maritime port digitalization lies in its ability to drive improvements in efficiency, safety, sustainability, and competitiveness. By embracing digital technologies, ports can remain competitive, meet the evolving needs of their customers, and ensure their long-term viability. This project aims to address some of these challenges and to explore new ways to optimize maritime operations. By leveraging the latest technology and innovative approaches, the project will seek to improve safety, reduce emissions, and increase efficiency in the maritime sector.

The work in the DIMECC S4V SMARTER program will certainly continue in a new program under preparation within DIMECC. Solutions for smart maritime operations are far from ready. DIMECC has enjoyed working with the consortium and is happy to further enhance such co-creative work. Such public programs cannot be possible without funding, and the program consortium is grateful to Business Finland.

Anssi Lappalainen
Senior Project Lead
DIMECC

PROGRAM PRESENTATION

Digitalization and increased levels of autonomy in transport are expected to take leaps forward in the coming years. This development can help in creating safer, more efficient, sustainable, and reliable service chains to meet the requirements for a better quality of life and global prosperity. Harbor operations connect maritime transport to other modes of transportation and enable multimodal transportation. Smart harbors are in a central role in future transport chains. Well-built digital infrastructure is essential in both optimizing operations and planning for future investment and maintenance needs. Progressive data management and data sharing are essential for transparent, interoperable, safe, effective, and environmentally friendly operations.

The Smart Terminals (SMARTER) project began in early 2021. It enlarges the scope of the DIMECC Sea4Value program to harbors and ports by developing solutions that benefit RoRo and RoPax harbors in reducing emissions by optimizing harbor operations and improving the cargo and people flow. The mission of SMARTER is to create replicable models for digitalization, service innovation, and data usage and sharing in harbor environments, and to prepare for the future by taking steps toward smart and autonomous maritime transportation. This will be achieved using advanced technology and innovative techniques, with a focus on sustainability and efficiency. The project will target the optimization of maritime operations, including the reduction of fuel consumption and emissions, the improvement of cargo-handling processes, and the enhancement of passenger experiences at the terminal. This will be accomplished through the implementation of smart solutions, such as digitalization, automation, and data analysis. The results of this project will have a positive impact on the environment, provide a better experience for passengers, and lead to cost savings for companies and stakeholders in the maritime industry.

SMARTER, as a transformative project, aims for wide societal influence by providing concrete, research-based recommendations on regulation, business, and data usage and sharing and for standardization. The project focuses on three use cases:

1. Speed up ship turnaround time
2. Optimize truck traffic
3. Improve people flow

The work is organized under five work packages, which are:

- WP1 Business transformation
- WP2 Analytics
- WP3 Data collection and management
- WP4 Sensors and connectivity
- WP5 VR/AR

The results of this project will have a significant impact on the maritime industry, providing valuable insights and best practices for companies, governments, and other stakeholders looking to improve their operations and reduce their impact on the environment. The project will also provide a better experience for passengers and cargo, making maritime transport a more attractive option for those looking to move goods and services around the world. In conclusion, this maritime project aims to create a more sustainable, efficient, and enjoyable experience for everyone involved in terminal operations. By leveraging technology and innovative approaches, the project will contribute to a better future for the maritime industry and the world.

SMARTER has the potential to deliver a wide range of benefits, including enhanced efficiency, reduced emissions, improved customer experience, and increased competitiveness. By automating manual processes and leveraging real-time data and analytics, ports can optimize their operations and reduce waste, leading to significant improvements in efficiency. By streamlining operations and reducing bottlenecks, smart terminals can help to lower emissions and minimize their environmental impact. With real-time data and insights into cargo movements, passenger movements, and vessel schedules, RoRo and RoPax terminals can provide a more transparent and reliable service to customers, enhancing their experience and building trust in the industry. By embracing technology and innovation, smart terminals can enhance their competitiveness and meet the evolving needs of the industry, helping them to stay ahead of the curve in a rapidly changing world.

The program consortium includes nine companies and five research organizations, which are: ADE, Ahola Digital, Awake.AI, Brighthouse Intelligence, Fimpec, Lingsoft, Nodeon, Teleste, VISY, Novia University of Applied Sciences, Turku University of Applied Sciences, University of Jyväskylä, University of Turku and Åbo Akademi University. Program management and facilitation was done by DIMECC. The project was funded by the consortium partners and Business Finland.

Anssi Lappalainen
Senior Project Lead
DIMECC

ADE

AHOLA DIGITAL

awake.ai

BRIGHTHOUSE INTELLIGENCE

Fimpec

Lingsoft®

NODEON

TELESTE

VISY

NOVIA UNIVERSITY OF APPLIED SCIENCES

TURKU AMK
TURKU UNIVERSITY OF APPLIED SCIENCES

JYVÄSKYLÄN YLIOPISTO
UNIVERSITY OF JYVÄSKYLÄ

UNIVERSITY OF TURKU

Åbo Akademi University

BUSINESS FINLAND

DIMECC

Port of Turku, Finland.
Photo: Igor Grochev

AHOLA
DIGITAL

AHOLA DIGITAL

Ahola Digital Oy Ab is a Finnish software company with over 20 years of experience in developing business software for the transportation and logistics industry. We help our customers to develop dynamic, profitable, transparent, and environmentally friendly transport operations and to get ahead in competition today and tomorrow. Thanks to our digital logistics concept, Ahola Digital's employees are leaders in our industry: they work with the best innovations and develop new solutions for the sector. We are committed to actively developing our employees' competence and know-how – the ability to be Way Ahead.

Calculating transport emissions and real-time truck driver communication

Contributors

- Tommi Hollström, Toni Penttinen, Roman Likhachev, Nikola Vojnovski (Ahola Digital)

According to Our World In Data, the transportation industry is the second largest contributor to global warming. The greenhouse gas emissions from transportation operations are predicted to grow drastically in the upcoming years. With the help of digital services, organisations can monitor emissions, and analyse and optimise operational processes to tackle the negative impacts of transportation operations.

Background

The sustainability of the road transport segment, as illustrated in the picture below, goes hand in hand with profitability. Optimisation of cargo capacity, operations, and processes results in sustainable transportation. The research work and the digital services developed by Ahola Digital focus on real-time information sharing among the relevant logistics partners to provide just-in-time arrival and digitalisation of harbour operations from the freight transport company's perspective. Greener logistics, reduced CO_2 emissions, and improved profitability are the consequences of an optimised flow of goods and the execution of operations.

Figure 1. **The sustainability of the road transport segment.**

Solution, method

Ahola Digital has researched and developed an emission calculator and real-time driver application to enable organisations to monitor emissions and optimise operations. Below is the process flow diagram describing the steps taken into account when calculating emissions.

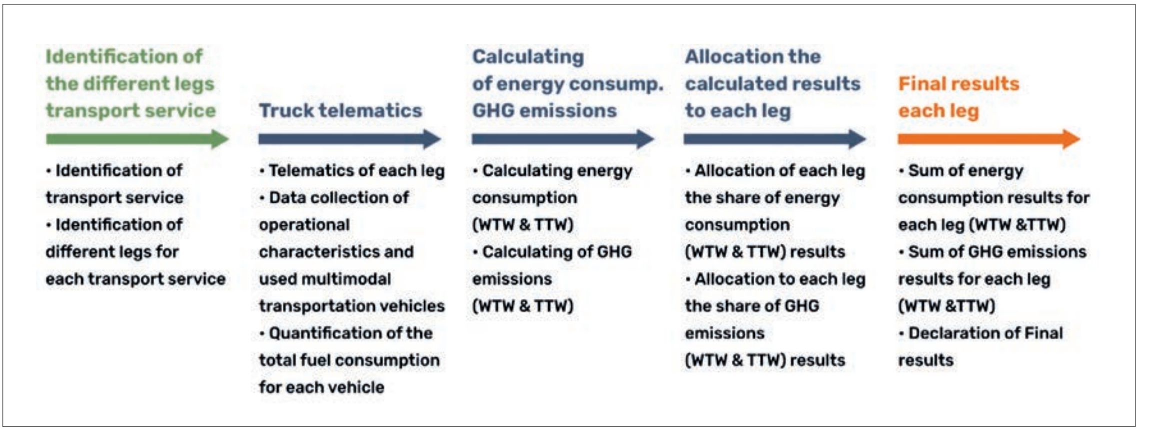

Figure 2. **Process flow diagram.**

The emission calculator app provides calculations of the emissions from operations in the multi-modal environment using the EN 16258 standard as a basis for calculations. The outcomes of the calculations show tank-to-wheels and well-to-wheels emissions and energy consumption. The application estimates emissions on a trip level, on each leg, and for every cargo in transportation. Moreover, the emissions calculator provides analytics in various charts and allows for the configuration of calculator methods and parameters. All calculations are finalised once the trip is marked as completed in an integrated TMS system.

Figure 3. The emission calculator app.

The real-time driver's application gives drivers access to real-time information regarding the shipments and events and enables two-way communication between drivers and dispatchers. The application includes relevant information about the cargo, instructions about loading and unloading, ferry instructions, and information about border crossings. Additionally, the application supports image uploads from drivers (e.g. regarding deviations) and integration into the cargo owner's app for additional instructions. The information in the application is always up-to-date, as it is connected via API to the transport management system (TMS). Drivers also have access to a map that shows the freight-appropriate routes that drivers are encouraged to take. Drivers can communicate with the back office and potentially with other drivers via instant messaging, and with the back office and potentially in future with other drivers using private chatrooms.

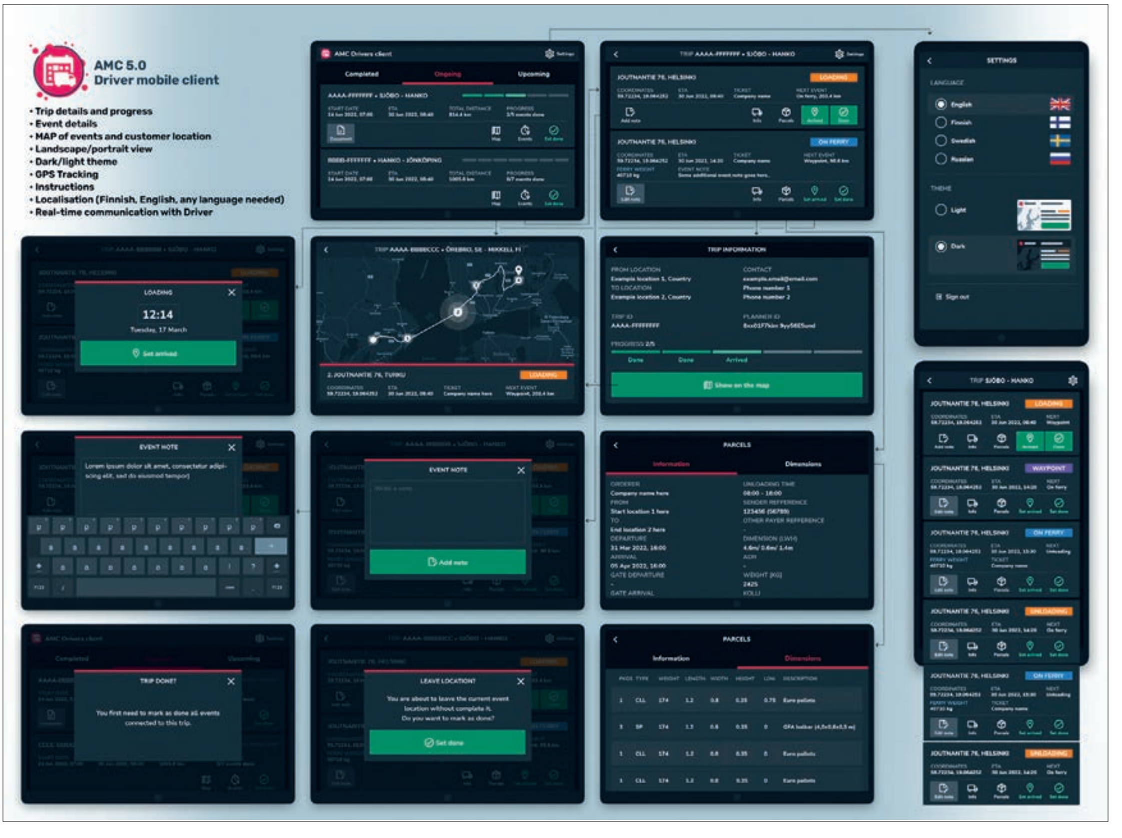

Figure 4. **The real-time driver's application.**

Results, findings, output, and impact

Access to real-time data is essential in optimising operations and taking the appropriate measures according to the in-field situations. Bi-directional communication between the drivers, back offices, and third parties in the logistics chain enables the latter to adjust the ongoing and upcoming trips according to real-time changes. The optimised operations result in improved profitability and decreased total emissions. Harbour operations rely on the physical presence of drivers. Drivers are needed to provide physical papers in the harbour office. Providing digitalisation to this process would increase efficiency amongst stakeholders involved in the logistics corridor. The figure below shows real-time status message contents shared in various formats (JSON, XML, etc.).

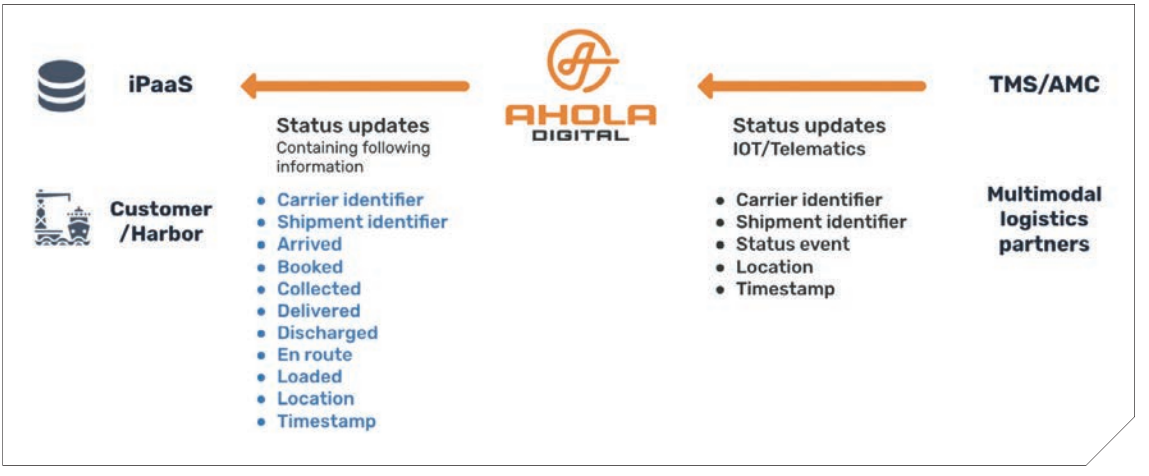

Figure 5. The real-time status message.

With an application that keeps track of all emissions from the organisation's operations and enables reporting of the emissions to the organisation's clients, transport service providers are prompted to act with greater responsibility towards the environment and to seek ways to decrease the negative impacts. Emissions are reduced by optimising operations, electrifying the fleet, increasing the biofuel proportion, and leveraging other transportation modalities. The new standard ISO 14083 Greenhouse gases — "Quantification and reporting of greenhouse gas emissions arising from transport chain operations" will be released in March 2023, potentially affecting the future development of emission calculator applications.

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- **Hannah Ritchie, Max Roser and Pablo Rosado**, 2020 "CO_2 and Greenhouse Gas Emissions". Published online at OurWorldInData.org. Retrieved from: 'https://ourworldindata.org/co2-and-greenhouse-gas-emissions' [Online Resource]

VISY

code

VISY

Visy Oy was founded in 1994 and provides gate automation solutions to manage the flow of traffic, cargo, and personnel in ports, terminals, factories, and logistics centers. Every asset that goes in or out of a facility, whether by road, rail or quay, can be managed using Visy technology. With a history spanning nearly three decades, Visy is a pioneer in optical character recognition (OCR), applied AI, and deep learning for camera-based solutions for logistics automation. Visy ecosystems manage more than 6,000,000 automation tasks per day in over 30 countries to improve the quality of the supply chain.

Artificial intelligence for lightweight terminal access infrastructure

Contributors

- **Heikki Huttunen, Jyrki Selinummi, Liang Fang, Joona Hakala, Konsta Juvonen, Elias Keso, Kristian Lempinen, Paula Sartori, Tomi Koskinen, Petri Sarpola, Iiris Kujala** (Visy Oy)
- **Vincent de Andrade** (Codeo Oy)

Traditional access control systems require significant infrastructure to operate. Developments in computing hardware and machine intelligence can be used to replace parts of the infrastructure with software, bringing significant CAPEX savings, but also improved flexibility and accuracy. The latter factors facilitate faster installation, less downtime, and manually handled exceptions, which all contribute to a lower total cost of ownership for the customer.

Background Traditional access control solutions are very hardware-intensive, consisting of physical infrastructure such as ground loops, laser scanners, driver kiosks, imaging portals, and so on. As the level of machine intelligence has developed, replacing physical infrastructure with intelligent software components has become an attractive option to gain a competitive edge in the market. Specifically, we focus on three aspects of the digitalization of access control, logistics, and asset management at international ports: (1) innovative mobile services for port end customers, (2) situational awareness and surveillance of yard logistics using artificial intelligence on low-cost surveillance cameras, and (3) exploitation of Edge AI to solve port logistics challenges.

Solution The solutions to all three aspects are described below.

1. Innovative mobile services for end customers

In most access-controlled facilities today, the check-in process for cargo traffic is based on very traditional infrastructure: the driver checks in manually at either service counters or physical driver kiosks at the cargo entrance gate. This is very different from, for example, air traffic, in which passengers check in using their mobile devices, and manual service desks and check-in kiosks are nowadays only a backup option. Therefore, the need for a driver app that would enable check-in using a mobile device is evident. Moreover, during the pandemic, customers were reluctant to implement any processes that risked spreading the disease (e.g., kiosk touchscreens or indoor service counters).

The technical requirements for such a driver app are unique, and they may include the following features: the driver application should be multilingual, should require no installation on the end device, should work on a wide spectrum of devices and, most of all, should be easy to use. Moreover, there are several non-technical requirements, such as privacy and legal (GDPR) design choices, which need to be taken into account with the largest possible geographical scope.

Technically, the application was implemented using Progressive Web Application (PWA) technology, which allows an attractive look and feel on any mobile device but avoids problematic management and installation through an application store. The application also features easy entry of data, such as automatically entering license plates or container codes using the mobile camera with Visy's in-house optical character recognition (OCR). In addition to the driver application, the process also requires administrative views for the customer, as well as for other involved third parties (such as haulage companies).

Results, findings, and impact In customer surveys, we have identified several benefits of the mobile check-in. Apart from those mentioned above, the mobile solution reduces the check-in time, reduces the need for physical hardware, and gives a better understanding of who is inside the facility. The latter is also a safety concern, since many locations require visitors to pass safety training before entering; however, if access permits are based only on the vehicle identity, the driver may not be the person registered in the access permit. The application is one way to increase the level of identification of the driver without extra personnel costs.

The system is being piloted during spring 2023 at a customer site with a significant amount of daily traffic. The different kinds of users of the system will be interviewed, and their experiences will be helpful for further development of both the software and the user experience.

2. Situational awareness and surveillance of yard logistics

Traditional methods of tracking the cargo flow in the yard rely on physical infrastructure: for example, intermittent checkpoints with vehicle identification either by RFID or license plate reading. Alternatively, vehicles have been tracked using, for example, cellular or Bluetooth signals emitted by drivers' mobile phones. However, all of these options involve compromises in accuracy, additional costs, or delays to the traffic flow.

Following our low-infrastructure approach, we implemented a track-and-trace system using overview cameras installed high above the terminal yard, such as on a light mast. The cameras work together, facilitating a smooth handover of tracked vehicles between cameras. The data is integrated with the Visy Gate Operating System, thus keeping track of vehicle and cargo identities instead of just statistically following the paths that vehicles commonly use.

Results, findings, and impact

There has been significant customer interest in the development. In particular, integration with other Visy databases has raised interest. Knowing the identity of every vehicle (to the level of license plate, container/trailer codes, contents of the cargo unit even the driver's name, if that is registered during check-in) is a unique feature not available from competitors. In an ideal case, the system would enable perfect situational awareness of the entire yard: a map of allocated parking places with a full ID of every cargo unit at all times.

The system is being piloted during spring 2023 at a customer site.

3. Edge AI for port logistics

Visy's machine learning expertise is among the most advanced in the industry in static recognition locations, such as the gate or the quay. As commercial-off-the-shelf hardware develops, we also want to bring this intelligence even closer to the edge, running the recognition models inside the camera. As a concept, edge computing is not particularly novel, but running it in a hardware-agnostic manner on a variety of platforms is more so. Therefore, our goal is to support several edge computing platforms with minimal changes to the development pipeline. This way, switching between vendors and platforms is seamless and helps to operate in a world where technical needs, supply, and even geopolitics may play a role in hardware selection.

As a great example of the benefits of edge computing, in the pursuit of lighter infrastructure, we have implemented event triggering directly from the video stream, instead of physical ground loops, photo cells, or laser scanners. This feature has been in production for years already, but during the project, we have moved the AI component from the server to the edge (inside camera). This decreases the need for CPU power, network bandwidth, and configuration, and also facilitates a higher level of privacy without compromises: in selected applications, we can promise that no pictures will ever leave the camera.

Results, findings, and impact

Recognition at the edge has been a success. For example, replacing physical detectors of when a car is approaching the gate with software-based ones has been transformative in terms of how the gate environment is designed nowadays. Many customers insist that they will only accept the new software-based solution, knowing that all hardware components will eventually fail – usually resulting in losses of productivity, uptime and efficiency at the facility.

Moreover, as a side product of the development, we have also prototyped the recognition inside a mobile phone: this example of integrating recognition into edge devices is now a standard feature of the mobile check-in application discussed above.


DAF
XF


VISY

awake.ai

AWAKE.AI

Awake.AI is a cloud platform startup providing digitalization and AI services globally for maritime logistics actors. Our products include AI-supported tools for planning and situational awareness, ML-based prediction services, computer vision solutions for cargo monitoring, and custom digital solutions for optimizing multimodal logistics operations. Awake.AI is building an ecosystem for smart ports and shipping, and the company's mission is to lead the transition to sustainable and intelligent maritime logistics, in which 10% of the global CO_2 emissions from shipping will be reduced by 2030 with the help of the ecosystem partners.

Ship and truck turnaround optimization

Contributors

- Petri Aarnio, Vaklin Angelov, Mikko Hakila, Sami Jalo, Jan Kinnunen, Santeri Kääriäinen, Eero Lehtonen, Jussi Poikonen, Simo Salminen, Karno Tenovuo, Petra Virjonen, Kari Virtanen, Jonatan Wiik

Background

In the SMARTER project, Awake.AI has focused on developing cloud-based data analytics and machine learning capabilities, and related software services and applications aiming to improve the efficiency of operations across the multimodal supply chain surrounding sea ports. The developed components include automated vessel fleet analytics, producing schedule prescriptions for vessel traffic planning, automated traffic event monitoring in ports, analytics-assisted port call planning, machine learning-based predictions of port operation durations, automated monitoring of port storage areas, and predictive analytics for hinterland traffic rates and turnaround times. The developed solutions contribute to enhanced overall situational awareness, predictability, and more efficient planning over the different phases of cargo flow through sea ports. In the following, we outline solutions related to the above-listed application areas developed during the project.

Continuous automated analysis of global vessel traffic

Solutions, methods Leveraging existing services in the Awake.AI platform for predicting global vessel schedules, additional analytics capabilities and applications were developed for automated monitoring of the status and performance of vessel fleets. These can be defined either dynamically based on, for example, arrivals at a given port, or as a fixed set of vessels of interest to an operator. For vessels in a given fleet, multiple performance metrics can be monitored continuously, including:

- Schedule validity (current realization vs. plans) – can the vessel meet its planned time of arrival (PTA) or not?
- Computing optimal speed vs. PTA – is the vessel rushing to wait?
- Estimated bunker consumption and CO_2 emissions for the remaining voyage leg
- Comparison of voyage metrics with historical outcomes (timeliness, bunker consumption, etc.)

Implementing these functions generally requires case-specific integrations (e.g., with planned vessel schedules and bunker consumption characteristics). The work included developing related data ingestion services for multiple types of data sources, including national single window systems for port call schedules, and vessel operators' proprietary systems. Prediction models were developed for estimating bunker consumption and CO_2 emissions for ongoing voyage legs versus dynamic factors such as vessel speed and draught.

The capabilities outlined above are necessary in the maritime industry to enable scalable and automated implementation of vessel just-in-time (JiT) arrivals, which is recognized by the International Maritime Organization (IMO) as one of the main steps toward improving the efficiency and sustainability of the industry (https://greenvoyage2050.imo.org/just-in-time-arrivals/). The key principle of JiT is that vessels should not rush to wait at anchor for berthing, which would generally reduce fuel consumption and emissions. However, this cannot be enabled by considering vessel traffic in isolation, as it also requires improvements in the situational awareness and predictability of port congestion, operations schedules, cargo availability, and so on, to know what the correct times are for vessels to arrive. These aspects are considered by the other components developed by Awake.AI during the SMARTER project, as outlined (Figure 1).

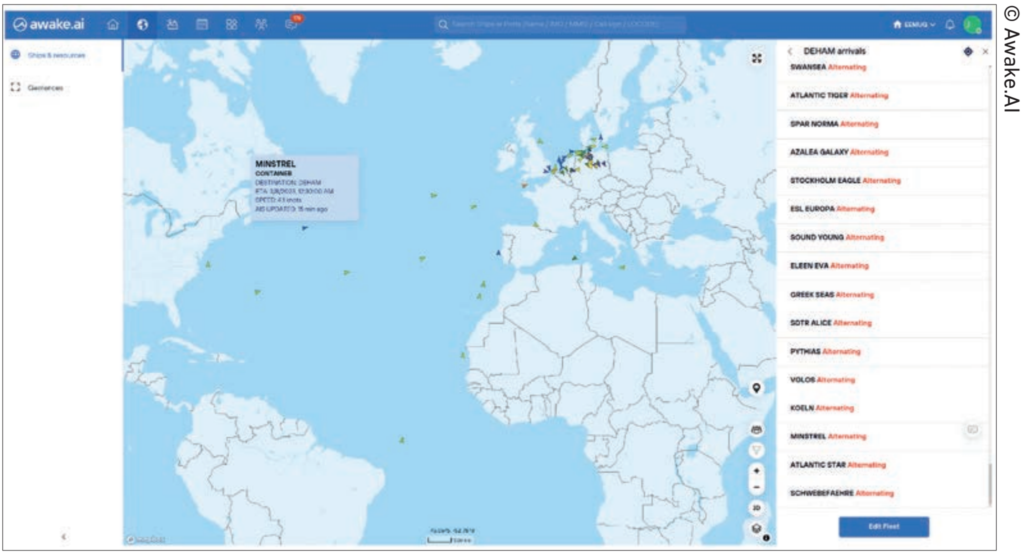

Figure 1. A dynamic vessel fleet corresponding to vessels under way to the port of Hamburg, as shown in the Awake.AI smart port application.

Automated schedule prescriptions and monitoring of port traffic events

In addition to ensuring that vessels are following their planned arrival times, optimization of port call turnaround times requires that the PTAs themselves are well selected regarding the traffic and cargo flows of the port. In large ports, this can be a highly complex task, as the possible arrival and departure schedules of vessels depend on the aggregated traffic at the port (i.e. the potentially evolving actual schedules of all vessels arriving at or departing from the port at a given time), and related restrictions on usage and availability of finite resources such as fairways, turning basins, tugs, and free berths. Furthermore, environmental factors such as tide cycles and wind conditions cause dynamic limitations, especially for the arrival and departure of large vessels.

During the SMARTER project, Awake.AI has developed analytics services that estimate possible vessel arrival time windows based on vessels' current voyage status combined with port-specific rules, restrictions, and current planned port call schedules for the whole port. This takes into account tide windows as functions of vessel size and draft, wind bans, fairway passing restrictions, bridge air draft restrictions, and planned berth availability, among other things. These functions have been deployed as microservices in the Awake.AI cloud platform, including integrations with external data sources providing necessary data such as tide and wind forecasts, port call planning information, and vessel positioning information. The produced schedule estimates are designed to be passed through application programming interfaces (APIs) to external information systems operated by, for example, port authorities or vessel traffic management organizations.

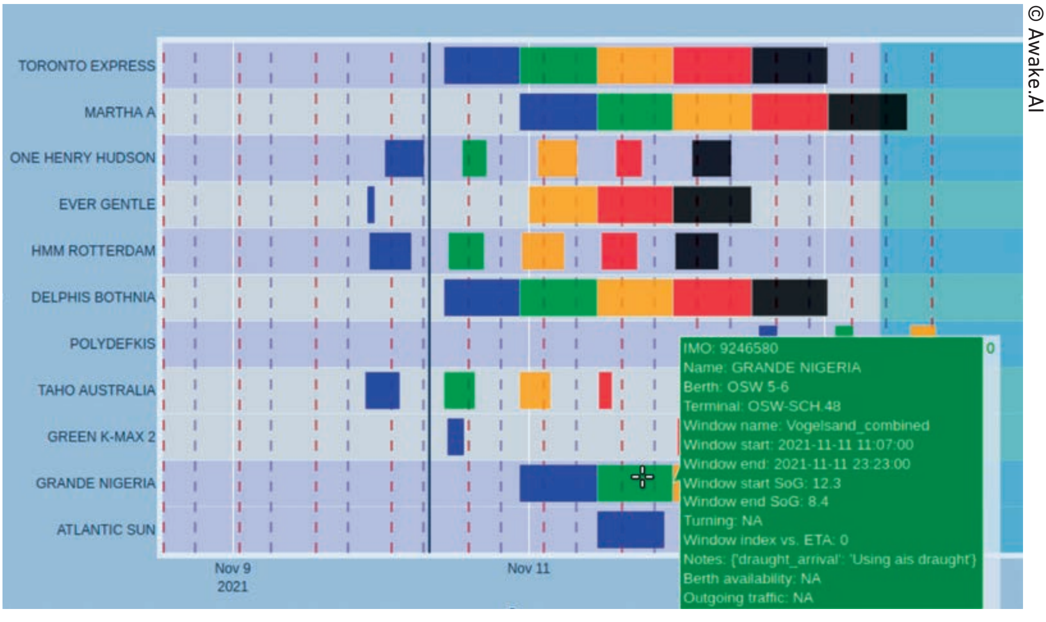

Figure 2. **Example visualization of automatically computed port approach time windows for arriving vessels, taking into account complex limiting factors such as tide, wind, passing restrictions, and berth availability. Dashed lines illustrate high and low tides, and the approach windows are colored according to schedule priority (green indicating the closest feasible time window to a vessel's current estimated arrival time).**

Within the port area, actors such as terminal operators, port authorities, and service providers also have varying needs to monitor and record traffic activities in specific port subareas. Furthermore, it is necessary to communicate, for example, temporary restrictions in area usage to the whole port community. To address these needs, Awake.AI has developed cloud-based analytics services and user interface features in the Awake.AI smart port web application, to enable automated monitoring of traffic in user-defined geoareas. This can be used for producing automatic warnings and notifications of traffic events in easily customizable areas and time intervals, with logging of all detected events to cloud databases for later analysis. Resource tracking and visualization has been enabled for both vessels and landside objects, such as cranes or land vehicles, based on IoT sensor integrations where available.

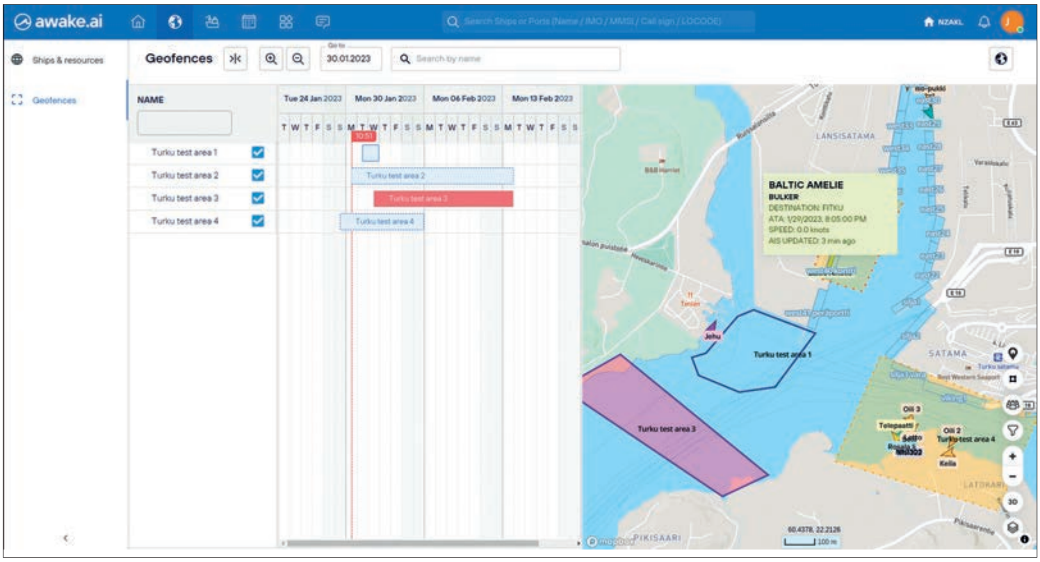

Figure 3. **A screenshot of the geofence function developed in the Awake.AI smart port application. This enables flexible configuration of tracked geoareas in both location and time, and also displays a live map of resources moving in the port.**

Port call planning with ML support

For detailed planning of vessel port calls, Awake.AI has developed a planning application that enables relevant organizations and users to plan in detail upcoming berth visits and use of port call resources such as berth pockets, bollards, and landside equipment. The application includes map- and timetable-based views for the current locations and predicted schedules of vessels, and it provides automatic warnings if conflicts between plans or between plans and actual events are detected. Furthermore, machine learning-based predictions provide continuously updated estimates on vessel arrival times to relevant port waypoints, and they can also be used as a basis for warnings and notifications when actual schedules start to deviate from plans.

In addition to efficient planning and monitoring of port calls, the application enables communication of the plans and related situational awareness to the larger port community, also providing other related information relevant for port calls, such as weather and tide predictions, and local weather sensor readings. The application also includes automatically generated chat rooms for each vessel port call, to enable related communications and logging of user-based port call events. This solution was developed as a web application maintained in the Awake.AI cloud platform, and it is currently provided globally as a commercial service for port authorities or related vessel traffic planners.

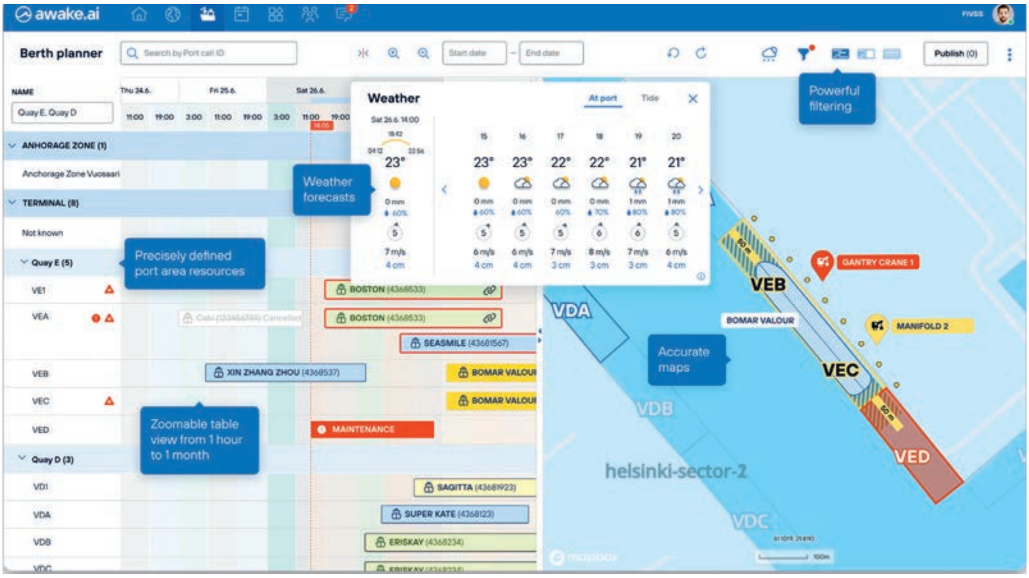

Figure 4. **Screen capture of the Awake.AI port call planning solution with selected UI features highlighted.**

Cargo operation predictions

Minimizing port turnaround times of vehicles (e.g., by reducing waiting times) for both sea and land traffic requires awareness and accurate estimates not only of vessel schedules but also of the durations of cargo operations, including discharge and loading times specific to each vessel, port call, and cargo type. These estimates should be made available to the relevant actors operating in the port ecosystem, to enable informed planning of operations and schedules.

During the SMARTER project, Awake.AI has performed case studies on applying machine learning regression models to predict cargo operation completion times, both for future port calls and for ongoing operations, using online data on their current progress. By combining cargo operation predictions with vessel voyage prediction capabilities, this enables the production of predictions on possible congestion and waiting times for vessels at port, which is a necessary capability for enabling just-in-time arrivals. Our aim is to deploy these capabilities in future research and commercial pilot projects, in combination with our existing vessel schedule prediction services, to facilitate large-scale JiT solutions globally.

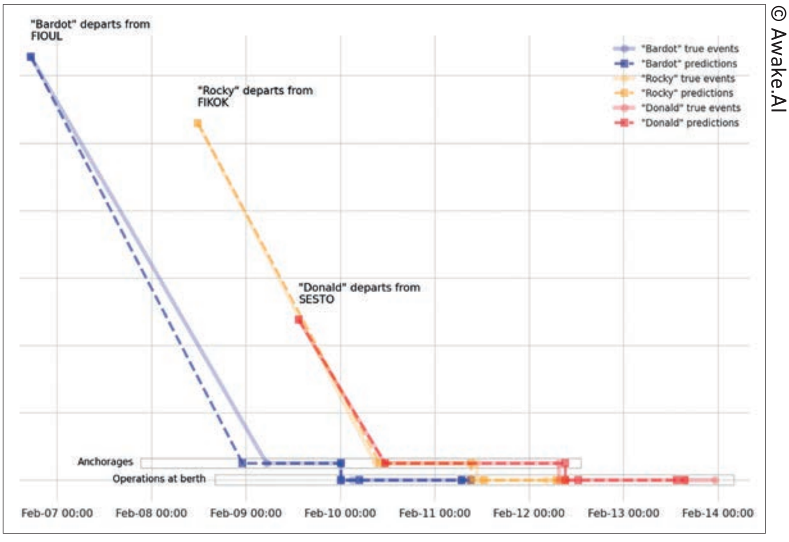

Figure 5. **Example visualization of combining prediction models for vessel voyage schedules and cargo operations during port calls. Three vessels are arriving in the same berth, and the combined prediction models indicate even before the start of each voyage that the vessels' port calls will include significant waiting times at anchor.**

Automated storage area inventory

Ports require capacity for temporary storage of various types of cargo (such as intermodal containers, trailers, cars, and bulk) and empty cargo containers. It is common for port actors to lack precise and up-to-date data on the status and available capacity of storage areas, requiring continuous manual effort to update inventories. To improve situational awareness regarding cargo storage, Awake.AI has developed a system incorporating local sensors, edge processing, and cloud-based analytics, to continuously monitor and automatically inventory the contents of storage areas containing various types of cargo.

The system is based on installing a number of lidar sensors in the areas to be monitored, along with edge processing units that fuse the data from the lidar sensors to a common coordinate system. Analytics services then combine the fused lidar sensor data with area specifications (such as what type of cargo is stored in which parts of the target area) provided by the storage area owner in, for example, a standard CAD software format. Based on these data, the system analyzes the area contents, providing a listing of cargo or container items by type, changes from the last measurement, and so on. The system can also be configured to analyze the volume of bulk cargo stored in the area. Furthermore, algorithms were developed to ensure the robustness of the analytics, for example, by automatically detecting temporarily degraded sensor data quality due to heavy fog or snow, and automatically calibrating the sensor measurements when affected by a vertical shift due to snow cover.

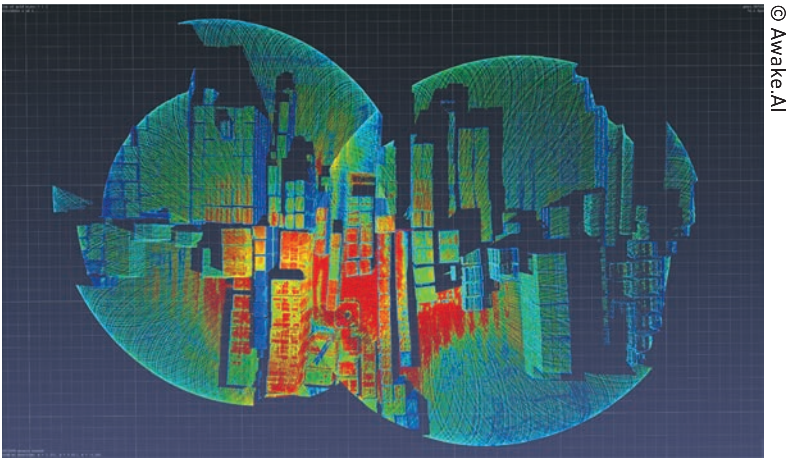

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Figure 6. **Visualization of fused lidar data from two sensors measuring a storage area containing several types of packages.**

Predictive truck traffic analytics

Combining the predictive modeling functions outlined above, Awake.AI has developed analytics services for predicting hinterland traffic flow rates and truck turnaround times, based on planned and predicted vessel port calls. This includes training dedicated regression models for cargo exchange volumes per port call, stochastic models for simulating the dwell times of cargo elements (e.g. containers) in the port, and turnaround prediction models that estimate congestion levels related to variation in hinterland traffic event rates (vehicles entering or exiting the port).

In short, this system provides a holistic overview of upcoming multimodal traffic activities and possible congestion at the port, which is significant for port traffic planning and scheduling, city traffic management surrounding the port, and hinterland cargo carriers' capacity planning, among other things. The models and functions described above were implemented as microservices in the Awake.AI cloud platform, with a dedicated web interface to visualize the service outputs.

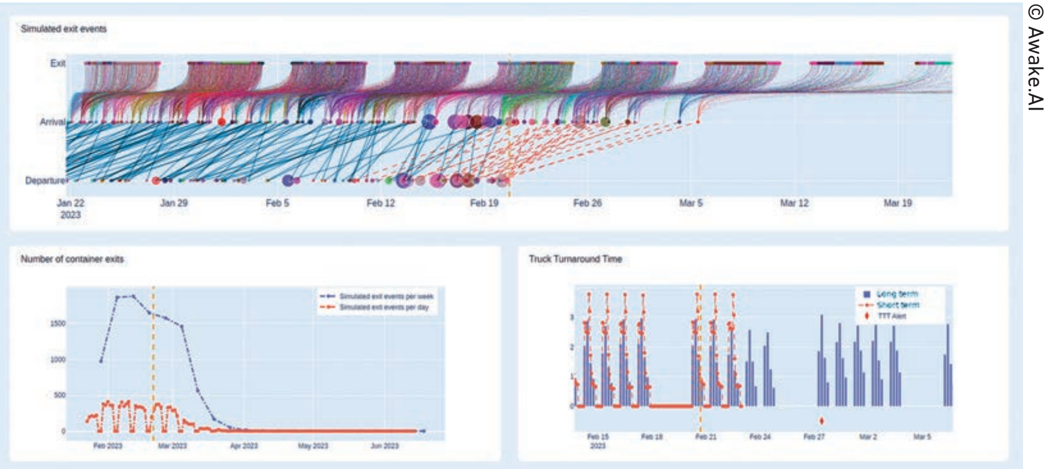

Figure 7. Screenshot of the web interface visualizing the information produced by the developed multimodal traffic prediction services. Top: illustration of predicted vessel schedules and container exit events. Bottom left: estimated metrics for daily and weekly traffic event rates. Bottom right: predicted truck turnaround times.

Summary of results

There is significant inefficiency in maritime logistics due to, for example, insufficient situational awareness and predictability of events and processes, lack of communication between actors, and lack of automation tools for scalable optimization of resource allocation. A practical margin for improvement exists for reducing the port turnaround times of vehicles on both the land and sea sides, but this cannot be solved with a single application. Instead, improvements in both digital tools and existing processes and practices are required across the multimodal supply chain.

During the SMARTER project, Awake.AI has worked on many solutions aiming to address the challenges outlined above for multiple stakeholders across the port ecosystem, such as shipping operators, vessel traffic coordinators, port authorities, terminal operators, cargo owners, and hinterland logistics operators. Some of the described solutions have been implemented as commercial pilots, some have already been developed into globally offered products, and some are prerequisites for future development, such as in enabling just-in-time port calls. However, all of these solutions have been implemented as working cloud-based services, tested in real data environments, and are ready to be applied in future commercial applications. In the future, Awake.AI aims to combine many of the developed functions in systems enabling holistic optimization of maritime supply chain operations.

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Passenger flow analysis

Contributors

- Professor Jukka Heikkonen
  Pouya Jafarzadeh
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Passenger flow analysis

Background

Object detection plays an important role in many applications, including autonomous vehicles, scene understanding, and pose estimation. It helps us to obtain complete image understanding by estimating object location, classifying objects, and tracking the object, as well. In other words, the purpose of object detection algorithms is to detect an object by precisely predicting the bounding box coordinates that contain the object. However, object detection still is a challenging problem due to illumination conditions and the variety of objects.

In an ideal situation, passengers should arrive at a port by a means of transportation that reduces congestion at the port and inside the terminal. Passenger flow is an intelligent video-based system to increase the operational efficiency of the passengers.

Solution, method

In the case study, we concentrate on automated video analytics of crowds related to harbor terminal buildings and their surroundings. This includes the detection of crowds and their level of occupancy and mode of behavior within an area of interest, as well as their predicted future behavior, for public surveillance and safety. A few examples of benefits of passenger flow are: optimized throughput times, increased safety and comfort of the passenger crowd, improved security and law enforcement response times, better estate utilization, and improved sustainability.

With the rapid development of deep learning, convolutional neural networks (CNNs) [1] show promising solutions in object detection. Inspired by the success of applying CNNs in several object detection methods, we used a CNN-based algorithm called You Only Look Once (YOLO) [2] to detect and classify passengers, and simple online and real-time tracking with a Deep Association Metric (Deep SORT) to track them in the harbor and terminal areas.

Automatic Human Pose Estimation (HPE) [3] can be employed in many real applications, such as sport analysis, video surveillance, and advanced driver assistance systems. HPE from an image or video is an important computer vision task that estimates human body parts from the data captured by sensors, particularly images and videos.

Results, findings, output, and impact

Using the aforementioned methods and algorithms, we built a system that is able to identify and localize people in the port area, monitor passenger flow inside/outside the terminal, and show current occupancies and detect any abnormalities by analyzing human poses and tracking movement routes.

Figure 1 shows a screenshot of the real-time system we built, which has identified people in the area (in order to comply with GDPR regulations, the system immediately blurs the people in the picture, to guarantee their privacy) and assigned a unique ID to each detected person, to enable the system to follow movement routes and to analyze the behavior of the person in the area of interest to detect abnormal conditions, such as falls, accidents or, if necessary, suspicious situations (*Figure 3*). The system provides real-time CSV data on the total number of people in the area and their location, including a timestamp (*Figure 2*).

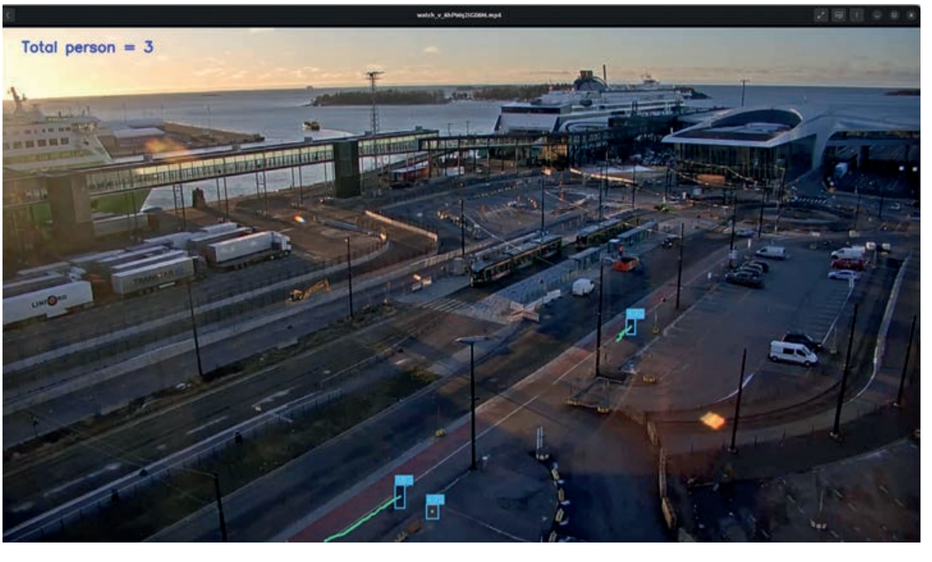

Figure 1. **An overview of the system.**

2023-01-30 15:03:14.7	1
2023-01-30 15:03:14.7	1
2023-01-30 15:03:14.8	1
2023-01-30 15:03:14.8	1
2023-01-30 15:03:14.8	4
2023-01-30 15:03:14.9	7
2023-01-30 15:03:14.9	8
2023-01-30 15:03:14.9	8
2023-01-30 15:03:14.9	8
2023-01-30 15:03:14.9	8
2023-01-30 15:03:14.9	8
2023-01-30 15:03:14.9	8
2023-01-30 15:03:15.0	8
2023-01-30 15:03:15.0	8
2023-01-30 15:03:15.0	8
2023-01-30 15:03:15.0	8
2023-01-30 15:03:15.0	8
2023-01-30 15:03:15.0	8
2023-01-30 15:03:15.0	8
2023-01-30 15:03:15.1	8

Figure 2. **Output data of passenger counting with timestamps.**

Figure 3. **Pose estimation.**

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Traffic analysis

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Traffic flow analysis

Background

In ports, the transport of cargo changes from ground to sea. The cargo can arrive by several means, of which truck traffic is one. Ideally, trucks should be able to arrive at the port in a way that minimizes the time spent in on the road while avoiding (and not generating new) traffic congestion. Another goal for optimization can be to minimize the time spent in the port area and in queues.

Road traffic and its entry into ports is an ample source for data. In the present work, we consider how a knowledge of the system might be helpful for future considerations in traffic planning. Two major targets were considered: predicting travel time and detecting traffic anomalies.

Solution, method

To analyze the traffic flow around the Port of Turku, the available data sources were mapped. In the analysis, we concentrated on three data sources: the publicly available TMS data provided by Digitraffic (https://www.digitraffic.fi/en/road-traffic/lam/), Distance API data from two major providers, and through-traffic data provided by the project partner Nodeon. The data collection points covered roads both around Turku city center and toward the city center (*Figure 4*). In addition, a number of other data sources were considered, including the cargo container counts provided by the Port of Turku and port gate vehicle counts provided by Visy.

TMS (traffic measurement system) data consists of observations of vehicles passing a measurement point on a road (*Figure 5*). For every vehicle, multiple fields are recorded, including the vehicle type and speed. From this raw data, a time series was created for each TMS station, consisting of the number of vehicles that passed the point in a given direction in each 5-minute interval in a day. This data was explored and prepared for further analysis.

Nodeon through-traffic data consisted of traffic measurements at various points around Turku (*Figure 4*). The measurement points consisted of input points and output points. At both points, the license plate of the vehicle was scanned. If a vehicle was detected first at an input point and afterwards at an output point, a point of data was generated recording the passing of time between both points. This data was anonymized, so further trips made by the same vehicle were considered as separate observations.

Further, the data from two major Distance API providers was sampled to complement the data collected by Nodeon. The travel times between the adjacent TMS stations and the different input-output pairs in Nodeon were queried for travel times over a two-week period in May–June 2022.

The data from the aforementioned sources was explored in a search for patterns or repeating subsequences. The similarity of subsequences was measured using dynamic time warping, which gives a score for the similarity of two sequences (*Figure 6*). In addition, the predictability of the travel times given by Distance API providers was examined using linear regression.

Results, findings, output, and impact

The TMS station data was found to be highly similar between weeks (*Figure 7*). In the data, business days are highly similar to one another, while weekends differ significantly. This observation confirms intuition concerning traffic. Using dynamic time warping for the distance between different days, the days can be clustered. We are currently working on clustering the traffic days into three categories: business days, weekends, and outliers. This would enable the creation of an early-warning system for traffic anomalies, such as accidents. In data analysis literature, this is known as "anomaly detection."

Regarding the travel time prediction using the Distance API provider data and the TMS station through traditional methods, the work is still ongoing. However, early results promise a reasonable prediction rate. Additional research is also underway on the possibility of predicting the travel time between two adjacent nodes by modeling the changes in traffic pattern propagation between the nodes: if a spike in traffic node A is observed with a lag at the adjacent node B, this lag could be used to predict the travel time between the nodes.

The outcomes of these two lines of research will be sent for peer review later in 2023.

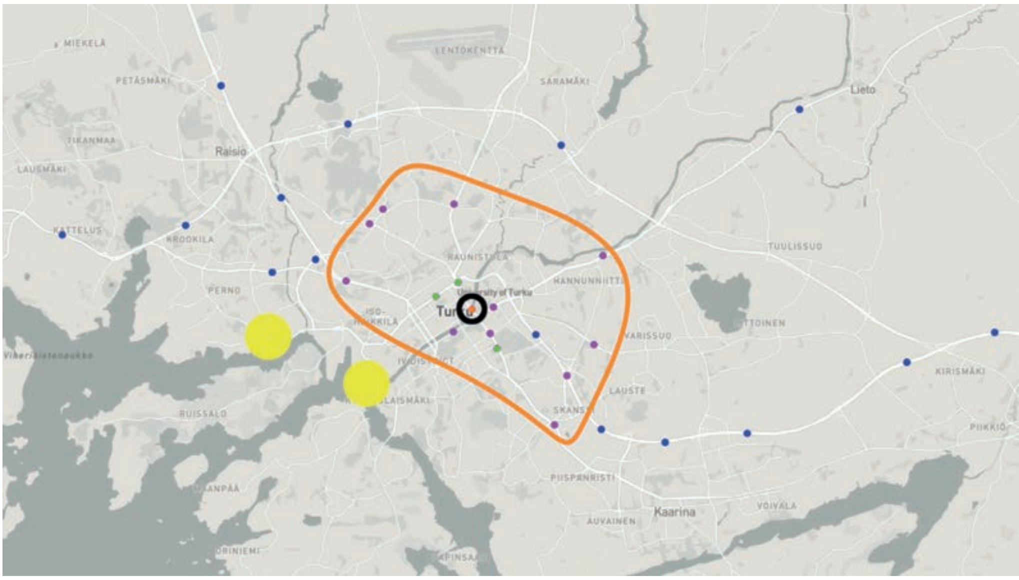

Figure 4. Data collection points around Turku. Blue points represent TMS stations. Magenta, green and orange dots represent Nodeon through-traffic measurement points: magenta for incoming and green for outgoing traffic, and the Turku Cathedral (orange) for both. The separation between the TMS data and Nodeon data points is marked with an orange line.

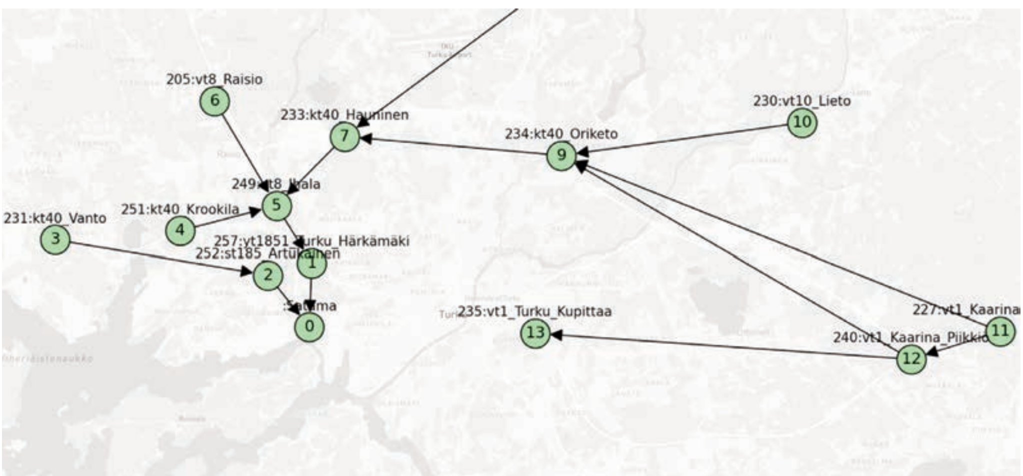

Figure 5. Some TMS stations with their TMS numbers and names, which were used for data analysis in the Turku area.

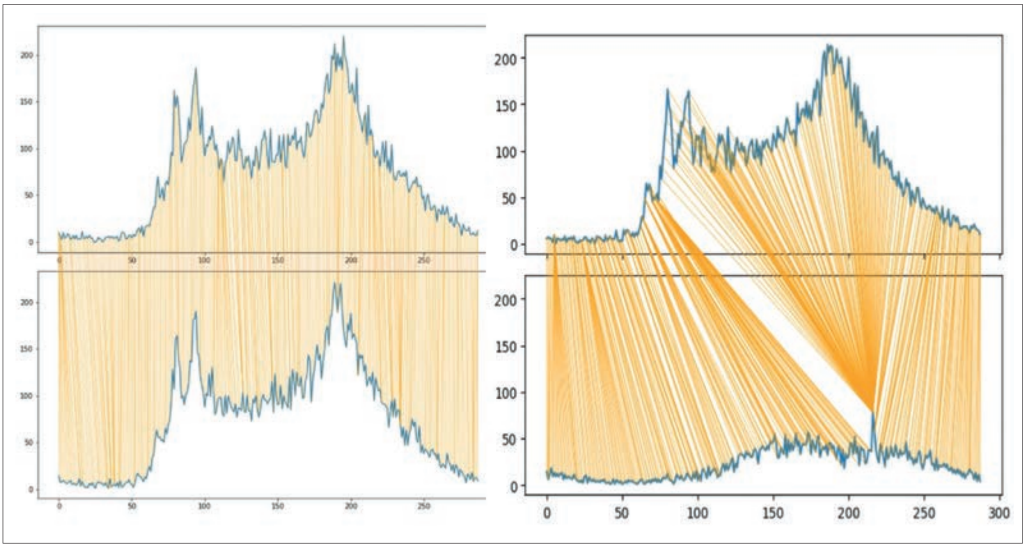

Figure 6. **Dynamic time warping can be used to calculate the similarity of two time series. On the left, the vehicle counts of two business days; and on the right, a business day and a weekend day.**

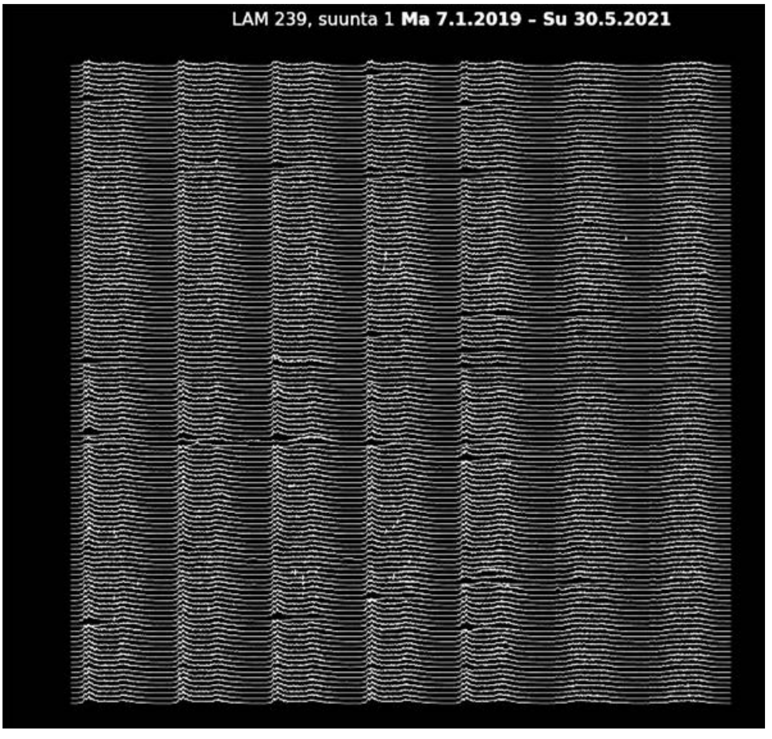

Figure 7. **Weekly vehicle counts of cars and delivery vans heading for Turku in Kaarina, starting in the upper-left corner from Monday, January 7, 2019. The data was recorded at TMS station 239 in Kaarina (60.424022 N, 22.402097 E).**

The Laboratory of Industrial Management at the Faculty of Science and Engineering at Åbo Akademi University focuses on industrial investments and project activities in the energy and transport sectors. Through previous projects, the research team at the Laboratory of Industrial Management has gained expertise in sustainable maritime logistics, the decarbonisation and digitalisation of shipping, and the governance of innovative transport solutions. The academic research performed at the laboratory revolves around industrial value creation, the evolution of business ecosystems for sustainability, institutionalisation, and transitions in socio-technical systems. The unit is also part of Åbo Akademi University's strategic profile area, 'The Sea', involving the collaboration of researchers from marine biology, public administration, maritime law, and industrial management to solve 'wicked' sea-related problems.

The laboratory has established international collaboration with the Stanford Center at the Incheon Global Campus (South Korea) on sustainable infrastructure and smart cities. The collaboration focuses on ways to generate value from climate-resilient infrastructure, and it expands to cover the governance and finance of smart and sustainable infrastructure in general. The researchers in the team are part of DIGEX (Digitalizing Infrastructure Group of Experts), established by the Florence School of Regulation at the European University Institute in Italy.

The typology of digital solutions for RoPax ports

Contributors

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- **Marikka Heikkilä, Kristel Edelman** (University of Turku)
- **SMARTER project partners**

RoPax ports face unique challenges due to the combination of passenger and cargo flows and services, which present digitalisation opportunities. Many digital solutions have been implemented in RoPax ports, including innovative solutions developed within the SMARTER project. We have developed a typology for understanding the value of these solutions for port authorities and stakeholders, and their impact on logistics chains. This typology is a benchmark for solution providers to position their offerings in relation to others. From a port perspective, the typology identifies common trends in digitalising RoPax ports and reveals new technological opportunities.

Background

Sea logistics is known to be among the slowest to adopt digitalisation technologies (Transport Intelligence 2019), still relying heavily on old communication and data exchange methods; thus, the potential benefits of aggregating and analysing the data on maritime transportation are vast. RoPax ports can be seen as critical nodes of the 'Motorways of the Seas'. Digitalising activities within and beyond the terminals can improve logistic chains.

The research results presented here are based on the work done within WP1 'Business transformation', which aimed to understand the need and potential for digitalisation in the context of RoPax ports and to study the impact of digital solutions on the value creation of various port stakeholders.

The burgeoning of RoPax transportation has been particularly relevant and pronounced for those countries around the Baltic Sea region with a geographically isolated or distant location and with limited access to continental markets through land-based transport systems. The RoPax connections have predominantly evolved around urban areas, major old cities, and trade lane nodes.

Over decades, the business model combining short sea passenger and cargo transportation has become an established and common transport concept, handling most of the intra-Baltic Sea trade. The concept of ferries and RoPax is based on a vessel design with roll-on and roll-off features (ro-ro), enabling the loading and unloading of wheeled commercial vehicles (lorries, trailers) and passenger cars, with the capability to accommodate and serve the needs of passengers. Quick, flexible, and efficient loading and unloading procedures are vital for operators with tight regular schedules and short turnaround times.

Ports are increasingly implementing innovative technologies and digital applications, providing new opportunities for greater collaboration, sustainability, safer and better-optimised operations, and improved overall business performance. However, most research and development efforts on ports have focused on measures and solutions introduced by large container ports, while (smaller) RoPax ports and terminals have received less scrutiny. Hence, the full potential regarding inter-organisational alignment and integration, data sharing, communication, and collaboration among actors within the entire end-to-end (intermodal) transport chain has not been exploited.

Along with the greening of the maritime sector, ports (and ship operators) are expected to adjust their operations to align with environmental and sustainability considerations. The question is, besides providing necessary quayside facilities, how could RoRo ports extend their role and responsibility as an integral part of the entire transport chain, alleviating externalities generated beyond the port boundaries and further, to the hinterlands and land-based modes? Although various mechanisms and measures available to ports have been identified (e.g. pricing tools, investments in technology, dedicated infrastructure, and regulatory instruments), a comprehensive study (Aregall et al., 2018) conducted among global ports indicated that only about a fifth of the reviewed ports had implemented measures improving the environmental performance of hinterland transport.

Managing and combining the flows and services of cargo and passengers leads to several specific challenges, all creating opportunities for digitalisation. On the passenger side, typical challenges are related to the unavailability of integrated and real-time information about transport connections, schedules, services, and notifications of traffic disturbances, causing delays along the transit journeys to and from the terminal. Today, the check-in, security and embarkation procedures cause unnecessary crowding and queuing in the passenger terminal, which are problems that the uptake and implementation of digital solutions could alleviate. The technology could also take safety and security matters to another level through tools for crowd management, identification of passengers' unusual behaviour, or unattended luggage.

Conversely, the multimodal transport chain is hampered by uncoordinated road traffic pulses and congestion at ship arrivals and departures inside the port, the associated urban area and its main approach roads. This problem is less likely to diminish with the expansion of residential and recreational urban areas and associated shrinkage of the port facilities and stowing areas. This is a common issue in typical port cities, where land value considerations already encourage more efficient land use. Furthermore, the vessels will likely grow in cargo capacity, further worsening the overcrowding of the road network. Traffic jams, in their turn, give rise to idling and unnecessary emissions.

Due to the relatively short distances over the sea and ship turnaround times in ports, the RoPax short sea segment is more time-sensitive regarding timely and efficient loading and unloading procedures, as delays may be difficult to compensate with speed out at sea. The accumulation of lorries in the harbour area and the usage of the harbour area as a waiting/parking area long before the actual departure is another unwanted phenomenon. This is principally a consequence of a limited number of dedicated resting and parking areas for lorries in the port's vicinity. Introducing an integral just-in-time (JIT) solution with an associated pre-parking concept offered to road haulage customers would benefit all stakeholders' operations and performance. Lorry drivers would be informed and called in when their vehicle can drive into the port area, using a dedicated application or another interface. To a predetermined degree, the given slot times would enhance the timely and orderly arrival of specific lorries in certain batches, benefiting the actual optimal onboard stowing plan and order.

Solution and method

We gathered data through desktop studies, interviews, site visits, and workshops, to identify the available and potential digital solutions that are relevant for RoPax ports. Interviews were conducted with each SMARTER partner. Organisations outside the project were also interviewed, such as relevant municipality departments, digital solution providers in urban and transportation sectors, or other RoPax ports in the Baltic Sea region. Altogether, over 35 interviews were conducted throughout the project.

With the University of Turku, six RoPax ports were selected for a benchmarking study on port digitalisation and business model changes. Existing digital solutions and upcoming digitalisation implementations were studied, and the potential impact of digitalisation on the evolution of the port authority's business model was discussed.

Two workshops related to identifying the types of digital solutions relevant to RoPax ports were organised: one focused on passenger traffic and another on cargo flow. Six field visits were made to RoPax terminals. Through the workshops and site visits, we gained an understanding of the current ecosystem's challenges and development bottlenecks. The participants were asked to identify existing bottlenecks, goals, potential digital solutions, and collaboration steps related to passenger and cargo traffic flows.

During the research, it became apparent that digital solutions designed for or implemented in RoPax ports provide different functions and thus value to port actors and involve smaller or bigger constellations of actors and respective data. Considering their effects, the solutions ranged from those addressing limited activities within the boundaries of an individual port actor to those affecting the efficiency of whole logistics chains. Certain solutions, such as those for situational awareness in ports, could provide data input for other solutions, such as the optimisation of cargo or passenger flow. Thus, creating a typology of digital solutions for RoPax ports, facilitating the understanding of the opportunities that digitalisation brings for ports in a structured manner, was necessary.

The solutions were categorised in two dimensions. The first was inspired by and elaborated further from the capabilities of smart, connected products that Porter and Heppelmann (2014) proposed. They identified four such capabilities: monitoring, control, optimisation, and autonomy. As we categorised digital solutions in the port environment, a need for three additional capabilities appeared: communication, visualisation, and prediction. Control and automation were considered one capability. Thus, the following capabilities or functions of digital solutions were used in further typology development:

- Communication
- Visualisation
- Monitoring
- Control and automation
- Prediction
- Optimisation

The second dimension included three layers of digitalising port operations (Tsvetkova et al., 2021):

- Infrastructure layer
- Service layer
- System layer

The first layer includes solutions directly relating to the efficient operation and maintenance of maritime infrastructure, such as the digital twins of port infrastructure and smart buoys that help identify the need for maintenance through predictive algorithms. The second layer includes solutions to improve how the users utilise this infrastructure. These solutions include managing the throughput of traffic, cargo, and vessel flows through ports so that maritime infrastructure is utilised efficiently, and the quality of service is maximised for cargo shippers, ship operators, and other parties relying on port infrastructure. By combining the data related to maritime infrastructure and cargo flows, achieving efficiencies on a larger scale at a system level is possible, ensuring a smart cargo and passenger flow through digital corridors, end-to-end journeys, and optimising whole supply chains.

Results, findings, output, and impact

We identified various solutions that are already implemented or planned to be implemented in the six RoPax ports we studied (*marked in blue in Figure 1*) and the solutions that have been developed or discussed within the SMARTER project (*marked in yellow in Figure 1*).

One of the findings is that RoPax ports strongly focus on digitalising and improving communication among the many actors. Without digitalising documentation flow and notification processes, it is too early to discuss more profound digitalisation and integration efforts across organisations. The solutions that the studied ports mentioned mostly focus on documentation exchange and notifications related to cargo and vessel arrival. Within the SMARTER project, several solutions were identified regarding the communication pertaining to passenger flow, creating an intriguing opportunity to improve customer satisfaction concerning passengers as customers of RoPax terminals.

With regard to the goals for sustainable development, digitalisation already aids in monitoring and communicating pollutant and greenhouse gas emissions from the operations within terminals. However, a high potential exists for optimisation solutions within the system layer to optimise cargo and passenger flow, which would result in reducing the environmental impact of RoPax transportation. For example, convenient mobility as a service (MaaS) solutions can reduce the passengers' need to use private cars when arriving at the port. Optimising traffic lights leading to the port reduces the stops and starts for lorries approaching the terminal, reducing fuel consumption and corresponding emissions.

In terms of monitoring, ports have implemented solutions for monitoring processes directly related to the infrastructure layer, such as energy use or air quality in the port area. Naturally, security monitoring exists in any RoPax port. However, SMARTER partners have proposed solutions for more automated security monitoring, including, for instance, automated identification of left luggage or identification of crowding in the terminal. Other solutions developed in the project include identifying and counting passengers and vehicles, which can provide input for several automation or optimisation solutions.

Control and automation seem high on the agenda for many ports, as passenger and vehicle flow automation can save costs, improve customer satisfaction, and reduce the workload of port workers. There were many overlaps between the solutions developed within the SMARTER project and solutions implemented (often partly) or planned by RoPax ports, confirming the indisputable value of these solutions.

Similarly to visualisation, solutions that fall under prediction capability are essential for human decision-making in RoPax terminals or optimisation solutions. Opportunities exist for predicting important data points regarding passenger, vehicle, and vessel flow.

Regarding optimisation, ports have implemented several solutions addressing the infrastructure layer. Thus, they are limited to the scope of a RoPax port (heat and power optimisation in terminal area, smart security). Other solutions aim to integrate several processes that go beyond actual port operations. However, the system layer is addressed much less. While intelligent supply chains have been mentioned in connection with RoPax ports, they are yet to be developed as a working concept. The SMARTER project has produced concepts for several optimisation solutions addressing passengers' end-to-end journeys or those integrating freight traffic flow with port and vessel operations, to maximise the use of vessels and port infrastructure.

In summary, digitalising end-to-end supply chains can fundamentally change logistics and thus has implications for the future management of maritime infrastructure. Specifically, increased transparency and a better understanding of cargo and vessel flow through ports are inputs for smarter decisions regarding port infrastructure investments going forward. Combining the data related to maritime infrastructure and cargo flows makes achieving efficiencies on a larger scale at a system level possible, ensuring a smart cargo flow through digital corridors and optimising whole supply chains. Such synchronous modality can enable significant transport cost reductions and optimum utilisation of transport infrastructure, while adhering to the respective delivery conditions (Tsvetkova et al., 2021).

We can observe certain differences between the technology push and market pull regarding digital solutions for RoPax ports. In particular, solutions for visualisation or prediction developed in the SMARTER project can provide valuable input for other functions, such as optimisation or control. One must understand, for example, how projections or visualisations of terminal flows can be used in, for instance, security management or passenger and cargo flow optimisation to develop a viable business offering.

The typology of digital solutions for RoPax ports thus serves as a benchmark for different solution providers to identify the role of their solution and the potential value it can create for port actors. Simultaneously, port authorities and port actors can use the results of this research to identify common trends in digitalising RoPax ports and discovering new technological opportunities.

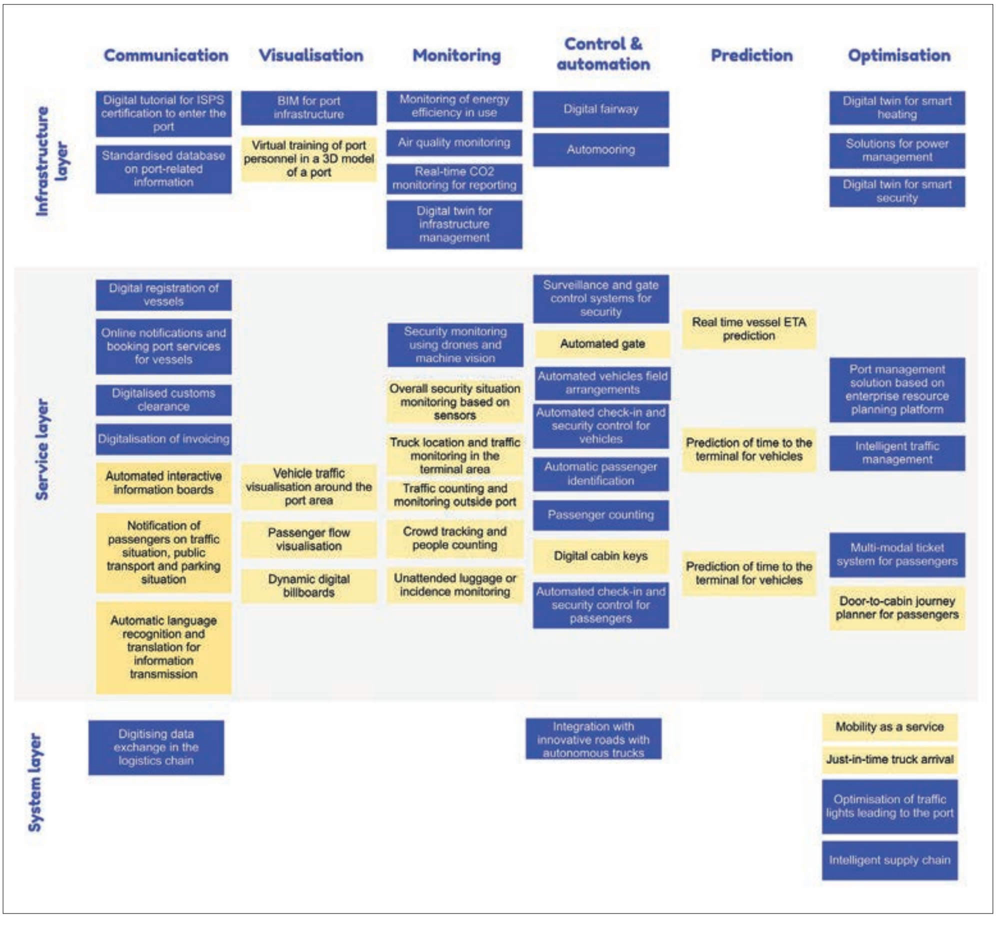

Figure 1. The typology of digital solutions in RoPax ports.

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The Faculty of Science and Engineering at Åbo Akademi University develops solutions and processes that slow down climate change, promotes a cleaner environment and healthier sea, and finds methods for detecting, treating, and preventing diseases. The faculty's ultimate goal is for people to prosper in a sustainable society.

Data-sharing in the maritime sector: a driver or a hindrance of progress?

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- SMARTER project partners

The maritime sector is one of the pillars of the global economy. Its resilience is essential in the face of adverse events, and digitalization arises as a main catalyst of innovation and a promoter of robustness. For industrial operators, the data economy is essential in long-term performance upsurge, predictability, and profitability. To promote the data economy, data exchange between operators is essential to produce system-level gains. Below, we analyze impediments and opportunities in data-sharing through a series of qualitative methods. The new wave in the data economy will reform the maritime landscape and will support maritime operators in abiding by forthcoming decarbonization and energy-efficiency regulations.

Background

The global economy and our very own subsistence are highly reliant on the maritime supply chain and maritime operations overall. The resilience of the maritime supply chain has come under scrutiny in the face of unforeseen disruptions, accelerating political tensions worldwide, persistent effects of the COVID-19 pandemic, and ever more drastic weather events. Many facets of its inherent vulnerability have been exposed. Reliable access to various goods was considerably limited due to outmoded, inefficient and segregated processes, implemented by many operators in the freight sector globally. Naturally, there is a dire need to devise strategies that promote imperative transformations to boost the resilience of the maritime sector, arguably through digitalization. While many companies made great progress toward digitizing their operations, only some were able to adapt to the new reality with minor consequences (Iancu, B. et al.).

Digitalization has been a prominent catalyst in accelerating the modernization of maritime operations. Through digital innovation, significant strides can be made in building safer, more resilient, and greener supply chains. Reinforcing a global digital ecosystem, however, requires a revision of attitudes. Maritime actors need to establish strategies that withstand the test of time and ensure that the ever-changing maritime ecosystem adapts to unanticipated events (Sarabia-Jácome, D. et al.).

Arguably the greatest vulnerability of the maritime supply chain is its limited transparency, originating in a persistent reluctance of stakeholders to share data across multiple ecosystem channels. The rationale behind this is intricate. There is a considerable number of independent actors. Although digitalization is progressively taking over the maritime sector, many operators still resort to non-automatic processes (email, phone, fax, etc.), which introduce human errors, thus hindering information exchange. Companies prefer to attain or preserve their competitive advantage through data, and they choose to share it only when it benefits their own interests. Many present acute concerns regarding data privacy and compliance, facing legal quandaries in the assessment of liability risks in the case of possible privacy violations. Others face challenges in addressing the complexity and cost of data-sharing (Morariu, A.-R.). Generally, data is seldom shared across the maritime ecosystem and, even when it is available, serious concerns are raised regarding its provenance, quality, and trustworthiness.

Solution, method

Data remains a largely unexploited resource across the maritime supply chain. Albeit the International Maritime Organization (IMO) requires its members to exchange information pertaining to cargo, crew, and passengers digitally, a mere few ports adhere to these obligations. This may be, in part, because digital data-sharing policies are scarce and challenges in adopting data-sharing platforms prevail. Interoperability emerges as one key factor in addressing digitalization of the maritime sector to the full extent. To manage their data assets, many maritime actors employ different data platforms and infrastructures, which are not readily compatible with others. The absence of globally standardized data-sharing platforms arises as one crucial hindrance to data-sharing.

To determine the challenges that port ecosystems face, we conducted a survey, a series of interviews, and workshops involving SMARTER partners. The survey was sent out to all companies involved in the project. The scope of the survey was to gather insights regarding the SMARTER data ecosystem, to understand the usage of data from collection to analysis to decision-making, and to identify potential impediments in data-sharing and development processes.

The scope of the interviews was to compile a systematized inventory of data assets in the project, documenting data collection efforts, data organization, and secure access to data with group-based policies. The selection of participants for the interviews was decided internally within the project and comprised experts and managers among SMARTER collaborators. The interviews were a follow-up to the aforementioned survey, aiming to elaborate on certain aspects regarding data-sharing among the project stakeholders. The interview framework relied on several functions that promoted understanding, data-sharing, and collaboration between partners:

- Search and discovery – to determine data availability and ownership;
- Metadata availability – to provide contextual information regarding data assets;
- Data-sharing – to identify existing and potential data flows between organizations;
- Data archiving – to establish key storage management features;
- Data quality – to review implemented solutions ensuring the completeness, reliability and accuracy of data assets;
- Data lineage – to document mechanisms of tracing and tracking data evolution within the project's organizations;
- Security – to elaborate on secure solutions for selective data-sharing within the project;
- Business impact – to evaluate profitability based on data governance and usage.

The workshops were designed to identify existing and potential data flows between collaborators in passenger flow and just-in-time truck arrival use cases, and to conceptualize a high-level architecture of a data management model that would mediate eventual deterrents in data-sharing and collaboration.

Results, findings, output, and impact

The research results presented here are based on the work carried out within WP3 'Data Collection and Management,' which aimed to understand data-sharing between different analytics layers and stakeholders, the impact of data privacy issues in data-sharing, and data management solutions in the context of RoPax ports.

Through surveys and interviews, we identified data assets produced/utilized by the organizations in the project and documented their access modalities. The aim was to achieve clarity in the data types, metadata use, data-sharing among organizations, and essential business attributes. This initiative was intended to achieve a holistic perspective of data assets within the project and to improve the understanding of available data to be able to promote collaboration between partners.

The main reasons for conducting a series of interviews were threefold. Firstly, challenges in large organizations and in projects involving many organizations often have comparable reasons, which might be shared among organizations. Hence, a holistic perspective of data assets in the project is crucial to even consider ecosystem data governance and lucrative collaboration. To enable such collaboration among project participants, exploring data and search functions is essential. This in turn brings about an improved understanding of available data and, thus, nurtures collaboration among partners.

We identified benefits of data-sharing with a special focus on data sources and access:

- Saving time and effort in locating data and accessing it;
- Creating a shared business vocabulary;
- Understanding the structure and variety of data within the project;
- Helping to assess the provenance, quality, and trustworthiness of data;
- Capturing tacit knowledge specific to one organization;
- Enabling the reuse of knowledge and data assets within the project;
- Guiding data preparation efforts by owners.

One of the findings is that the port is at the center of the data-sharing ecosystem and, together with regulatory incentives dictated by port authorities, it is of utter importance to design and adopt robust data management systems that serve port operators. One such model is presented in Figure 1. Data streams come from different flows, such as camera surveillance or other sensors designed for situational awareness in different environments. Different dynamic networks are used for communication, and they come with a specific level of uncertainty. Classifying and validating data from different sources and sensors to build valuable recommendations for port operators can be achieved only by understanding how each operator plans their activities and how they execute them. Upon reflection and seeing results from similar operators, best practices spread throughout the community. Trust and transparency are of utmost importance. Data quality monitoring is promoted by establishing data taxonomies and performing exploratory analysis. Domain knowledge establishes causal relationships between data streams (Jaimini, U. & Sheth, A.) and can be the catalyst between various data sources in establishing data fusion solutions to create a holistic perspective of the data-sharing ecosystem. Incorporating causal knowledge with collected data, we can provide AI models with new information that facilitates learning of causal relationships responsible for erroneous inferences, ultimately improving the performance of algorithms. These algorithms can provide situational awareness for (semi-)autonomous navigation, prevent risks by employing preventive rather than predictive maintenance for machinery involved in maritime operations, recommend new solutions for various challenges in ports, and simulate diverse scenarios in the functioning of the data ecosystem at various levels of resolution.

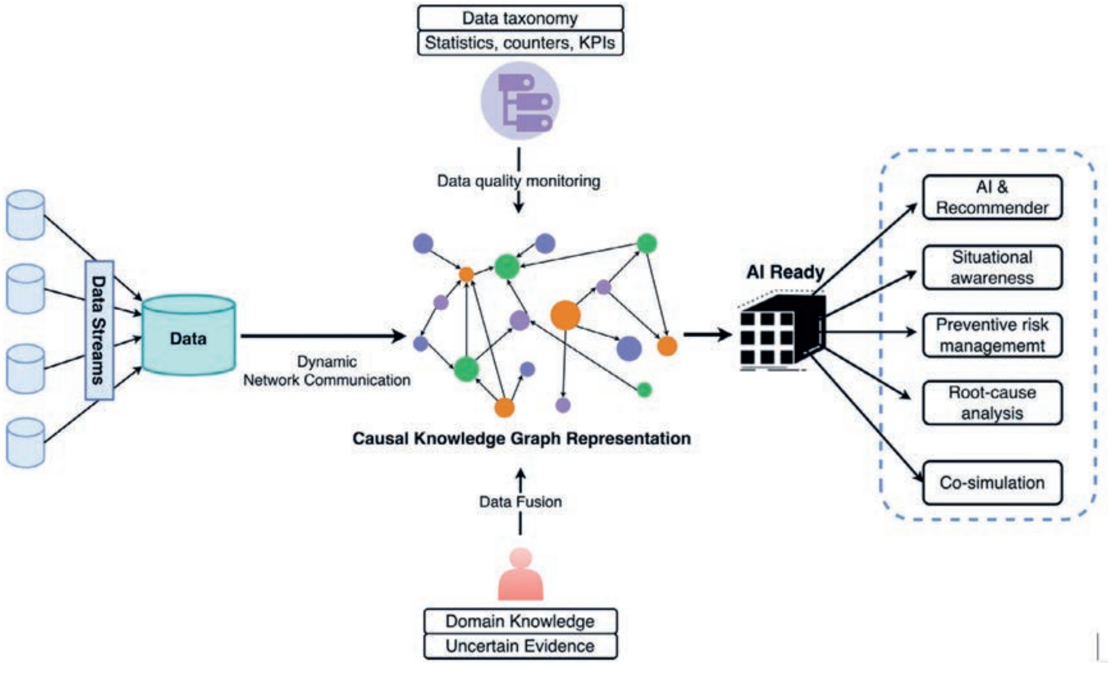

Figure 1: **Conceptual model for a data management system for a RoPax port.**

During our interviews, one major concern was data privacy and security and how it can be protected within a large data ecosystem. A few privacy solutions for data-sharing emerged that could be implemented in the future:

- Homomorphic encryption (Yi, X.): computations can be performed on encrypted data directly, and the output is identical to that from computations performed on unencrypted data;
- Differential privacy (Dwork, C.): allows sharing information regarding group patterns in a dataset without divulging information about specific individuals in the dataset;
- Federated (collaborative) learning (Li, L. et al.): promotes training AI algorithms across multiple decentralized devices, on local datasets, without explicitly exchanging data;
- Zero-knowledge encryption (Yang, C. et al.): is performed with a user key that is unique and that is only known by the end user, who can solely access the encrypted data;
- Privacy-preserving computation (Kerschbaum, F): computation is distributed across multiple devices in such a way that no one device can see the entire array of inputs.

To summarize, stakeholders can assess the financial impact of a project and compare predicted and actual expenses by sharing and aggregating data. For the initiative to meet its objectives, having access to data is essential. Data-sharing has several advantages, including expanded market potential, improved company and investment stability, more productive workflows, and lower, more predictable expenses. Data from previous projects help stakeholders make better decisions by enabling them to draw lessons from the past and offer solutions. Maritime facilities can therefore be the imposing stakeholders that can establish data centers with regulated access for the connected businesses in the port areas. Hence, we consider that our research has raised the awareness of data interoperability and offered new methods of increasing economic growth and collaboration within SMARTER project partners.

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TELESTE

Teleste has been providing equipment and technologies for video networks since 1954, and it has been listed on Nasdaq Helsinki since 1999.

The company was founded on two principles: customer understanding and quality. From the very beginning, we have also been well known for tenacious Finnish engineering skills. As our customers' needs, technologies, and the world around have changed, so have we. Here you can take a sneak peek into some of the steps along our journey. In the Video Security and Information business unit, we provide professional video and information management applications, systems and services for **public safety authorities and operators**, as well as **public transport operators** and **rolling stock manufacturers**. Our portfolio meets the highest international standards and requirements for demanding operational environments and large-scale, integrated implementations.

Passenger Flow and Safety

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Passenger safety and the optimization of passenger flow are crucial factors to consider when operating passenger terminals at ports. Ensuring the safety of passengers is of utmost importance and requires a comprehensive approach that includes measures such as risk assessment, security checks, and emergency response plans. Additionally, optimizing passenger flow is necessary to ensure that passengers can move through the terminal efficiently and with minimal delays. This requires careful planning of the terminal layout, the use of technology to manage passenger traffic, and the implementation of effective communication strategies to keep passengers informed. By prioritizing passenger safety and optimizing passenger flow, port operators can provide a seamless and enjoyable travel experience for their customers.

In SMARTER, Teleste focused on implementing a use case that improves public safety and passenger flow in a passenger terminal. The integration of the video surveillance system and the situational awareness system prototype was developed during the project. In addition, integrations were done with other vendors, such as TUAS, Brighthouse, Lingsoft and Focusplan.

Background

- The Teleste video surveillance platform was used as a basis, and it was integrated with situational awareness, video analytics and different sensors, and other third-party systems. Figure 1 illustrates an overview of the system.

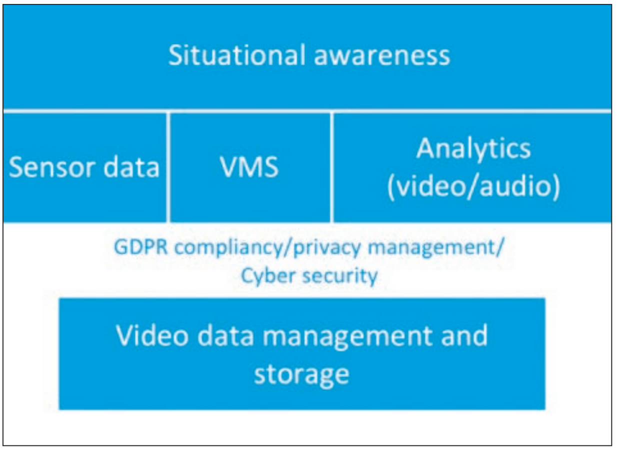
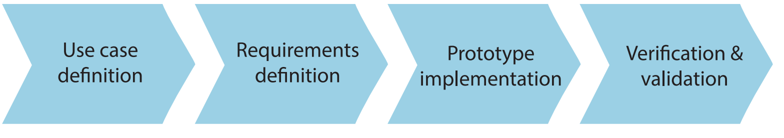


Figure 1. **An overview of the system implemented in the project.**

Solution, method

The solution was developed by first using the following procedure:



The use cases were defined during the first phases of the project, with contributions from all the consortium partners. Eventually, passenger safety and passenger flow optimization were selected as the main use cases.

The solution was implemented using a prototype developed by Teleste, integrated with other subsystems from other project partners, such as wireless solutions from TUAS and Brighthouse. The system was installed at the Silja-Tallink terminal in Turku, where the implementation was verified, validated, and demonstrated. Figure 2 illustrates an overview of the Teleste platform and related project partners.

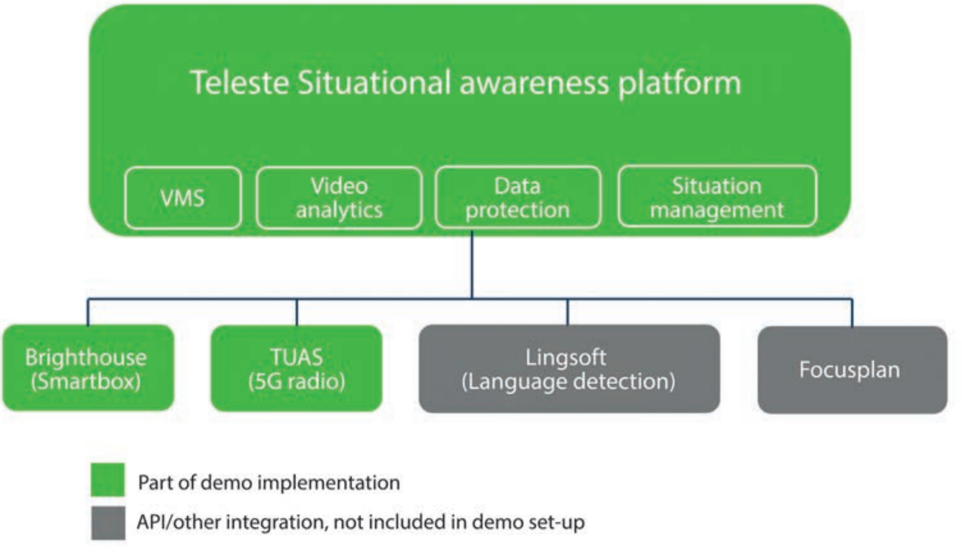


Figure 2. **Teleste platform and related project partners.**

Results, findings, output, and impact

A comprehensive situational awareness system, supported by efficient video management, is an efficient tool for safety and optimization.

The optimization of passenger safety and passenger flow in ports is an important solution that offers numerous benefits. First, ensuring passenger safety is a top priority for any port, and an optimized system helps to reduce the risk of accidents and incidents. With advanced technologies such as facial recognition, passenger tracking, and monitoring systems, port authorities can easily identify potential safety hazards and take appropriate measures to prevent accidents. Second, an optimized system can help to streamline passenger flow and reduce waiting times. This is particularly important during peak travel periods, when there is an influx of passengers arriving and departing from the port. By implementing intelligent queuing systems, real-time information displays, and efficient baggage handling systems, ports can reduce bottlenecks and improve passenger flow, enhancing the overall travel experience.

Another key benefit of an optimized passenger safety and flow system is the potential to increase revenue. By improving efficiency and reducing waiting times, passengers are more likely to have a positive experience and return to the port in the future. This can lead to increased revenue from both repeat customers and new customers who have heard positive reviews about the port's operations.

Moreover, optimized passenger flow and safety systems can also help to reduce costs for port operators. By reducing the risk of accidents and incidents, ports can lower insurance costs and potential legal fees. Furthermore, an optimized system can help to reduce staffing requirements, as many processes can be automated, reducing the need for human intervention.

In conclusion, the optimization of passenger safety and passenger flow in ports offers numerous benefits. By reducing the risk of accidents and incidents, streamlining passenger flow, increasing revenue, and reducing costs, an optimized system can enhance the overall travel experience and provide a competitive advantage for port operators. As such, it is essential for ports to continually invest in new technologies and solutions that improve passenger safety and flow.

The solution performed as expected during tests and experiments. The number of used cameras and other sensors was sufficient, and available infrastructure allowed streaming of high-resolution video feeds from many cameras simultaneously.

Teleste will continue testing and developing the prototyped system and expand it. Looking to the future, the optimization of passenger safety and passenger flow in ports is likely to become even more important. As the world becomes increasingly interconnected, ports are set to play a crucial role in facilitating global trade and travel. However, with this increased traffic comes an increased risk of safety hazards and congestion.

One potential solution for the future is the increased use of artificial intelligence and automation. With AI and machine learning, ports can gather and analyze vast amounts of data in real time, enabling them to identify potential safety hazards and optimize passenger flow more efficiently. Additionally, the use of automated systems for baggage handling, security checks, and passport control can reduce waiting times and improve efficiency.

Another key aspect of the future of passenger safety and flow in ports is the need for collaboration between different stakeholders. Ports are complex ecosystems involving numerous actors, including port operators, shipping companies, transport authorities, and local communities. By working together and sharing data, these stakeholders can develop a more integrated and efficient system that benefits everyone involved.

Overall, the future of passenger safety and flow in ports is likely to be shaped by a combination of advanced technologies, collaboration, and sustainability. By embracing these trends and investing in new solutions, ports can ensure they continue to play a crucial role in global trade and travel while enhancing the experience for passengers and stakeholders.

TURKU AMK

TURKU UNIVERSITY OF APPLIED SCIENCES

Turku UAS is a higher education institution of 12,000 experts, researchers, students, faculty members and teaching professionals. We create solutions for a better tomorrow – both regionally and globally. Our graduates are practice-oriented professionals with top competencies.

As a significant regional actor, we harbor close ties to businesses and municipalities in Southwest Finland. Turku UAS is the fourth-largest technical university in Finland. Students are sought-after experts, with 99% employment within five years of graduating.

For future societies, major challenges include the immense amount of data being transferred, the proliferation of cloud services, the shift in the focus of data transmission to wireless networks, and the security of data flows and repositories. From a corporate point of view, new technologies bring valuable business opportunities, but at the same time they increase the business' vulnerability as operations increasingly move online. At the heart of the Wireless Communications and Cybersecurity research group is the development of test platforms for wireless networks and the transfer of know-how to companies. The focus is on 5G technology and the cybersecurity of IoT systems. We work closely with companies that develop and utilize new technologies.

Futuristic Interactive Technologies (FIT), a research group at Turku University of Applied Sciences, has profiled itself as one of the leading RDI organizations in Finland in virtual training and metaverse tech development in the areas of technology industry and healthcare. FIT has won various awards in the above-mentioned research area. In 2019–2021, FIT invested over MEUR 0.5 in XR and AI technologies. FIT has versatile expertise in XR development and applied research, utilizing user-centric design and rapid prototyping principles. FIT has years of experience conducting field experiments in the fields of usability, user experience, and effectiveness studies.

Sensors, connectivity, and VR/AR applications for the port environment

Contributors

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Sensing is an inevitable component in the digitalization of different environments. The sensors can provide valuable information and means for automatizing and optimizing passenger flows in terminals, truck traffic in port area, and ship turn-around. Connectivity is an essential part of the sensoring platform, as the data from the sensors needs to be transmitted for processing, visualization and storage. Local cellular networks present a viable solution allowing for digitalization in the form of sensoring and information exchange between operational systems in a port and terminal environment. In addition, properly planned and executed cybersecurity is an integral part of digitalization. Visualization is another essential component in the digitalization of different environments, such as a harbor. The use of AR and VR technologies enables not only immersive and rich end-user experiences, but it also makes it possible to visualize different kinds of phenomena in truck traffic, passenger flow, and ship turn-around. The latest advances in XR technologies, especially metaverse and AI, have brought new ways of working in visualization: professionals in harbors can collaborate in training sessions, design processes, and remote operations, and the collaboration routines can be analyzed utilizing AI and data collected from the environment and wearable sensors.

Background To develop methods for the digitalization of operations in the port area, the Turku University of Applied Sciences 5G test network was installed at the Tallink-Silja terminal to enable studying the local network connectivity, sensoring, and cybersecurity for passenger flow analytics, together with Brighthouse and Teleste. As it is probable that in the future there will be several local cellular networks utilized in and near the port area, an interference measurement campaign was performed to provide information on a suitable separation distance between two local networks.

Visualization methods utilizing VR/AR technologies were chosen based on various workshop, events, and meetings organized especially during the first half of the project. Focusplan and Lingsoft were interested in seeing how NLP could be used in Cave environments. In addition, Focusplan was also interested in finding alternatives for game controllers in Cave environments. Ade, in turn, expressed their interest in collaborative VR training. Awake was searching for appropriate scanning technologies in harbor environments, while Brighthouse was investigating AR or let's say XR visualization of a ship's arrival at the harbor. Ways to visualize passenger flow in the terminal building were also identified as a possible cooperation area with Teleste, Brighthouse and Focusplan.

Solution, method For the passenger flow analysis, a lidar sensor was selected. A neural network was trained and a tracking algorithm developed to detect passengers from the point cloud data. From the connectivity point of view, a local cellular network was installed in the terminal building, and its coverage and capacity were measured to analyze its suitability for transmitting sensor data and allowing for secure transmission of operation-critical data. The interference between local networks was first estimated with analytical calculations, and further verified with a field measurement campaign.

Visualization of the passenger flow was found to be challenging because of privacy issues, and research activities around this use case were quite minimal during the project. Based on requirement analysis, collaborative training in a harbor environment was chosen as the key focus area, covering both identified needs in ship turn-around and truck traffic. A generic virtual harbor environment was chosen as the research prototype to be developed. Experiences of multi-user environments were found by testing existing technologies such as Microsoft AltspaceVR. Various limitations were identified, such as a limited number of users, complicated registration, limitations in hands-on-training, and so on. Existing technologies were also compared with the metaverse technology developed at Turku University of Applied Sciences, and based on this comparison, a metaverse environment designed for harbor professionals with required features was found to be the research approach to be followed.

A lidar sensor was selected for the passenger flow analysis, due to its good localization possibilities. It is also not problematic from the GDPR point of view, as the passengers are unrecognizable from the produced data. Local cellular networks were selected, as they provide secure connectivity and predetermined quality of service, as the network is in the hands of the company itself and, from the frequency resource point of view, they operate on licensed frequencies.

A metaverse environment designed for a harbor was chosen because it should be possible to be used as

1) a collaborative training environment for harbor workers, including training scenarios especially in a truck traffic and ship turn-around context, but if needed also in passenger flow, and
2) a remote-controlled visualization solution for vessels, forklifts, and cranes operation in the harbor area.

Figure 1. **Installation of the lidar sensor and indoor base station (top of the pole, on the right).**

The lidar sensor and local cellular network were installed in the Tallink-Silja terminal and integrated with the trialing systems of Brighthouse and Teleste. The installation is shown in Figure 1. Lidar data from busy hours in the terminal was recorded. A snapshot of the data is shown in Figure 2. A neural network for passenger detection was trained using GPUs, and a tracking algorithm was implemented. The detection capability of the developed point cloud-based detection was compared to detection from RGB images using the popular YOLOv5 network. Finally, the cybersecurity of the installation at the terminal was tested.

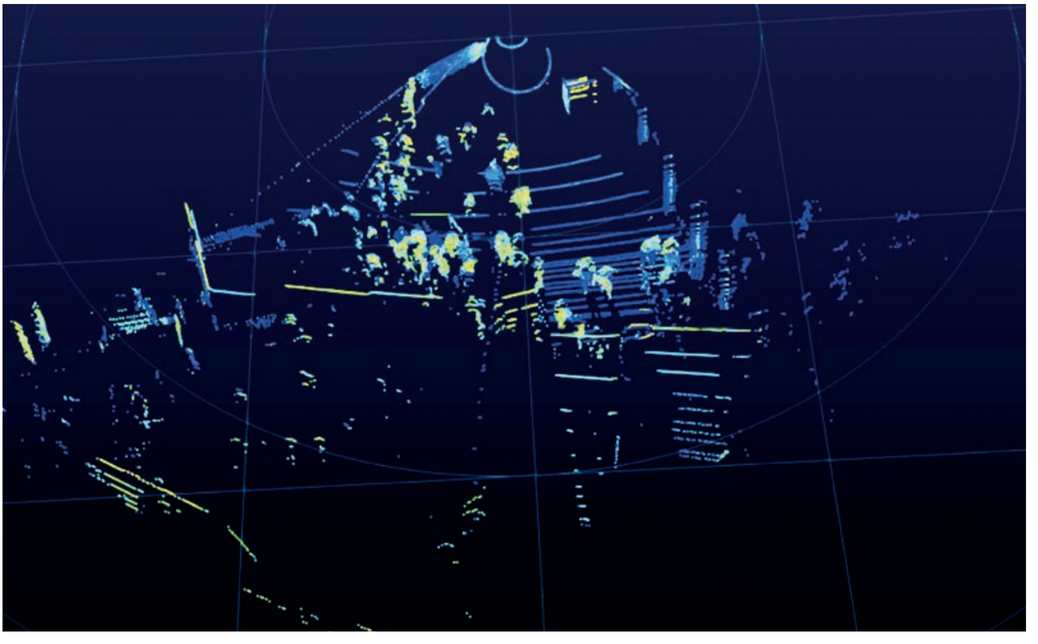

Figure 2. Lidar point cloud.

The local network interference campaign was performed by installing two separate local network base stations and using a measurement device on a drone, flying at selected distances from the base stations. The base station antennas were hoisted to 30 m using man lifts. The setup for the measurements is illustrated in Figure 3.

Speech-to-text and real-time translations were tested with Lingsoft in a fire safety scenario in close cooperation with Ade (which was at the same time focusing more on LNG fire-safety drills in ship bunkering). Some challenges in translations were found when translating Finnish spoken words to English text. Later, together with Lingsoft, remote presentations with translations were also tested inside the metaverse.

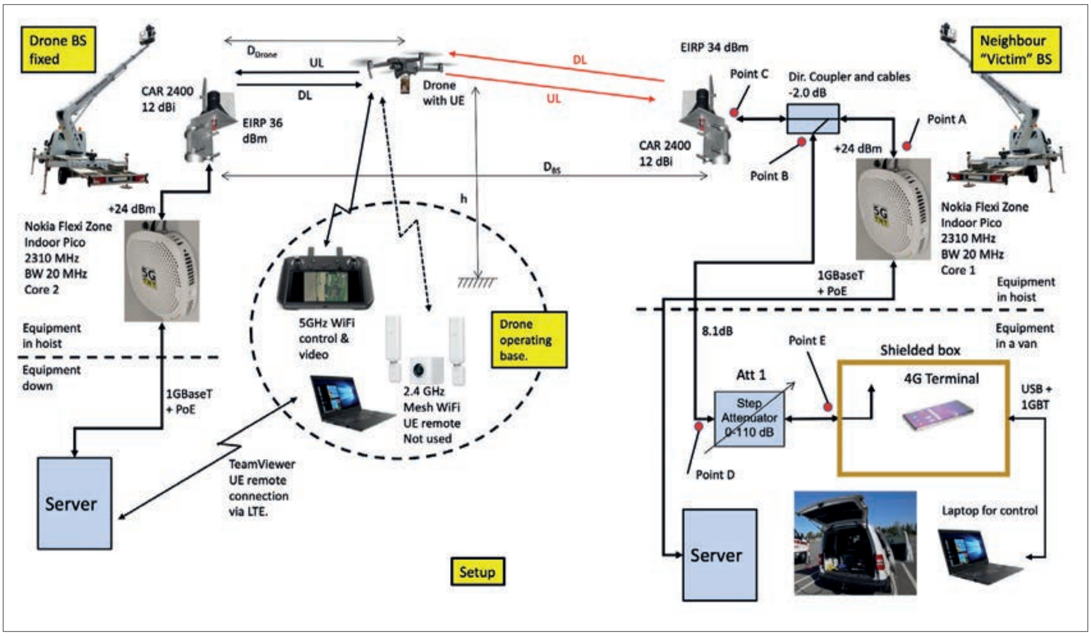

Figure 3. **Local cellular network Interference measurement setup.**

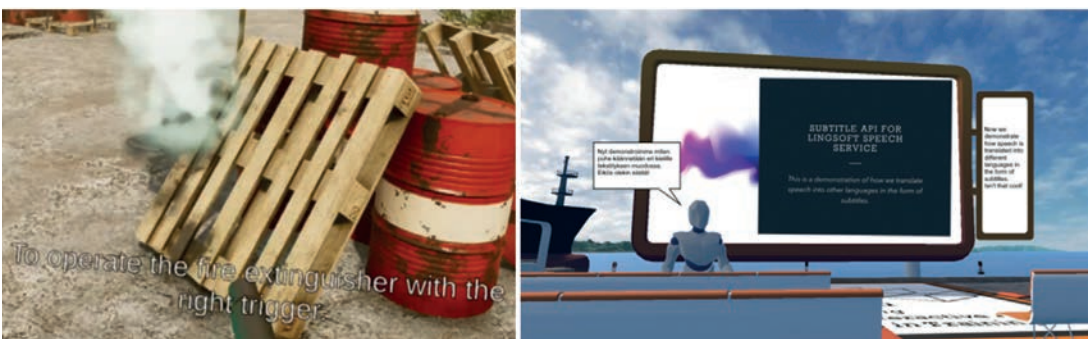

Figure 4. **Real-time translations tested in fire-safety training and presentations inside the metaverse.**

Professionals working in harbors require intensive collaboration, which can be challenging when experienced professionals such as crane drivers operating 24/7 are replaced with novices (for example, because of sick leave). Novices can drive but cannot understand well how to collaborate with other professionals to enable an efficient logistics chain. While Ade was focusing on three different harbor crane simulators, Turku University of Applied Sciences was participating in the prototyping phase, and these prototypes were brought inside the collaborative training environment (inside the metaverse). To be able to train in the collaboration, other vehicles such as trucks and forklifts were also decided to be included. Once completed, effectiveness studies were designed for crane drivers, together with Meyer Turku (spring 2022). After realizing that not enough test subjects were available, the researchers were forced to change the study plan a bit and to conduct a study for forklift drivers in cooperation with TAI, Turun AKK, and TTS (fall 2022). Because of this delay, the results from the study have not yet been published.

Figure 5. **Two type of cranes, a truck, and forklifts as a part of a collaborative training environment.**

A researcher from Valencia Polytechnic University, from Prof. Gomez-Barquero's research group, stayed for six weeks at Turku University of Applied Sciences during spring 2022. The research focus was on remote-controlled robots with VR headsets and smart gloves, and the ultimate goal was to control forklifts remotely in Valencia port. As a result, a working prototype was demonstrated at the Valencia V5G Days in May 2022. In this demonstration, a tank robot in Finland was remotely controlled from Spain successfully. At the end of 2022, a remote-controlled tank was introduced in a metaverse harbor environment at an internal seminar on digital shipping and advanced UIs.

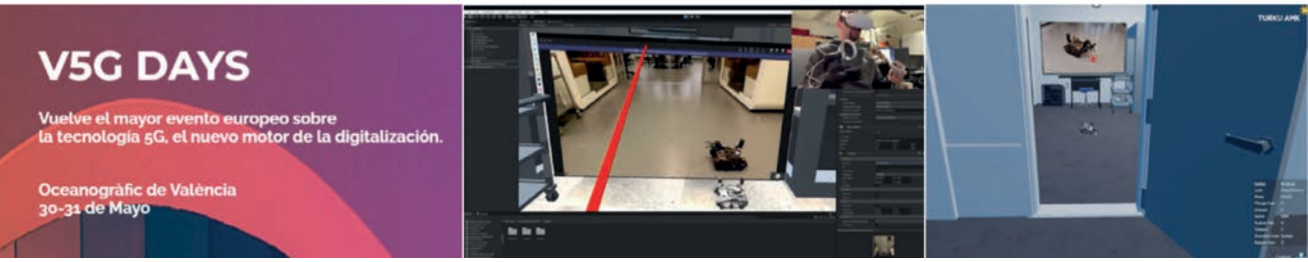

Figure 6. **Remoted-controlled robot system tested in Valencia and finally integrated in a metaverse environment.**

Results, findings, output, and impact

A lidar sensor was seen as a potential sensor for passenger flow analysis, although the detection probability was not as high as with an RGB camera. Localization of passengers is more accurate using the lidar, though. Potentially, with more effort on training, the neural network for lidar passenger detection could be enhanced to perform better.

Already, using one base station inside the Turku Tallink-Silja terminal building, good indoor coverage and capacity was obtained. To obtain outdoor coverage around the terminal building or port area in general, additional outdoor base stations are required. The local network interference measurements validated that the developed relatively simple calculation model can be used for estimating the interference between local cellular networks.

Three conference articles have been published so far. The metaverse has been defined as a combination of social communication, hands-on experience, and digital twins, and the first experiences of the collaborative training environments, one of these developed in the SMARTER project, have been reported. In addition, existing technologies for virtual-reality social platforms (a sort of precursor of the metaverse) have been analyzed in the training context. As already mentioned, the results from the effectiveness study of the collaborative training have not yet been published.

Lidar sensors enable coverage of a rather large area already with one sensor. They also preserve the privacy of the passengers that are sensored, due to the sparse nature of the point clouds provided. Local cellular networks are beneficial when a good and constant quality of service and privacy are required. For example, WiFi networks can observe a loss of capacity if several networks are operational in the same area. Local cellular networks operate on licensed frequencies, meaning that there should be no other users in the area. The interference study shows how the required separation distance can be calculated so that there is no interference when installing and operating local cellular networks.

A collaborative metaverse environment can be used to train harbor workers in an immersive training environment, which can contain even hazardous tasks to be completed. A collaborative environment can also be used when designing harbor operations. The use of a collaborative environment also enables remote operations such as remote-controlled vehicles.

The number of local cellular networks in Finland is increasing, and the trend seems to be that they are increasingly utilized in larger companies and on industrial campuses. Therefore, the planning for their installation and frequency allocation are important. From the safety perspective, automatic passenger flow analysis is increasingly desirable in crowded locations. For passenger flow sensoring, a fusion of RGB camera and lidar detection could be performed to enhance the overall performance. For local networks, several base stations could be installed for both indoor and outdoor coverage of a larger area in the port environment.

In addition, a combination of different displays or devices can be considered. That is to say, users can be remotely present with mobile phones or sophisticated VR headsets or even in a Cave environment. More studies will be needed on safety and security before this can become reality in harbors, using rich end-user experiences in a multiuser context inside the metaverse.

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During its 30-year history, Lingsoft has continued to evolve and diversify: from a research laboratory to a language technology supplier, from a translation agency to a full-service language management company, from a language sector multitalent to a language management partner and creator of linguistic digitalization solutions.

Lingsoft 4.0 is a partner that generates value for its clients. We want to conceptualize and create digital solutions that are based on the enrichment, refinement, and utilization of language capital. Whether the challenge is about multilingualism, interactivity, accessibility, discoverability, productivity, efficiency or quality, our primary focus is always on language: text, speech, and meaning.

We actively participate in the development of the language industry by attending collaborative forums, and we are developing new technologies and value innovations in cooperation with universities, higher education institutions, and research institutes, both in Finland and in international co-operative projects. Our eye is on the future.

LINGSOFT

The possibilities of language technology in the communicative challenges

Contributors

- Lingsoft and Novia

Background

As navigational and safety communications from ship to shore, from ship to ship, and on board ships must be precise, simple and unambiguous, there is a need to standardize the language used. This is of particular importance due to crews speaking many different languages, since problems of communication may cause misunderstandings, leading to dangers to the vessel, the people on board, and the environment.

The Standard Marine Communication Phrases (SMCP) is a set of key phrases in the English language developed by the International Maritime Organization (IMO). The SMCP was adopted by the 22nd Assembly of the IMO in November 2001.

The SMCP includes phrases that have been developed to cover the most important safety-related fields of verbal shore-to-ship (and vice versa), ship-to-ship, and on-board communications. The aim is to reduce the problem of language barriers at sea and to avoid misunderstandings that can cause accidents.

Solution

Lingsoft annotated VHF audio and text data provided by Novia. Annotation was used to identify and produce SMCP entities within the text, thus providing standard phrases for further processing or use.

The annotation process was started using speech recognition to produce raw transcripts with Lingsoft's speech recognition (ASR). Lingsoft's speech recognition (ASR) engines are based on open source neural/deep learning tools. The same ASR engine can be used to provide both speech-to-text and speech-to-subtitle services. Lingsoft's ASR work has been highlighted in the European Union's Innovation Radar

(2020, “New improved methods for Automated speech/speaker and Named Entity Recognition to generate test descriptions”.[1]

Later, the acoustic model was retrained for Lingsoft’s existing English ASR. The results of speech recognition were compared in terms of accuracy between trained and untrained acoustic ASR models. The output of the ASR was compared based on a test set with manually created output. The accuracy was calculated based on how many words were recognized correctly.

After producing the raw transcript, the annotation was completed. Lingsoft’s annotation provides semantic linking, in which recognized target concepts are linked to a semantic reference. In this study, we used Standard Marine Communication Phrases (SMCP) applied as string replacement, meaning that SMCP phrases were tagged where applicable (<SMCP></SMCP>) (*Figure 1*).

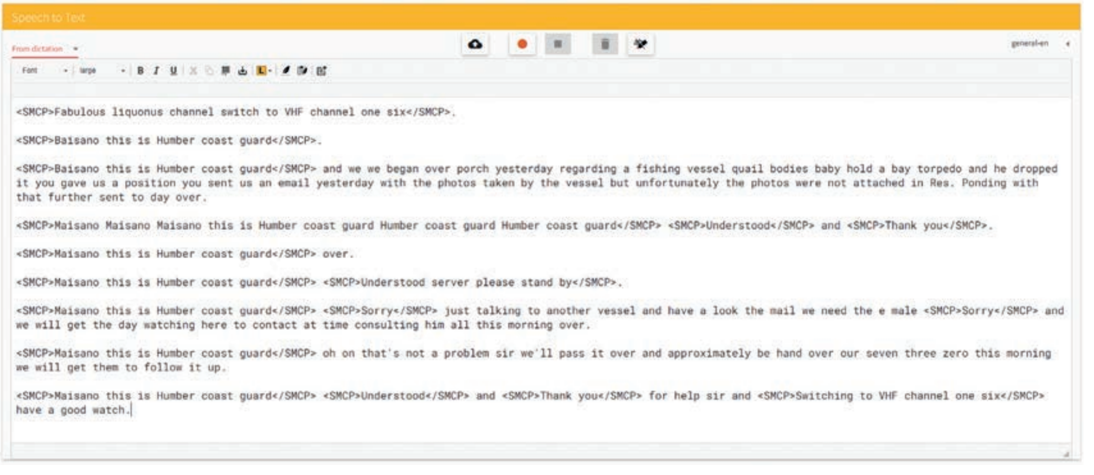

Figure 1. **SMCP annotation applied where applicable and tagged in the transcript (<SMCP></SMCP>).**

Result, output, impact

According to our study, the results of speech recognition with the trained ASR model were better than those with the standard ASR model (*Figure 2*) in terms of accuracy. We thus recommend training the ASR model to improve accuracy in speech recognition. In addition, we show that annotation can be used to tag SMCP phrases.

Speech recognition and annotation provides the means to improve the efficiency and accuracy of various workflows. It may reduce the time spent on manually typing and translating or recording entries and may reduce errors when crews speaking many different languages commu-

[1] see https://www.innoradar.eu/innovation/34080 and https://memad.eu/2020/10/15/innovation-radar/ for details.

nicate using a language other than their mother tongue. At the same time, recorded information is available more quickly to other experts and customers, which makes the service smoother and improves customer satisfaction, for example, in ports. More importantly, improved communication may improve safety. One potential scenario is when you have one operator communicating with multiple ships, so the ability to analyze the speech in real time and alert the operator if specific triggers appear in communication during an emergency could potentially save lives.

Moreover, both speech recognition and annotation can be provided as a service through an application programming interface (API). The Lingsoft Annotation API can be used to identify and produce metadata such as keywords and named entities based on text. The Lingsoft Annotation API can be integrated into third-party systems so as to create completely automated annotations, but the results can also be validated manually before adding them to the final result (semi-automated annotation). When fully integrated into the workflows, it can also be used for, for example, similarity and recommendation purposes.

Lingsoft Speech Service APIs can be used for speech recognition (transformation of spoken word into text). The solution can accept both live audio and pre-recorded audio material. In addition to the API service, speech recognition can also be provided with an easy-to-use web user interface for end users. This web interface enables end users to do live recognition (dictation) using their computer microphone. The recognition result is then delivered as text in the web interface's text editor. The text editor allows basic text processing, such as editing, copying and saving. Our web interface is currently used by subtitlers, transcribers, and doctors working in several organizations. It has also enabled organizations to work remotely, as our solution is accessed via the Internet.

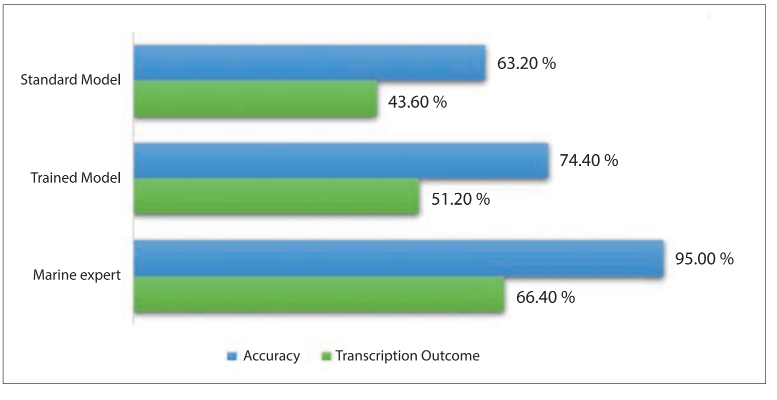

Figure 2. **Accuracy of speech recognition was improved using a trained ASR model.** (Source: Novia)

NODEON

NODEON

Nodeon is a dynamic and innovative technology company at the forefront of Finland's intelligent transportation system (ITS) industry. As a leading provider of ITS services and solutions, we specialize in planning, implementing, and maintaining large-scale road infrastructure technology systems, such as tunnels and motorways. Our expertise also includes cutting-edge traffic counting solutions, traffic data storage solutions, traffic data management systems, and advanced C-ITS systems.

We are passionate about innovation and driving positive change in the transportation industry, and we work closely with our clients to understand their unique challenges and provide them with the most advanced solutions and technologies available. With our unparalleled technical expertise, we help our clients optimize their transportation networks, improve traffic safety, and enhance the overall quality of life for citizens.

Informed terminal customers: traffic and parking

Contributor

- **Timo Majala,** Nodeon Finland Oy

In this research and development project, Nodeon focuses on addressing one of the most stressful aspects of ferry travel: the journey from home to the terminal building. Once travelers complete the check-in process and enter the terminal building, they can finally relax and start enjoying the ride.

To improve the overall ferry travel experience, we have identified a key theme for this project: "informed terminal customers." Our aim is to provide necessary and relevant information to customers about their journey from home to the terminal building, and to provide more enhanced parking solutions, creating a more environmentally friendly traffic system in the harbor and improving customers' overall experience.

Background

Nodeon has a proven track record of working with intelligent transportation system (ITS) themes, such as traffic situational awareness, traffic data fusion, and traffic management solutions. The company has also explored future ITS solutions, including managing automated bus fleets and co-operative ITS solutions, which involve communication between vehicles and infrastructure.

Traditionally, Nodeon's solutions have been utilized for the development of traffic systems in cities and inter-urban environments. The primary objective of their development has been to enhance traffic safety and fluency, creating a more environmentally friendly traffic system. In this project, Nodeon leverages its expertise in the harbor and terminal building ecosystem, combining its experience from the above-mentioned environments.

The project encompasses three main research and development areas:

(1) Informed long-distance customers, which aims to provide necessary and useful information to customers driving from home to the harbor and terminal building, reducing stress and uncertainty during the journey.

(2) Improved harbor area and city network traffic fluency, which focuses on real-time awareness of traffic situations in the harbor area and developing solutions to alleviate congestion.

(3) Smart parking concepts, which aims to provide an efficient and convenient parking system for customers, optimizing the use of parking spaces while reducing traffic congestion.

Through this project, Nodeon seeks to enhance the overall customer experience, increase traffic safety and fluency, and create a more environmentally friendly traffic system in the harbor and terminal building ecosystem.

Informed long-distance customers

Solutions

The "informed long-distance customers" theme aims to provide essential and helpful information for customers travelling long-distance to the harbor and terminal building. This trip can be stressful and can take several hours, with potentially unexpected roadworks, traffic jams, and uncertain parking situations, leading to increased anxiety and uncertainty for ferry and terminal company customers.

To address these issues, Nodeon gathered data from various sources, including the Finnish Meteorological Institute's open data, the national open traffic data system Digitraffic (by Fintraffic), Google data, and parking garage data interfaces, to create a centralized real-time data storage system using Microsoft Azure. This data is used to develop an easy-to-use interface for customers, providing real-time information on the best route to the harbor, unexpected situations on the road, parking availability, weather conditions, and ferry timetables.

Nodeon's proposed solution is a simple mobile application that displays the current status of all relevant data, enhancing the overall

Figure 1. **The mobile application.**

customer experience for long-distance travelers. By offering this information, ferry and terminal companies have the opportunity to significantly increase customer satisfaction while traveling long distances to the harbor terminal.

Improved harbor area and city network traffic fluency

The "improved harbor area and city network traffic fluency" theme focuses on enhancing the traffic situation in the harbor area and developing solutions to alleviate congestion. The core objective is to identify traffic congestion as soon as possible, to implement processes to increase fluency.

Nodeon conducted research and tested various technologies to recognize traffic situations at the city's traffic network intersections and on longer stretches of roads. The project tested the following technologies for this purpose:

- 360 3D LIDAR and edge intelligence
- Radar solutions
- ANPR solutions (automatic number plate recognition)
- Google travel time

The primary goal of using these technologies was to recognize when traffic congestion starts to build up. Nodeon conducted versatile testing at traffic light-controlled intersections, where the technologies were used to identify changing traffic conditions and vehicle queues at the intersections and on their inbound roads. The ANPR and Google travel time solutions were utilized to gain real-time understanding of the travel time between selected points, especially when it starts to increase.

In addition, the project aimed to develop and test an edge-intelligence solution for a traffic light-controlled intersection, to connect to the intersection traffic light controlling unit. The solution creates situational awareness of the intersection traffic situation, providing the possibility of connection to the traffic light controlling unit.

Overall, Nodeon's research and testing of these technologies provide a foundation for understanding the traffic situation in the harbor area and the nearby city road network, to create solutions to alleviate congestion and increase traffic fluency.

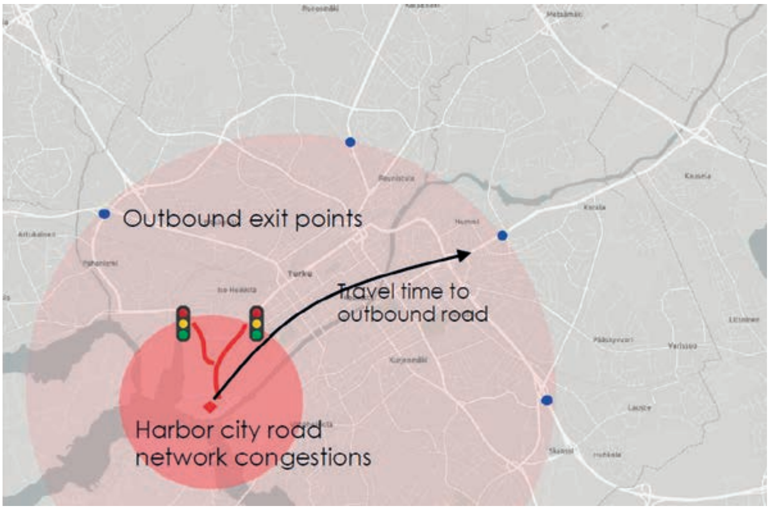

Figure 2. **City network traffic fluency.**

Smart parking concepts

Nodeon's "smart parking concepts" theme aims to address the parking challenges faced by ferry travelers, by offering new and intelligent parking solutions in future smart harbors. To achieve this, we have developed an innovative concept that consists of three different parking zones.

> The first zone is located closest to the harbor, in the terminal building parking areas. However, these areas are often congested and generate unnecessary traffic and pollution.
>
> The second zone is situated in large parking fields located in the harbor area, no more than 2–3 kilometers away from the terminal building. To provide seamless transportation from these parking areas to the terminal building, Nodeon has designed a non-stop automatic bus transport connection.
>
> The third solution involves using city park-and-ride facilities outside the city center, with access to public transport services that connect to the harbor area.

Situational awareness is key to using these solutions effectively. Customers should be informed of the situation in each of the three parking zones, to make an informed decision on which parking service to use. Nodeon has built a cloud-based parking management platform that connects to various parking facilities and counting solutions, to provide up-to-date information on the current status of each parking facility, including the number of available spaces. The platform also enables parking operators to monitor the parking situation and control changeable VMS signs in the city network, providing drivers with information on available parking spaces in each facility. Additionally, the platform provides information for mobile applications, serving the needs both of the city and of customers approaching the terminal.

Figure 3. **The illustration of the parking zones.**

Results

In conclusion, Nodeon's research and development project has focused on improving the customer experience and traffic situation in ferry harbors. The lack of real-time information about traffic, environmental conditions, and parking in harbor areas and the surrounding cities has been identified as a significant issue. Nodeon has developed solutions for improving situational awareness in the harbor area, data fusion to provide useful information for long-distance travelers, and parking concepts that reduce unnecessary traffic and increase customer happiness.

Modern harbors should invest more in these areas to provide intelligent parking experiences and wide-scale information for long-distance travelers, ultimately improving the overall customer experience and reducing environmental impact. With Nodeon's solutions and ongoing development in this field, we believe that ferry harbors can become intelligent, sustainable, and customer-centric transportation hubs.

Fimpec is a top expert specialising in project management and engineering. We work as a project consultant for large investment projects in the industrial and energy sectors, and as a specialist in the real estate and infrastructure sectors. We are ~400 top experts with a revenue of MEUR 41 in 2022.

In Finland, our offices are in Kouvola, Helsinki, Jyväskylä, Kotka and Turku. Abroad, we operate locally in Chile, Germany, Sweden, Uruguay and Estonia.

We don't settle for just the best possible result; we also think that the way in which the result is achieved is important. Our collaboration is based on transparency, responsibility, listening, and the capacity to continuously develop our own operations in an agile way. We guarantee that we keep our promises.

Our experience and expertise come from our workers. To us, people are individuals, not just a resource; they are all professionals with complementary competence. We want the best specialists working on our customers' challenges, so we invest in their continuous development. Client-orientedness and high standards guide our operations. To ensure the success of projects, our operating system is certified with the ISO 9001: 2015 quality certificate.

A platform for future traffic development of Turku Harbour

Contributors • Vesa Ranta, Heikki Wendelin, Joni Heino, Kyösti Meriläinen, Elias Meriläinen, Valtteri Holma, Marko Pakanen, Tuukka Wiker

Background

Focusplan Oy, acquired by Fimpec in 2022, invested in CAVE in 2018. CAVE (Cave Automatic Virtual Environment) is a virtual reality (VR) environment consisting of a cube-shaped VR room or a room-scale area in which the walls, floors and ceilings are projection screens.

In a CAVE system, actual scaled computer graphics and stereoscopic displays create an immersive virtual reality environment for one or more users. The CAVE is contained within a larger room that is completely dark when in use. Three-dimensional (3D) images and models within the VR CAVE appear to float in mid-air, and the user is "inside" the model.

First, the CAVE was used mainly for model reviews of industrial plant design projects and accessibility/usability reviews, which are quite normal and standard ways to use cave. To identify good additions to CAVE, to utilise it more efficiently, we looked back to our own experience of what we were missing in our engineering projects.

We first developed tools for conceptual design "on the go". These tools enable us to design concepts in the CAVE, without needing to use any design software. We can build basic designs such as buildings, steel structures, and piping, and we can also acquire material lists from those to spreadsheets.

These tools are very useful in very early project phases, when there is only a concept or an idea for investment. One can quickly draw up several concepts and the material available from those concepts, to help determine some of the costs of the investment.

Developing this into a business would require us to be involved in projects very early, and to be involved in these as an engineering and consulting company requires a lot of sales and contact work. As we were at the time quite small, as Focusplan Oy, our capabilities to invest in that way were limited.

However, given the reception of clients to CAVE, the tools developed, and the possibility to develop further, we realised that there is potential to widen the business dramatically with the correct actions.

Figure 1. The CAVE is contained within a larger room that is completely dark when in use.

Fimpec in SMARTER

At that time, the SMARTER project was introduced to us by TurkuAMK, with whom we had other co-operation at the time.

The SMARTER project gave us a perfect opportunity to develop the platform with a real-world case and to be able to contribute to the SMARTER goals.

The development would give Fimpec (Focusplan at that time) a good opportunity to have a new product to offer to existing client segments, but more importantly to new segments and even exports.

The general concept of what we wanted to bring to SMARTER was the creation of a visual representation of data from our partners. The data was to be presented in a virtual harbour developed for our CAVE

(cave virtual environment). CAVE is a four-wall projector-based system that is used for reviewing 3D models. It is especially suited for noticing spacing issues that would otherwise be hard to spot.

As we had previously worked on other projects that aimed to visualise parts of Turku, we knew we had the pipeline and the experience to tackle the modelling required for the harbour. While this has been our most technically ambitious project to date in terms of programming, we did have some former experience with transferring data to and from projects made in the Unity Game Engine. This was due to our need for a back and forth between design software and CAVE.

Solution, process and results

Evolution of the vision for our solution

What originally led us to the idea for our solution was the desire to turn CAVE into a more connected system instead of just a standalone 3D viewing device. There was already a system in place for remote control of CAVE, which we wanted to improve upon. The logical next step was to start work on creating a framework for data flow in our models. We saw that SMARTER provided the perfect opportunity to do just that.

However, due to GDPR issues hampering our original vision for the project, we shifted our focus to creating traffic simulations and refining our 3D environment. Our reasoning here was that a strong foundation of logic for simulations, and a model that as closely as possible followed the constantly changing layout of the new harbour, would be of most use for when more data could be accessed.

Implementation of our solution

Road traffic

Developing our road traffic logic was the first programming-oriented section of our solution. The created system includes a variable range for car acceleration and top speed to make the traffic seem more natural. Intersection logic contains detection for when lanes on the other side are full, so as not to create blockages. On top of having a working traffic light system, our traffic simulation also works with uncontrolled intersections without issues.

We have also included the ability to adjust the maximum car limit in the harbour. While the limit has not been reached, spawning of cars happens all along the spline system, which governs the pathing of our traffic. Once the limit is reached, the spawning will only take place on the edges of the model. This system enables the simulation to quickly fill the harbour with cars while also avoiding undue breaking of immersion once the car limit is reached. Together with the ability to block lanes and turns, manipulating the car count could be used to simulate specific traffic conditions and predict possible traffic jams. The spline system can be used to seamlessly add specified routes for taxis, buses, or lorries, as needed.

Maritime traffic

Although we were prevented from accessing data from our partners, we managed to implement open-source maritime data from Digitraffic in our solution. The Digitraffic site is specifically made for application developer usage, so it is a good example of how data logging and transfer should work.

The current implementation of the visualised maritime data shows ship traffic to and from the logged berths. Many of the more regularly visiting ships have custom ship models for faster recognition. The data itself is presented chronologically and parsed into an easily readable format. The data set shown is always for the date currently active in our simulated time system. The date and time can be changed at will, to review maritime activities in the harbour from as far back as the year 2018. Currently berthing ships also have floating tags with their relevant data entries visible on them.

Figure 3. Visualised maritime traffic data.

3D modelling

Our 3D model was in constant flux during the whole length of the project. The frequent updates to the harbour layout and the multi-layered nature of our model meant that it was rare for us not to be tweaking the model.

The visualisation was made with a base layer of 3D drone data that serves as the backdrop for our model of the new harbour buildings and infrastructure. This was supplemented with geometry generated within the Unity Game Engine, mainly covering the more nature-related aspects of the model, such as terrain, elevation and vegetation.

Figure 4. **3D model of harbour area.**

Testing and speculation

Benefits of our solution

The one-to-one scale of objects in the CAVE allows for easy understandability of 3D models and goes well with the self-evident benefits of having a visual representation of complex data. This makes for a potent combination, when delivering lots of information simultaneously is the goal. Implementing this solution in any pipeline that does not solely rely on experts would doubtless speed up information flow. Our solution also works independently of the CAVE system, which makes it more of a general use tool, as well.

Tests and experimenting on the data

The data visualisation system was tested to work with data input from both the cargo gates and the passenger flow. In addition to visualising the arrival and departure logs, we managed to use our test cargo gate data to change vehicle type and size, to create a depiction of the real vehicles as accurately as possible. Development of passenger flow simulation took a back seat for this project. We found that the design and modelling of the new terminal would not allow time to make sufficient progress during our involvement with SMARTER for us to start developing our simulations on top of it.

Our most extensive tests were run using the Digitraffic maritime data, to visually simulate ship movements in the harbour. Much of that data was manual input, which meant we needed to account for typos and other incorrect language when handling the data.

For road traffic simulation development, we experimented with different spline systems to find the perfect base for the pathing of our traffic. Development on the intersection logic was a balancing act in how extensively physics should be incorporated into the model while still avoiding collisions that would mess up the simulation.

Future perspectives

The final implementation of our solution serves as a great basis for future development on the data consolidation front. It has all the visual elements in place and some real-time external data functions in the form of visualised maritime traffic in the harbour. All the developed traffic and data visualisation systems are also transferable to other harbour models, making the creation of smart models like this one a notably easier task in the future.

Next data-independent steps

When the design of the new terminal progresses to a point at which its interiors can be modelled, we can start implementing and further developing pedestrian traffic flow simulations. This makes pedestrian traffic a future development point that does not necessarily require any additional data.

Adding a day/night cycle is another point we could work on. As lights in general are rather resource intensive when it comes to visualisation, we saw it prudent not to tax the system unduly before knowing the extent of the data the build would be required to handle. While lighting in visualisation projects can be precalculated to reduce the processing load, this is not possible for moving lights, of which this project would have plenty, due to traffic. To make this type of realistic large-scale night-time lighting possible, we would need to further develop our lighting systems.

It might be possible to fake the lighting of road traffic by creating texture maps for both day and night and then projecting one over the other in the places where the headlights are pointing.

Maintenance

Visualising the open maritime data will eventually face some issues when input conventions, berth names, and so on change. We could further develop the system to give users the tools to do such maintenance on their own.

Next data-dependent steps

Other maritime-related things we could work on include more accurate pathing for the animations of our shipping lanes. While the berth locations are accurate, the arrival animations are mere approximations and could be made vastly more accurate/realistic by having some tracking data for reference.

Obviously, the development area with the most potential would be further developing external data integration systems. This would require first solving the GDPR issues with which the project has been struggling.

Other perspectives

Presentation in the CAVE environment is very effective due to its collaborative nature. It is also quite spectacular when the environment is presented on a scale of 1:1 in 3D visualisation.

But as the CAVE is a local unit that requires participants to be at the location, this limits its usability. As modern collaboration is more and more carried out remotely, this is a challenge for CAVE-based businesses. Our platform is therefore developed further, enabling its use in any Windows-based OS environment.

Even when, for any reason, real collected data may not be used, predicted and created (not collected) data can be utilised to demonstrate the traffic and predict different scenarios that any deviations may bring.

The developed platform, in which data controls the movement of visualised objects, is ready and implementable for any other infrastructure, requiring only the modelling of the environment. This opens opportunities to widen our business. In the Fimpec group, we have a business area that is dedicated to infrastructure sectors.

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Novia is a dynamic and international university of applied sciences with high-quality education, as well as research, development, and innovation activities that support working life. Novia´s automation and maritime simulation research team combines the operational expertise of the maritime field, a deep understanding of safety, and the impact of human factors with skills that focus on technology, digitalisation, and smart solutions. We are experts in maritime operations and safety, and we are constantly developing new, sustainable solutions to improve these areas within the industry.

Seamless cargo flow through the port

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Introduction

The increased demand for carbon-neutral logistics networks has a direct impact on business strategies worldwide. As a result, the implementation of efficient and environmentally friendly sustainable solutions is prioritised over traditional time and cost-saving operations. This is especially true for the backbone of logistics: transportation (Sople, 2009).

Over 80 % of the volume of international trade in goods is carried by sea (UNCTAD, 2021). The logistics hubs where waterborne transport meets with other transportation modes to exchange cargo and passengers are the ports. Therefore, optimizing the ports to provide a seamless cargo flow in an environmentally responsible manner is a must.

Background The essence of transport is the need to transfer goods and passengers from one place to another. The flow of cargo and passengers must be uninterrupted, ideally without any delays or waiting times. Maintaining a continuous flow is a challenging task due to multiple constraints, such as a wide variety of actors, business competitiveness, infrastructure, legislative framework, environmental compliance, socio-economic factors, and others. A possible solution to resolve most of the challenges is the implementation of autonomous means of transportation. However, achieving full autonomy in logistics networks requires disruption of the existing models and practices. Transforming the traditional business environment and business ecosystems has started with the introduction of the Fourth Industrial Revolution also known as Industry 4.0. The main drivers of Industry 4.0, such as artificial intelligence, internet of things, sensor fusion, big data and quantum computing, are already applied in one part of the transport modes (e.g. road and rail), but they barely touch other sectors (e.g. maritime domain). As a result, only a fraction of the full capabilities of the existing high-end technology is utilised, which leads to inefficient multimodal transportation.

In the SMARTER project, Novia decided to focus primarily on finding sustainable and replicable models for the smart harbour environment through digitalisation and data sharing. The first step towards achieving the project goals was performing a thorough analysis of previous research in the area of the port call process. The analysis encompassed various port call optimization solutions, as well as initiatives fostered by national and EU authorities. Then, based on the analysis outcomes, Novia divided the further work into two streams.

The first stream was created around road traffic from and to the project's test bed, the port of Turku. The goals were identification of the existing gaps and bottlenecks, mapping of the potential future challenges, and providing recommendations and possible solution for safer and more efficient arrivals, turnaround, and departures without affecting any urban areas or the environment.

The second stream concerns the communication challenge in the first and second autonomy degree of Maritime Autonomous Surface Ships according to the IMO classification (IMO, 2021). The challenge is related to the communication between the remote vessel operator and the on-board crew. Establishing smooth and reliable shore-to-ship and ship-to-shore communication will increase safety at sea, improve situational awareness, generate time savings, and thus enable seamless and more environmentally friendly maritime transportation. The plan was first to identify the root causes of the communication challenge, and after that to propose a practical working solution to improve the communication between the remote operational centre and the vessel.

Both streams above were aligned with the main project's objectives: reduction of emissions by optimizing port logistics and enabling an exceptional flow and experience for the passengers and cargo.

Analysis of previous studies

Solution The aim of the analysis was to gain insight into what is going on in forms of research, development, testbeds, different approaches, and available solutions.

The analysis approached the optimization challenge from three different perspectives: optimization of ship traffic flow, optimization of port operations and port flow, and optimization through smart technology.

In the 'optimization of ship traffic flow', the Port Collaborative Decision Making (PortCDM) concept and its derivative, the Port Call Message Format (S-211), were scrutinised along with the just-in-time approach, virtual arrival, the Port Forward project, Pronto and the PortXChange programme, as well as the Port Activity Application developed during the STM Efficient Flow project.

The 'optimization of port operations and port flow' part consisted of a thorough analysis of the modifications made in the layout, operational procedures and practices in the port of Montreal and the port of Tianjin to solve their challenges with inefficient operations, traffic congestion and carbon footprint.

The analysis aimed to find similarities and common patterns between different activities that could be used in the SMARTER project.

The analysis of 'optimization through smart technology' included the port of Hamburg's traffic management system, SMART lighting, automatic radar identification system, and other advancements based on IoT, sensor fusion and AI.

The reason to go over the high-end technologies applied in ports was to determine to what extent the ports are ready to synchronise with the other players' parts of the logistics network, where the Fourth Industrial Revolution is already implemented.

Finally, the governmental initiatives concerning Finland were outlined. A brief overview of the European Maritime Single Window (EMSW), Portnet and the upcoming NEMO platform was made.

Feasibility study on just-in-time arrival of lorries and trailers in the port of Turku

The feasibility study aimed to provide insights into how to better organise the inbound flow of road vehicles to the port of Turku. The need for a new road traffic scheme is caused by the upcoming port renewal, in which two RoPax terminals will be merged into one, resulting in the sharing of a common terminal and stowing area by two RoPax ferry operators (Figure 1).

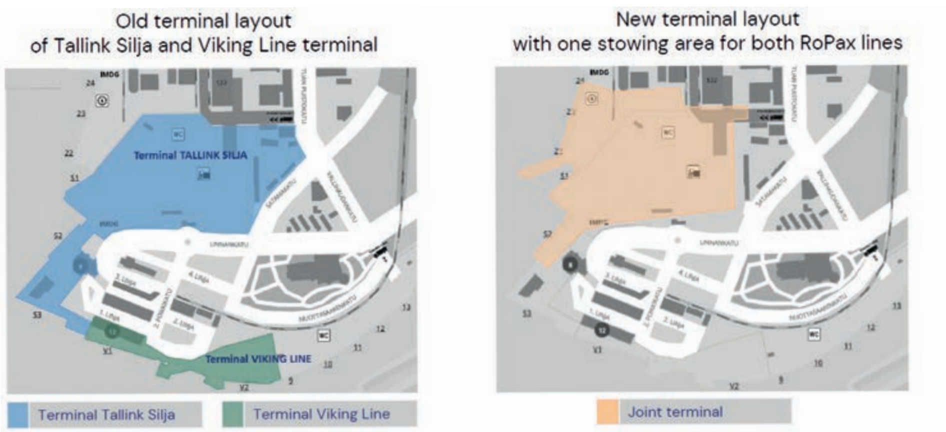

Figure 1. **Port of Turku current and future layout.**

The main objective was to find a practical, efficient, and globally replicable solution for handling lorries and trailers to achieve a 'just-in-time' regime in any RoRo port.

At the core of the study lies a sophisticated simulation carried out according to VDI 3633 (Figure 2).

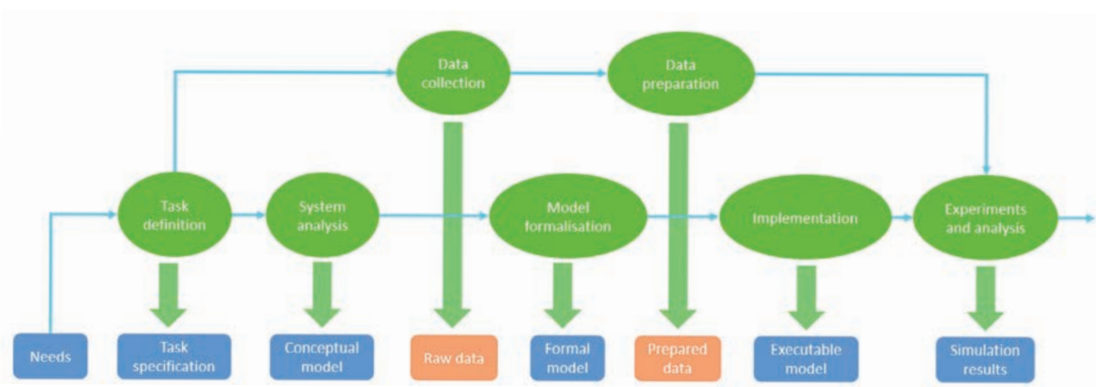

Figure 2. **Extended process model (based on Rabe et al. (2008)).**

The simulation was based on the following static and dynamic parameters. Static parameters are the road network, speed limits, truck prohibited areas, railway crossings, and city infrastructure. Dynamic parameters are the road and railway traffic composition, traffic light programs, schedules of crossing trains, routing of arriving vehicles, and type, quantity, and composition of arriving vehicles at the port gate.

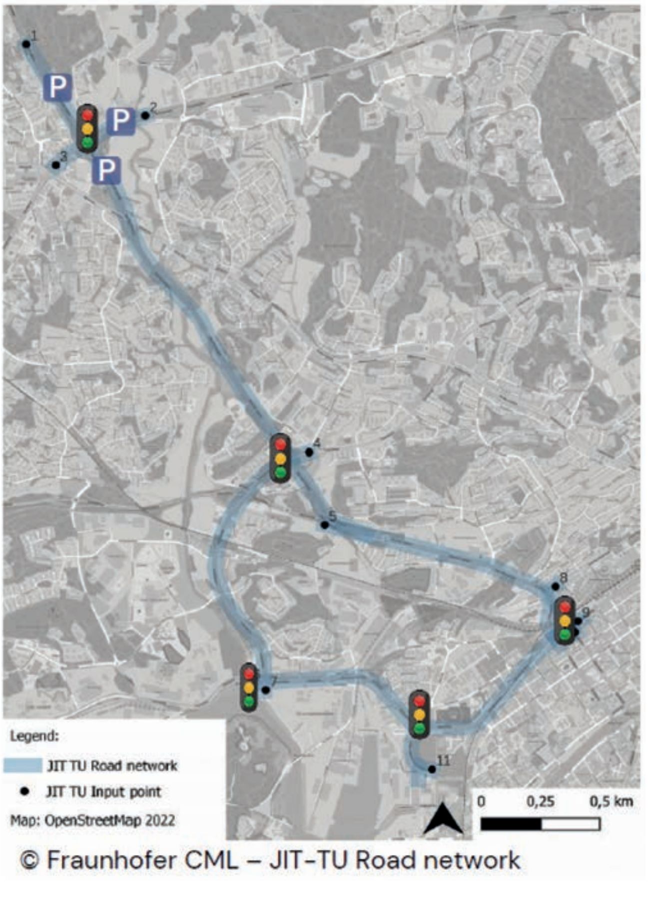

Figure 3. Static and dynamic parameters loaded in the simulation model.

For the simulation, microscopic multi-modal traffic flow simulation software was selected, as it enables the modelling and simulation of every entity individually, as well as the interactions between the entities.

The input data was provided by different stakeholders such as Ely-keskus, Turku City data, Fintraffic, Silja Line, and others.

The simulation contained six scenarios differentiated from each other by season, availability, and location of parking areas.

Figure 4. **Screenshot from the used microscopic multi-modal traffic flow simulation software.**

Scenario	Strategy	Pre-parking	Vehicle composition
A.1	random	No pre-parking	summer
A.2			winter
B.1	ordered	Pre-parking ahead of Raisio junction	summer
B.2			winter
C.1		Pre-parking beyond Raisio junction	summer
C.2			winter

Figure 5. **List of simulation scenarios.**

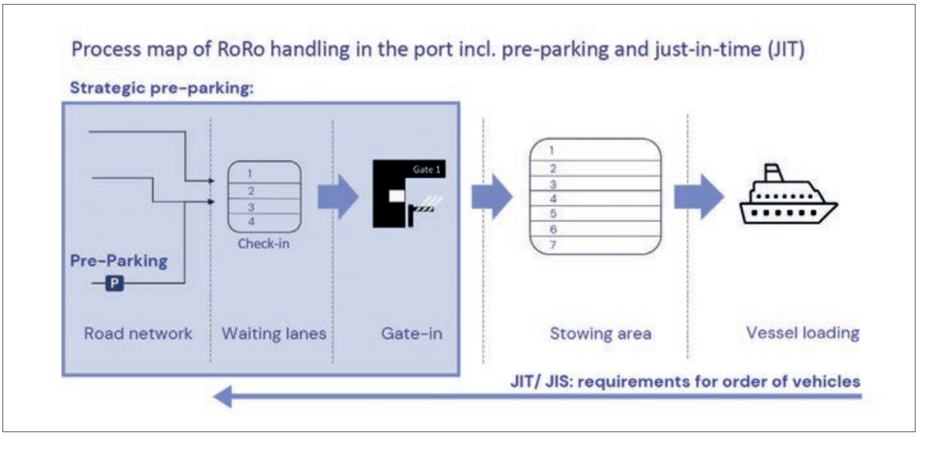

Figure 6. **General process map of JIT combined with the pre-parking concept.**

In addition to the simulation, the study included interviews with key stakeholders and a literature review. Among the key stakeholders were Viking Line, Tallink Silja, Fintraffic, City of Turku, Telia, VISY, Turku City data, Port of Turku, Finnlines, Ely-keskus, and others.

A simplified, generally applicable process map for RoRo handling in a port is shown in Figure 6.

The focus is on the handling of cargo entering the port area from the hinterland by road. The vehicles arriving at the terminal wait in waiting lanes to process the check-in to enter the terminal. At the terminal, the RoRo cargo is sorted in a stowing area (e.g. depending on size and specification) and then stowed on the ship (e.g. the ferry).

The blue square in Figure 6 indicates the process considered in this study to investigate the implementation of a pre-parking and JIT concept. Pre-parking areas are placed outside the port area. In the JIT approach, the terminal operator has to establish a communication channel to call vehicles from the pre-parking area to the gate-in. The terminal operator needs to plan the departure time of vehicles from pre-parking area. The just-in-time arrival concept enables the arrival of vehicles at the right time. However, the exact number and type of arriving vehicles is determined by a just-in-sequence (JIS) strategy. In other words, JIS is a prerequisite for enabling the JIT arrival concept.

Figure 7 summarises the state of the art in strategic pre-parking concepts in RoRo ports.

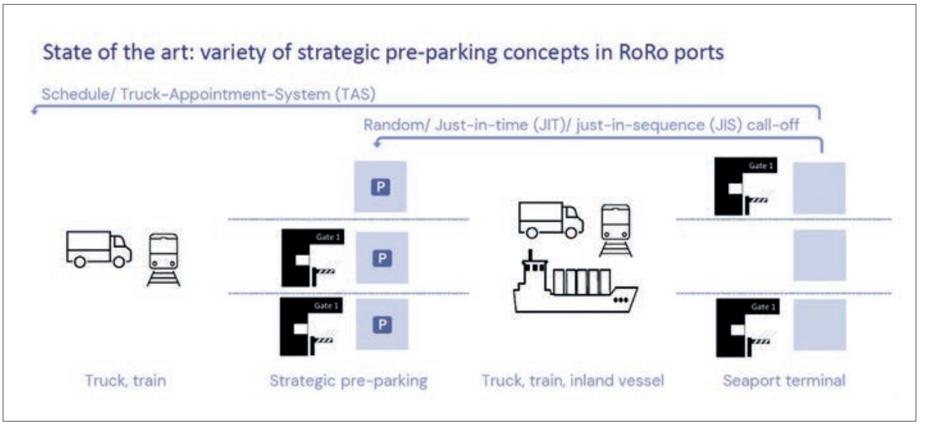

Figure 7. State of the art: variety of strategic pre-parking concepts in RoRo ports.

Access from the hinterland to pre-parking areas can be by different or multiple means of transport: by truck, rail, or inland vessel. A strategic pre-parking area can be either a simple car park with parking spaces only, or it can also be equipped with service facilities, such as petrol stations, restaurants, or sanitary facilities. A gate-in could be included in order to prepone registration processes. The distance between the pre-parking area and the terminal varies in the literature and in practice: a car park can be from a few hundred metres up to 30 km away from the seaport terminal. The use of the car park is optional, recommended, or compulsory. Means of transport between the pre-parking area and the seaport terminal can include one or more modes of transport (truck, rail, inland vessel). The mode of transport can be either publicly accessible or privately operated by the port or port stakeholders. The seaport terminal may operate in three modes: check-in at pre-parking, check-in at seaport, or check-in at pre-parking and seaport. This depends on whether the transport between the pre-parking area and the seaport terminal is organised privately by the port or publicly. The arrival of transport units at the seaport terminal can be controlled in different ways: the transport units arrive at the seaport terminal at random, without following a specific timetable or an allocated slot; or the transport units follow a specific timetable or have a booked slot from a truck appointment system (TAS); or the transport units are called off by the seaport terminal according to a just-in-time (JIT)/just-in-sequence (JIS) concept.

The location of the pre-parking areas in different scenarios is shown in Figure 8.

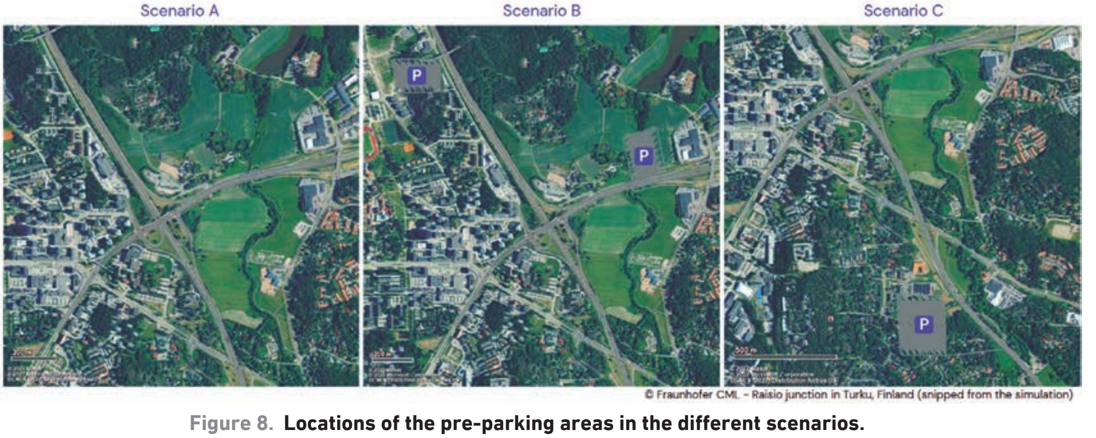

Figure 8. Locations of the pre-parking areas in the different scenarios.

Scenario A represents the status quo, in which pre-parking areas do not exist, and vehicles arrive directly at the port in a random order. In scenario B, two pre-parking areas are available ahead of Raisio junction: one for traffic coming from the east via E18 and another one accommodating traffic from the north via E8. The vehicles arrive at the port from the pre-parking areas following a certain order. Scenario C is similar to scenario B, except that there is only one pre-parking area located beyond Raisio junction.

The division of the parking spaces in the pre-parking areas is shown in Figure 9, in which the vehicles are divided by type (car, standard truck, semi-trailer combination, full trailer combination, trailer) and specifications (electric vehicle, dangerous goods vehicle).

Figure 9. **Pre-parking: division of parking spaces in pre-parking area.**

The departure of the vehicles from the pre-parking area(s) is in sequence, with fixed departure times. The number of vehicles in a group varies. One group contains only one type of vehicle, and the departure times are as requested from the responsible loading personnel in the port.

An example of a simulation scenario is shown in Figure 10.

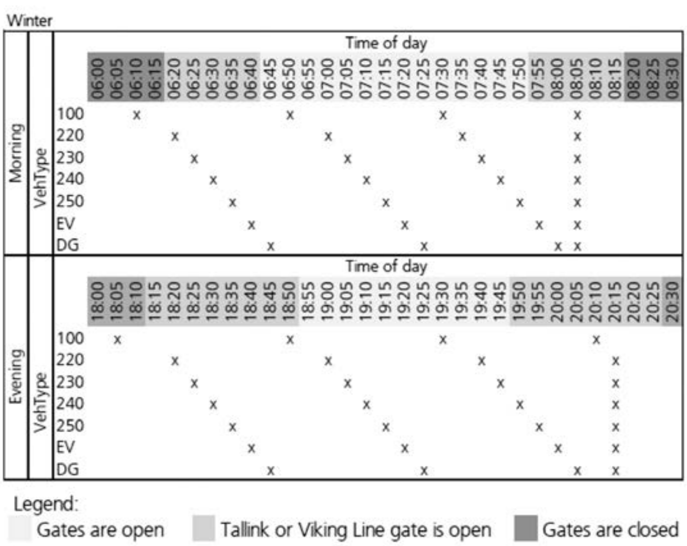

Figure 10. **Example of a simulation scenario.**

Remote operations communication challenge

Reliable communication between the remote operational centre and the on-board crew is essential when MASS is operated in first and second degrees of autonomy. Having crew members on board either monitoring and being on standby (Autonomy degree 2) or actually operating the vessel (Autonomy degree 1) requires information exchange with shoreside services (IMO, 2021). When a vessel is engaged in coastal navigation, the most frequently used and effective communication method is VHF radio communication.

Therefore, Novia started working on a PoC solution utilising the AMROC developed in the S4V Fairway project. The end goal is to make AMROC able to fully support a shore-based operator in the decision-support and decision-making processes. Such a solution would be able not only to ensure seamless ship-to-shore communication, but would also facilitate the reporting and coordination of multiple ships or fleets, which often leads to multitasking and high workload levels that affect safety at sea, as well as the mental health of fleet managers and VTS operators. A high-level flowchart explaining the handling of the communication process is shown in Figure 11.

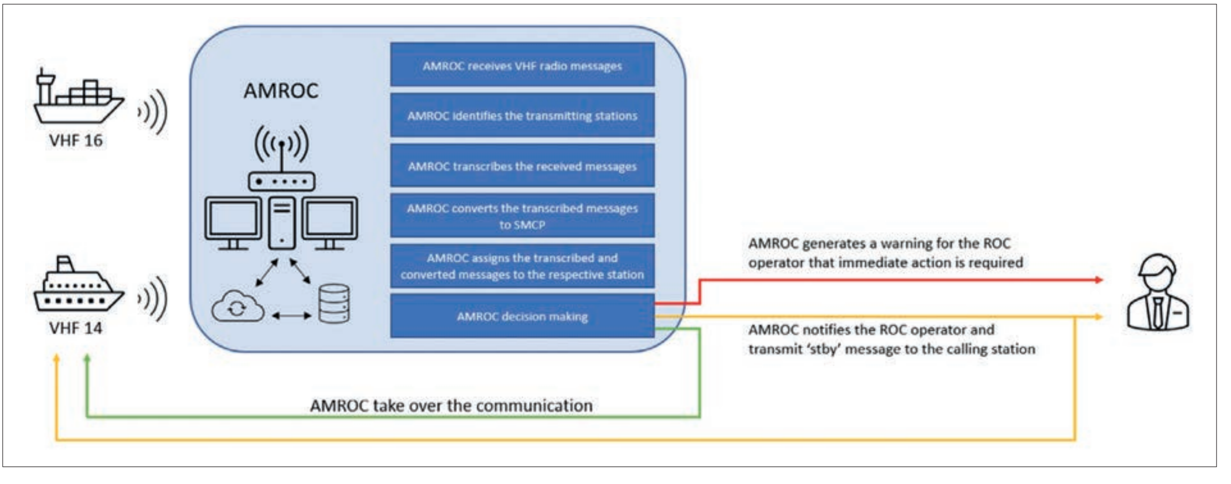

Figure 11. **AMROC's communication solution described on a PoC level.**

Novia looked for assistance from project partners and external stakeholders, as the set target required complex AI-driven software, the development of which is beyond Novia's expertise. The challenge was accepted by one of the project partners: Lingsoft. After a series of meetings, the plan was revised, and the scope was narrowed to the use case shown in Figure 12.

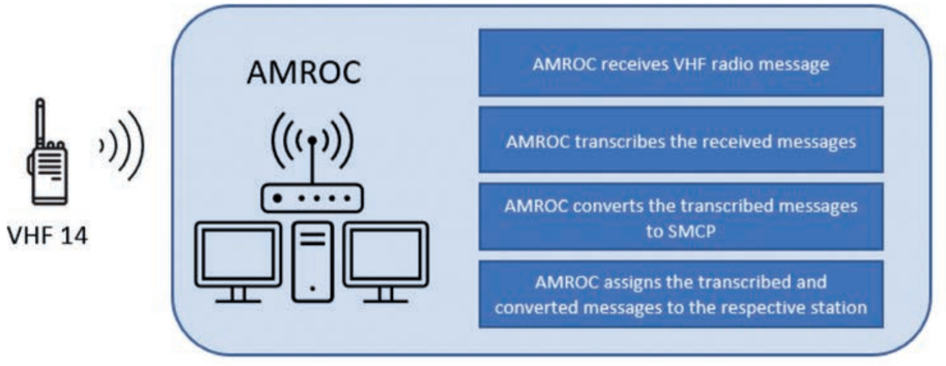

Figure 12. **AMROC's use case in SMARTER.**

The main objective of the agreed use case was to prove that the currently existing AI models are applicable in the maritime environment, as the VHF radio signal is characterised by high levels of noise, is prone to interference, and has a range that depends on many factors, such as atmospheric conditions, hardware configuration of the transceivers, and so on. It is important to mention that the VHF audio samples used in the project are authentic. They are neither simulated nor recorded in any other 'sterilised' ambient setting. Instead, a set of mixed real-life maritime VHF radio recordings in English language from different countries was used. The aim was not only to cope with the VHF noise and signal disturbances, but also to scrutinise how the language dialects and accents would affect the quality of the input data.

The first task was the generation of input data. This was divided into two subtasks: converting maritime audio recordings to text and adapting the transcriptions to Standard Marine Communication Phrases. The VHF recordings were transcribed by experts with a maritime background and by an ASR engine. The results were then analysed and compared. The second subtask was carried out only by the maritime experts, because currently there is no digital solution able to do it.

Analysis of previous studies

Results, findings, output, and impact

The analysis of the research on existing solutions pinpointed some common observations and findings. The most important of all is that regardless of what optimization approach is chosen, and regardless of which process is selected, the following enablers are must-have: digitalisation, data sharing, standardisation of data format and protocols, governance structure, and contractual and legislative changes. If just one of these is omitted, the optimization goals cannot be achieved. This is visible in the high-level chart (Figure 13).

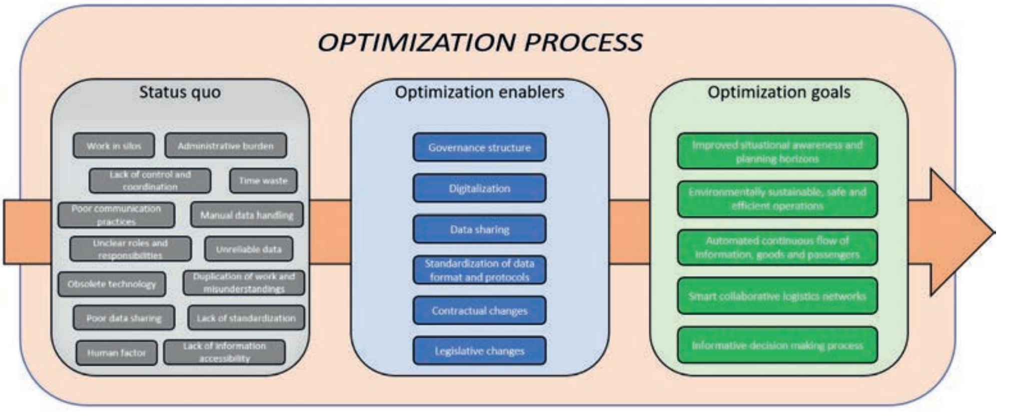

Figure 13. **Optimization process on a high level.**

More detailed research on the relationship between the different elements and the mapping of dependencies between them must be conducted in the future. Such research would reveal the weight and the importance of every individual component. However, the research shall also explore the combinations of binding different elements into groups and how the grouping would affect the overall process. The expected outcome is a step-by-step guideline on how optimization can be introduced in the maritime industry.

Feasibility study on truck and trailer just-in-time arrival at the port of Turku

As already mentioned, the feasibility study consisted of a literature review, interviews, and a simulation. The major finding from the literature review was that there is very little available research data on RoRo and RoPax port calls. Therefore, to determine the most suitable optimization concept for the port of Turku, which can be easily applied in any other RoRo or RoPax terminal, the interviews were adequately planned in terms of question preparation and interviewee selection. The results from the interviews not only showed the common pain points and bottlenecks, but also outlined the similarities and the differences in the challenges and needs of every stakeholder.

Among the top three common findings were the spatial conflict between the growing housing areas and port activities, the traffic congestion at the intersection of European routes E18 and E8 in Raisio, and the insufficient capacity of the port's parking area. Another frequently observed challenge is the earlier arrival of trucks. From a haulier's viewpoint, this makes sense, as it allows the drivers to better organise their work schedules and rest periods, and it guarantees embarkation. However, from a port authority perspective, earlier arrivals are unwanted, as the trucks produce excessive amount of GHG and increase the possibilities for congestion in the vicinity of the port.

Bearing in mind the outcomes from the interviews and the literature review, the following solution was proposed to be simulated: a combination of JIT, JIS, and pre-parking area(s) outside the port.

Simulation indicators

During the simulation, a total of three indicators were measured: 'travel time', 'arrival time', and 'queue length'.

'Travel time' indicator

The first measured indicator was 'travel time'. 'Travel time' is the time measured between a vehicle's departure from the per-parking area (scenarios B and C), or the moment it enters the simulation from the road network (scenario A), and its arrival at the port. An example of a travel route in scenario B, for which 'travel time' is measured, can be seen in Figure 14.

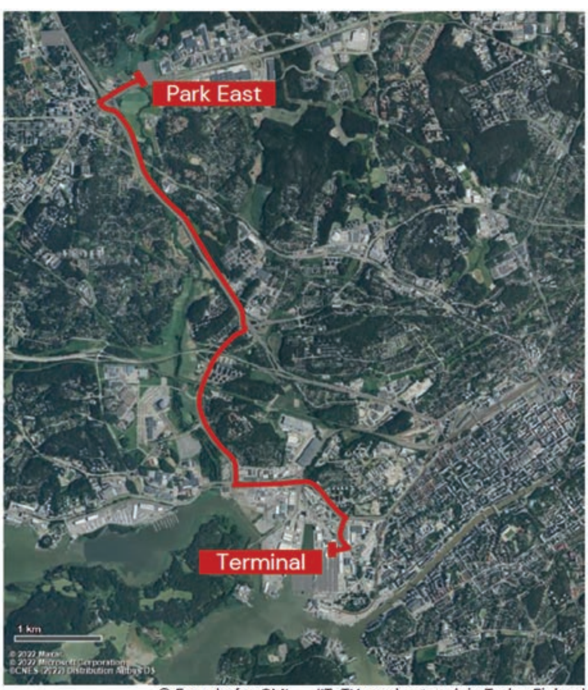

Figure 14. An example of a travel route in scenario B.

The starting points for each scenario are shown in Figure 15.

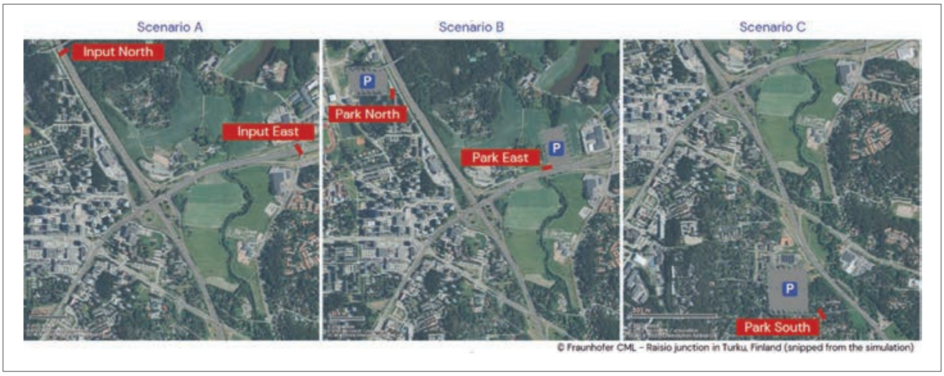

Figure 15. Simulation scenario starting points.

The 'travel time' in scenarios A.1 and A.2 varies between 8 to 12 minutes, regardless of the other factors (season, time of day, vehicle type).

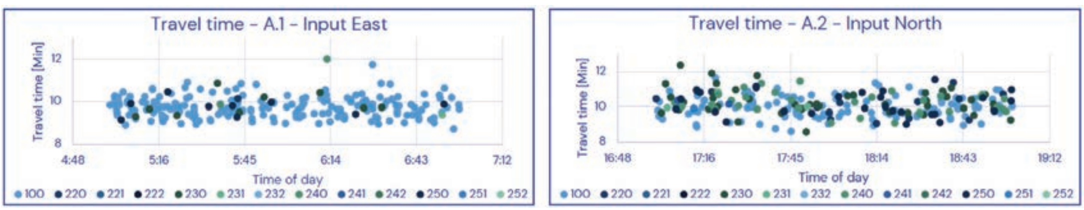

Figure 16. Simulation results A.1 and A.2 ('travel time').

In scenarios B1 and B2, the travel time depends on the season and vehicle time. The travel time in summer is between 9-30 minutes, while in winter it is from 8–17 minutes in both the morning and the evening. It was noticed that as soon as a group of one vehicle type leaves the pre-parking area, the travel time for each following vehicle increases. Because more cars than trucks have to pre-park in summer than in winter, the percentage distribution of vehicle volume per vehicle type, and thus also the travel time per vehicle type, is more balanced in winter. The increased traffic volume in the network at any given time due to the groups of vehicles cannot be handled by the currently existing infrastructure (traffic light programs).

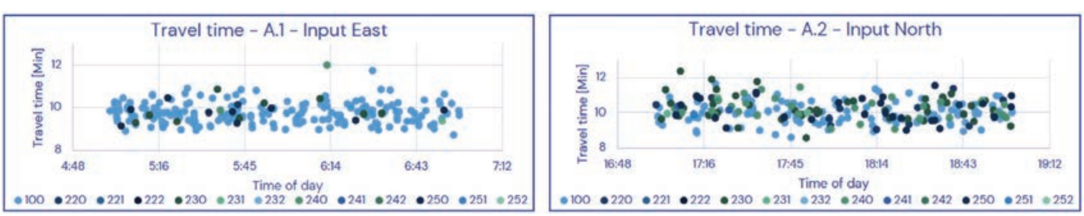

Figure 17. Simulation results B.1 and B.2 ('travel time').

The travel time in scenarios C1 and C2 also varies according to the season and vehicle type. In the summer, cars need 7 to 28 minutes, while trucks need 7 to 15 minutes. In the winter, cars need 7–15 minutes, and trucks need 7–15 minutes. As soon as a group of one vehicle type leaves the pre-parking area, the travel time for each following vehicle increases. Since the respective size of the groups of vehicles is higher in summer than in winter, the traffic volume in the network increases at any given time, which is why the travel time for cars is longer in summer.

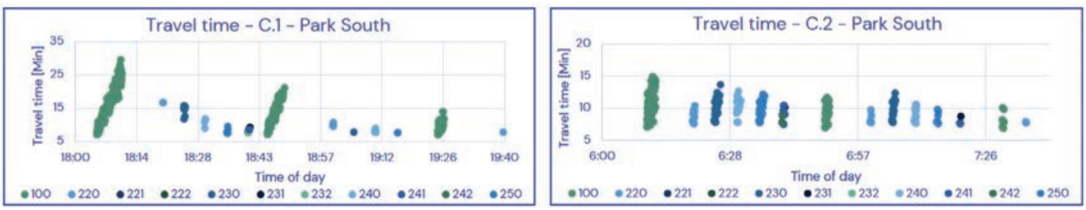

Figure 18. **Simulation results C.1 and C.2 ('travel time').**

Comparing the travel time measured in the different scenarios, it can be concluded that the travel time in scenario B is the highest, as the vehicles need to cross the Raisio junction, and the size of a group of vehicles is proportionally larger in summer than in winter and in scenario C. Leaving pre-parking areas in groups strains the network at certain points, wherefore travel times increase with a JIT concept because the existing traffic light programs are not designed for the size of group leaving the pre-parking area. In scenario C, the vehicles bypass the Raisio junction and are pre-sorted, so that the vehicles per vehicle type can be called at a specific time of the terminal operator's choice.

Figure 19. **Comparison of the results between scenarios A.2, B.2 and C.2 ('travel time').**

'Arrival time' indicator

The next measured indicator was 'arrival time'. 'Arrival time' is the time when the vehicle arrives at the RoRo terminal. The arrival points are shown in Figure 20.

Figure 20. **Arrival point in all scenarios.**

In scenarios A1 and A2, the arrival of vehicles at the terminal is discontinuous and not evenly distributed, regardless of whether the season is summer or winter, or whether the time of day is morning or evening.

The vehicle types arrive at random and in a disorderly fashion. The unpredictability of arrivals results in a lack of transparency. As a result, stowing at the terminal is neither plannable nor controllable.

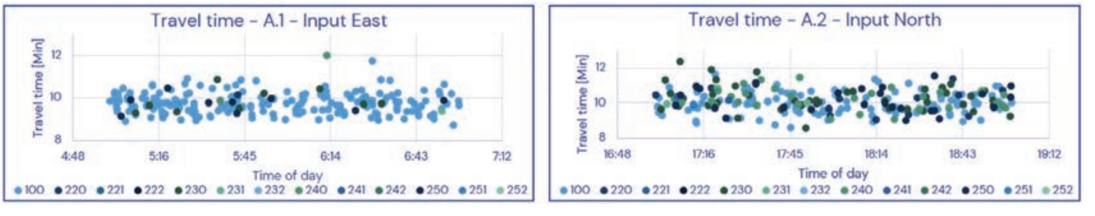

Figure 21. **Simulation results A.1 and A.2 ('arrival time').**

In scenarios B1 and B2, the arrival of vehicles at the terminal is sorted and sequential both in summer and in winter, as well as in the morning and in the evening. This shows the composition of vehicle types per season: in summer, the majority are cars; in winter, trucks. The JIT regime of vehicle departures from the respective pre-parking area is reflected in the sorted arrival of vehicles at the terminal. There is transparent and predictable information about the arrival of a vehicle type and vehicle specifications. As a result, stowing at the terminal is plannable and controllable.

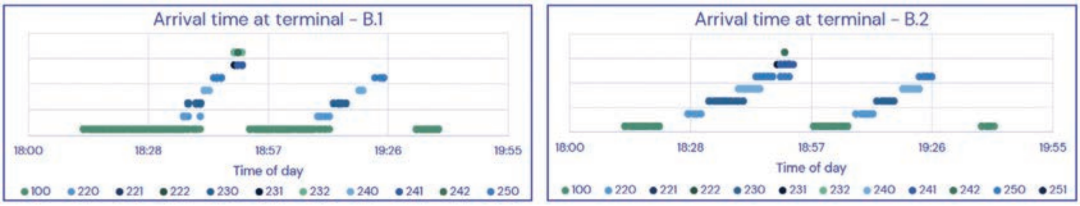

Figure 22. Simulation results B.1 and B.2 ('arrival time').

In scenarios C1 and C2, the arrival of vehicles at the terminal is sorted in both seasons as well as in the morning and the evening. The composition of vehicle types varies per season: in summer, the majority are cars; in winter, trucks. There is no difference from the structure of vehicle arrival time in scenario B. The information about the arrival of a vehicle type and vehicle specifications is transparent and predictable. As a result, stowing at the terminal is plannable and controllable.

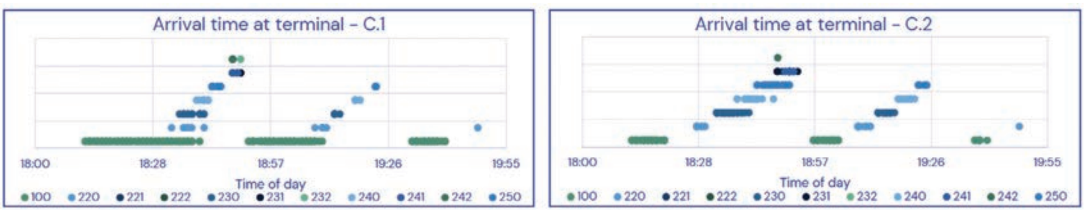

Figure 23. Simulation results C.1 and C.2 ('arrival time').

A comparison of the arrival time in different scenarios leads to the following conclusions. In contrast to the unpredictable arrival of vehicle quantity, type and specification in scenario A, scenarios B and C structure the arrivals of vehicles at the terminal. Scenarios B and C achieve transparent and predictable information about the arrival of vehicles at the RoRo terminal. Scenarios B and C enable the terminal to control the arrival of the vehicles with the help of the JIT regime, in order to plan the terminal processes (e.g. stowing) in advance.

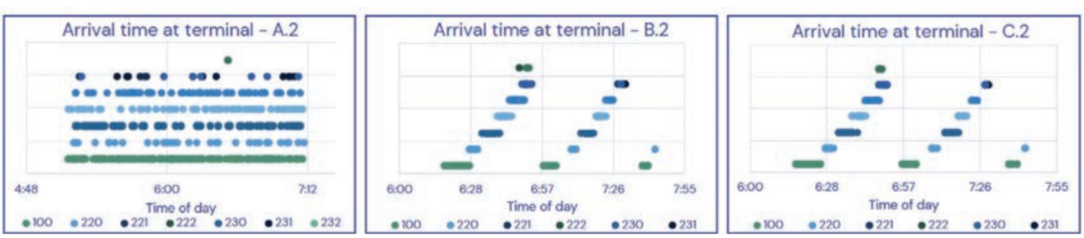

Figure 24. Comparison of the results in scenarios A.2, B.2 and C.2 ('arrival time').

'Queue length' indicator

The third indicator was 'queue length'. A vehicle is considered to be in a queue if its speed is less than 5 km/h, and it remains in the queue as long as its speed has not yet exceeded 10 km/h. 'Queue length' is the distance between the traffic counter and the farthest vehicle that meets the defined queue conditions. The counter is a measurement point from which the queue starts. In total, six counters are located in the main bottleneck, which is Raisio junction (Figure 25).

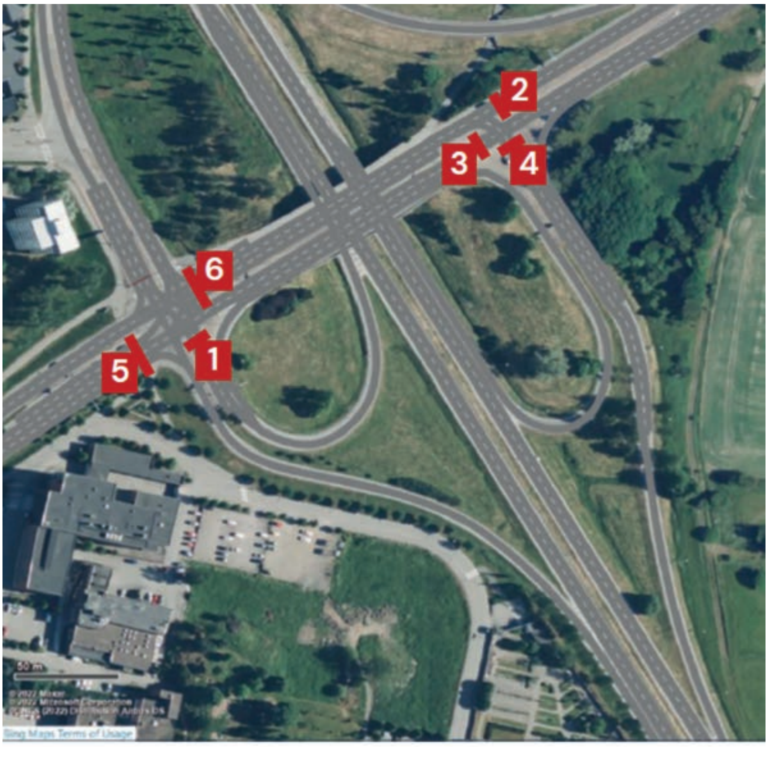

Figure 25. Measurement points (counters) at the main bottleneck, Raisio junction.

The focus is on counters 2 and 6, as they have the most significant impact on the simulation results.

First, the queue length was measured in the summer scenario at counter 2. In this case, scenario B has a significant increase in average queue length (15 m) as well as in maximum queue length (up to 150 m), while scenario C is similar to scenario A. Pre-parking ahead of the Raisio junction leads to an interruption at checkpoint 2 in summer and increases the travel time of vehicles driving from E18 to E8 in the direction of Turku city centre.

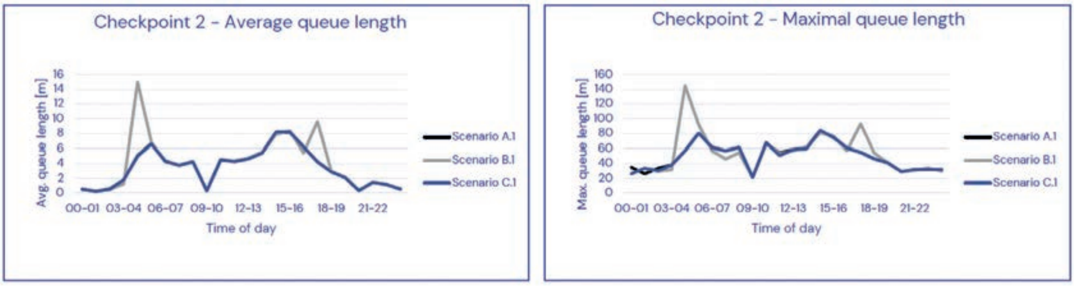

Figure 26. **Simulation results at counter 2 in the summer ('queue length').**

The queue length was then measured again in the summer scenario at counter 6. The scenario B results again showed a significant increase in average queue length (55 m) and in maximum queue length (up to 190 m). Scenario C is similar to scenario A. Pre-parking ahead of the Raisio junction leads to an interruption at checkpoint 6 in summer and increases the travel time of vehicles driving from E18 to E8 in the direction of Turku city centre.

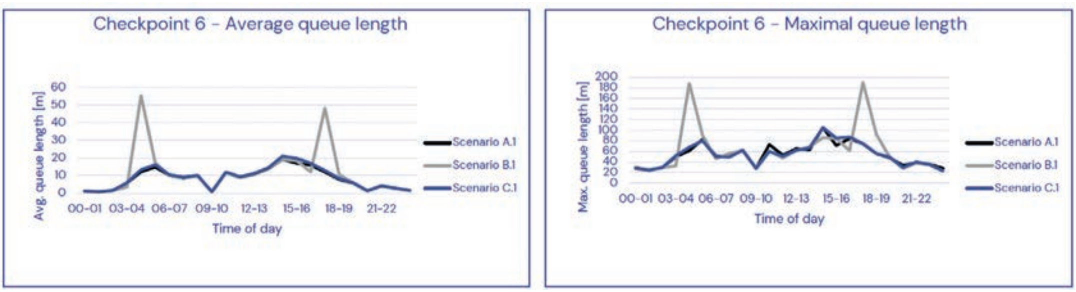

Figure 27. **Simulation results at counter 6 in the summer ('queue length').**

The winter scenarios at counter 2 showed that the three scenarios have almost similar values for average queue length. Pre-parking beyond the Raisio junction leads to a traffic situation at Raisio junction that is similar to the status quo.

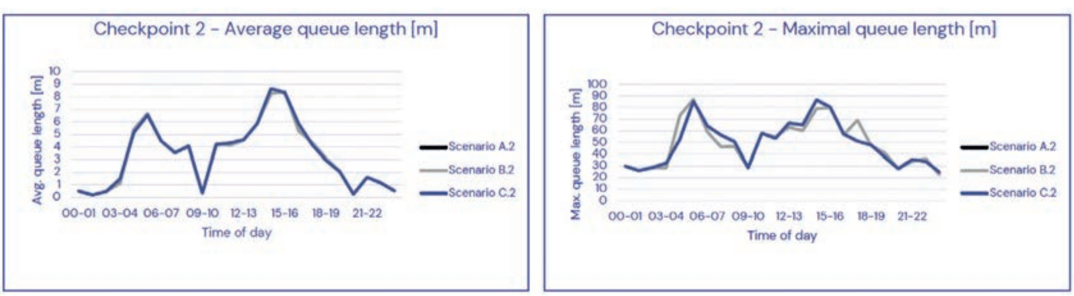

Figure 28. **Simulation results at counter 2 in the winter ('queue length').**

The winter scenario at counter 6 led to the following conclusions. Scenario B has an increase in average queue length (up to 25 m). Scenarios A and C have a higher maximum queue length between 2 and 6 pm (up to 135 m). Pre-parking ahead of the Raisio junction lowers the maximum queue length at checkpoint 6 at the Raisio junction. The lower maximum queue length is a result of equalised traffic flows.

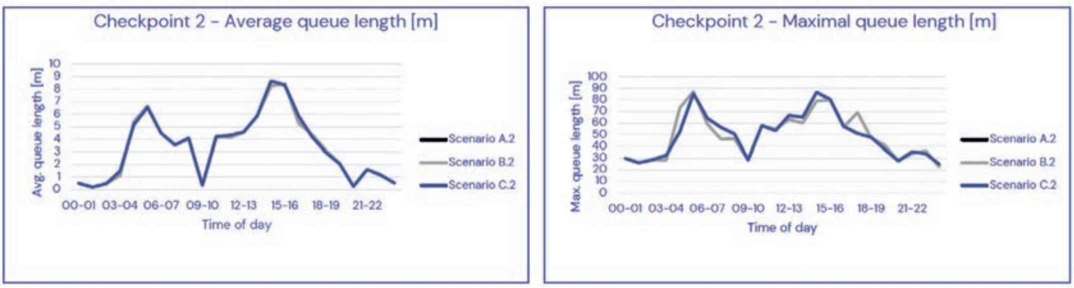

Figure 29. Simulation results at counter 6 in the winter ('queue length').

Finding, observations, and recommendations

Some of the findings and observations received from the simulation results are listed below.

Pre-parking ahead of the Raisio junction leads to an increase in average traffic jam length at Raisio junction but lowers the maximum queue length as a result of equalised traffic flows. The existing traffic light programs are not designed for the size of groups of vehicles leaving the pre-parking area, which is why the travel times increase within a JIT concept. Pre-parking beyond the Raisio junction leads to a sequential call-off service combined with predictable travel times for trucks, which is beneficial for a JIT regime.

Pre-parking combined with JIT regime: vehicle types arrive at gate-in in sequence according to the terminal operator's choice.

Based on the above, the following recommendations were made. In terms of applicability of the JIT arrival concept at the port in Turku, the introduction of parking area(s) is recommended. The new parking area(s) shall be located in the vicinity of the port, and their total size should match the forecasted traffic volumes. The port, the parking(s), and the port actors should be digitally interconnected. When all parties are linked via a common digital tool, work in silos will be avoided, and therefore information will flow seamlessly, ensuring smooth port call operations. Such a digital solution should not only be able to orchestrate the vehicle flow by managing the slot allocation and recommended times of departure and arrival, but it should also support remote check-in, automated access, and documentation-handling processes. Another recommendation concerns the current traffic management system. From the simulations, it became clear that the existing traffic light programs must be adapted to the sudden traffic peaks in the period between vessels' arrivals and departures. Initiatives in that direction are the implementation of green waves and the organisation of city traffic in a manner that gives priority to traffic to and from the port. Applying these measures in properly scheduled time windows will lead to improved road safety, shortened travel times, reduced congestion, and decreased levels of air and noise pollution.

Remote operations communication challenge

Before pursuing genuine maritime VHF radio data, Novia looked for an off-the-shelf solution. It was found that a library for performing speech recognition in the maritime domain does not exist. Thus, the transcription was carried out manually by experts with a maritime background. The lack of a specialised maritime voice-to-text solution was noted and considered as an opportunity for a future project.

The next constraint was Finnish radio law, as it considers any communication not broadcast to the public as confidential. This did not allow the usage of communication between ships and Finnish VTS. Therefore, Novia had to acquire maritime VHF recordings from foreign sources.

Novia purchased a total of 55 hours of maritime VHF recordings, of which only 27 hours were processed. The reasons for the low processing percentage (50 %) were the quality of the recordings and the human factor. The sound quality was affected by already-mentioned background noise, voice fluctuation and distortion, strong accents, and so on. The human factor, however, was the main concern, as it was noticed that the nature of the work rapidly raised levels of the fatigue and stress. After a certain amount of time, declining focus and sedentary behaviour were observed, as well. Therefore, the workload was carefully controlled during the transcription process (e.g. the people involved were asked to take frequent breaks, the utilisation rate was kept under 60 %, etc.). As a result, on average it took approximately 15 minutes for a maritime expert to produce 1 minute of transcription.

From the 27 hours, only 18 hours were successfully transcribed. One of the reasons for the low percentage of successful transcription was the fact that the maritime VHF communication was in English.

Successful transcription in native English-speaking countries was an average of 68% and within a range of 7 % (min, 64.17 % and max, 71 %), but in countries where English is a secondary 'working' language, the percentage dropped to 50 %.

Table 1. **Transcription data outcome representation.**

Territory	Raw data (hours)	Successfully transcribed (%)	Weighted %	Transcribed data (hours)
US	14	67.14	34.81	9 hours 30 mins
CA	5	71.00	13.15	3 hours 30 mins
UK	3	68.33	7.59	2 hours
AU	3	64.17	7.13	2 hours
EU	2	50.00	3.70	1 hour
	27 Hours		**66.40%**	**18 Hours**

Another observation that is worth mentioning is the use of SMCP in real-life professional maritime verbal communication. It was found that standard phrases were used more often in non-native English-speaking countries and barely used by mariners on fishing vessels and pleasure craft.

Table 2. **Territorial comparative analysis of successful conversion to SMCP from transcribed data (broadcast messages transmitted by official bodies such as the coast guard, vessel traffic services, and meteorological institutes are not included).**

Territory	From transcribed data (hours)	Successfully converted to SMCP (%)
US	9 hours 30 mins	6.55
CA	3 hours 30 mins	6.52
UK	2 hours	11.18
AU	2 hours	19.74
EU	1 hour	19.00
	18 Hours	**9.21%**

It could be concluded that not only does the accent of the seafarers matter, but so does their proficiency in English. Native English speakers, who are able to express themselves easily, do not follow the protocol strictly. It was also noted that the communication flow was smooth when all parties adhered to the SMCP, speaking at a conversational pace and in a clear manner, regardless of their language capabilities. Using standardised and well-known communication patterns allows seafarers who are less proficient in English to understand key words and phrases. Understanding the terminology allows for following and comprehending the context of the conversation and hence the message. Recreating the content of the message from key words and phrases was found to be one of the challenges in automatic speech recognition.

In the end, a comparison was made between the maritime experts' transcription, transcription done by a standard ASR engine, and transcription done by ASR trained with maritime data. For this purpose, two indicators were used: successful transcription rate and accuracy. The results are shown in Figure 30.

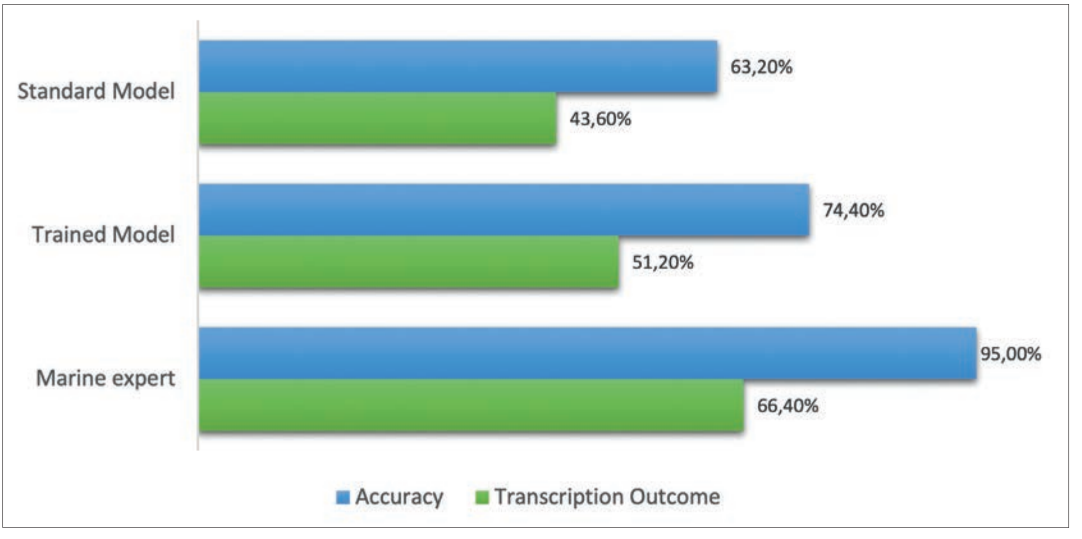

Figure 30. **Comparison of the transcription outcome and accuracy.**

In relation to accuracy, Table 3 lists some examples of where the standard ASR engine was unable to transcribe key information properly.

Table 3. **Qualitative comparison between ASR engine and maritime expert's transcription outcomes.**

Message	ASR engine	Comments
... starboard side ladder ...	... stop side ladder ...	Ship's side is either port or starboard
... pilot will be standing by on one three and one zero one zero working channel all the time ...	... pilot will be standing by on 13 working channel all the time ...	Second working channel was not detected
... port side ...	... court side ...	Ship's side is either port or starboard

As shown in Figure 30, there is a significant increase of 10% in the transcription rate and in the transcription accuracy when maritime data was input into the ASR engine. The improvement was achieved by applying a relatively small amount of maritime data. Based on that, it can be concluded that achieving a satisfactory level of automation and autonomy of radio communication using ASR engines requires more training with specialised maritime data. Obtaining such data and creating a speech recognition library is a feasible task, as the marine vocabulary is limited and standardised. Exploiting this opportunity further will provide valuable information, and it will be a step towards resolving the communication challenges in the first and second degree autonomy of MASS.

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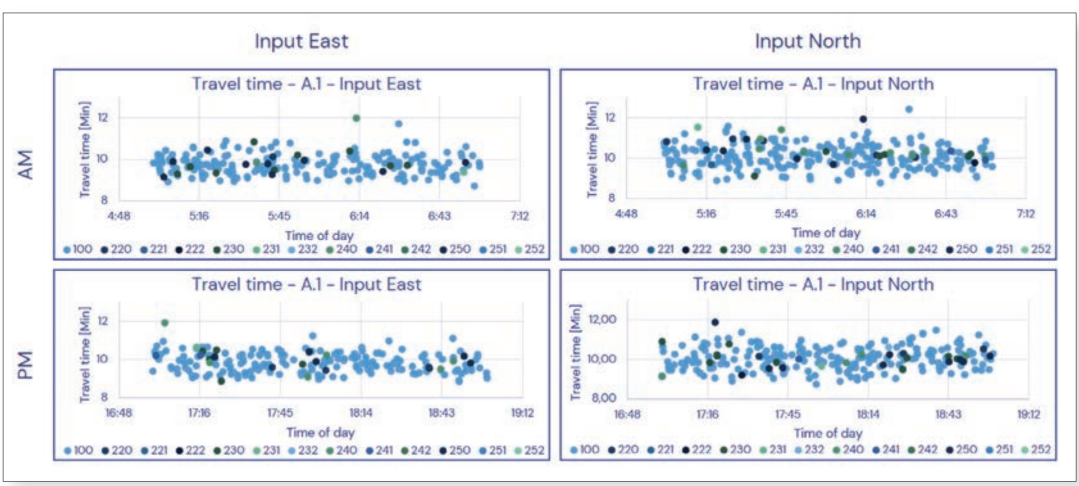
List of Abbreviations

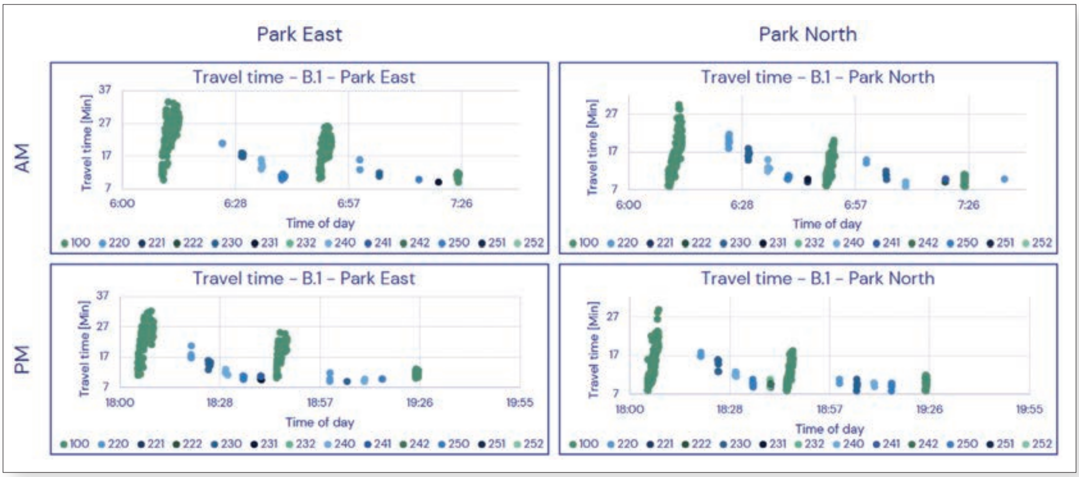
AI	Artificial intelligence
ASR	Automated speech recognition
EMSW	European Maritime Single Window
IMO	International Maritime Organisation
JIS	Just in Sequence
JIT	Just in Time
MASS	Maritime Autonomous Surface Ships
PortCDM	Port Collaborative Decision Making
RoRo	Roll-on/Roll-off
RoPax	Roll-on/Roll-off and Passengers
S 211	Port call message standard
SMCP	Standard Marine Communication Phrases
STM	Sea Traffic Management
TAS	Truck Appointment System
VHF	Very High Frequency

Appendices

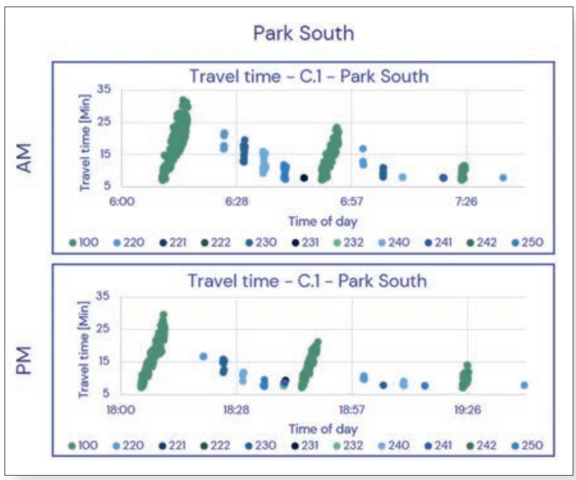
Appendix 1 – Travel time scenario A.1



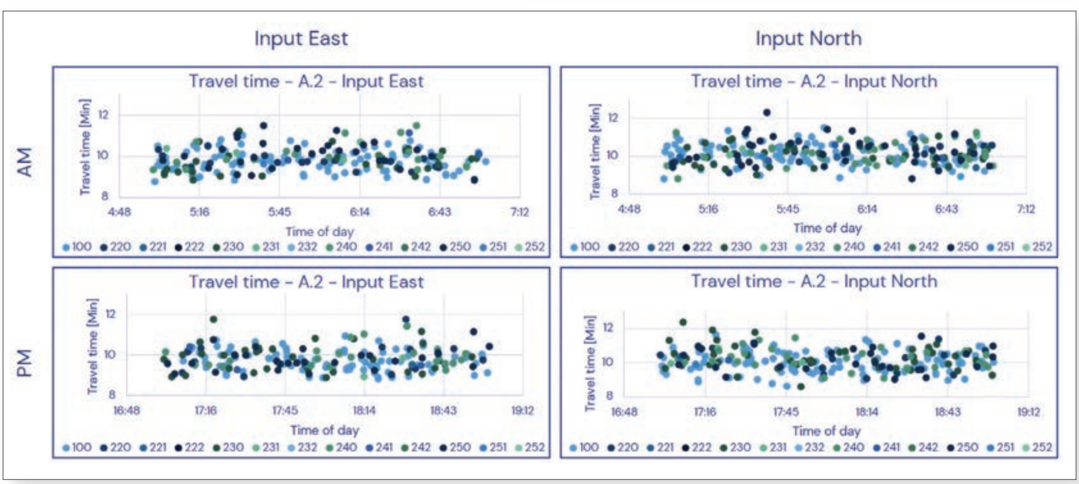
Appendix 2 – Travel time scenario B.1



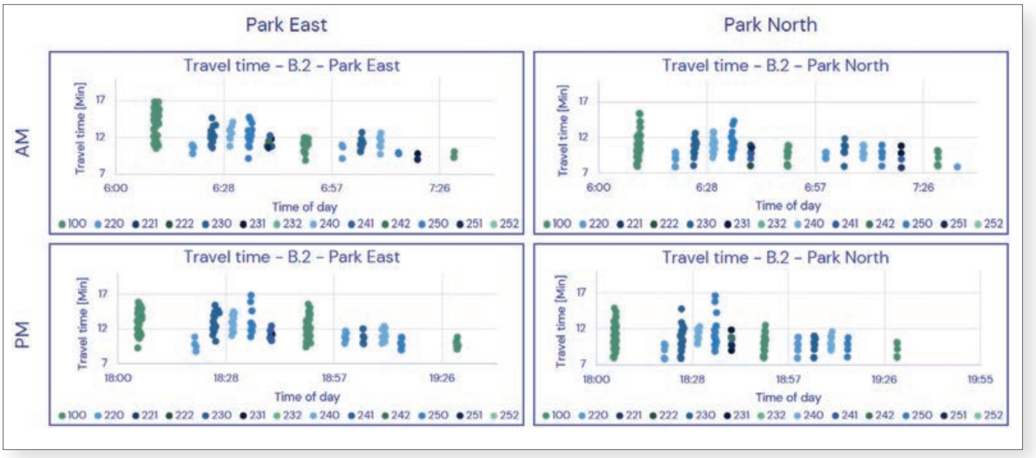
Appendix 3 – Travel time scenario C.1



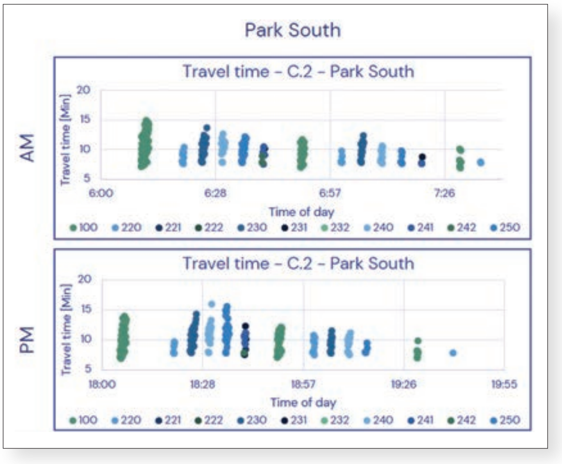
Appendix 4 – Travel time scenario A.2



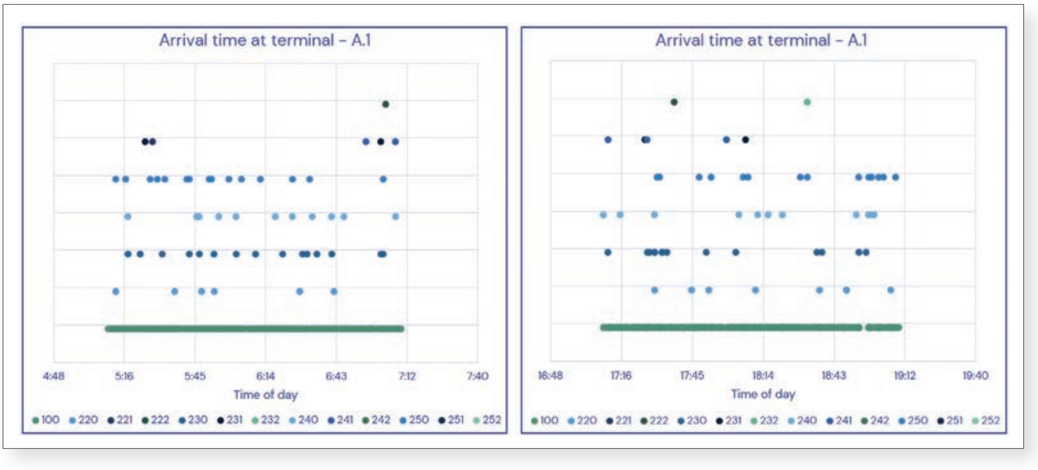
Appendix 5 – Travel time scenario B.2



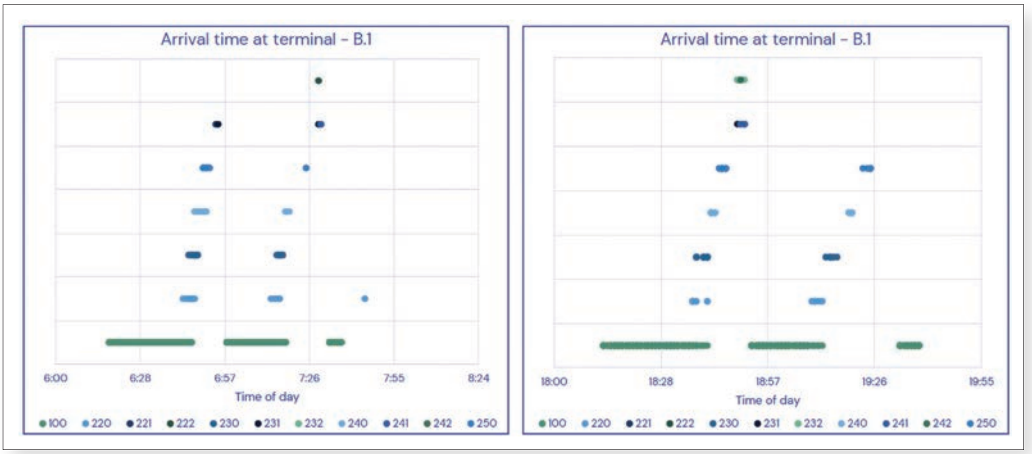
Appendix 6 – Travel time scenario C.2



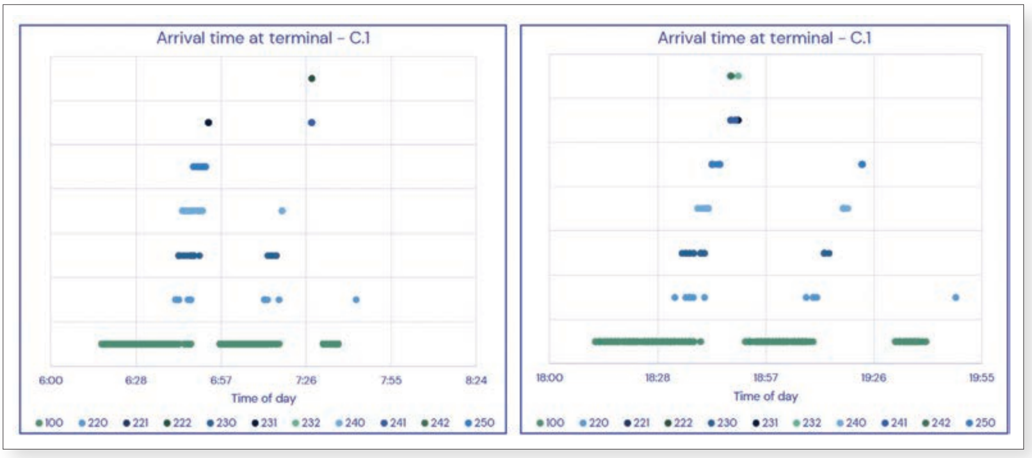
Appendix 7 – Arrival time scenario A.1



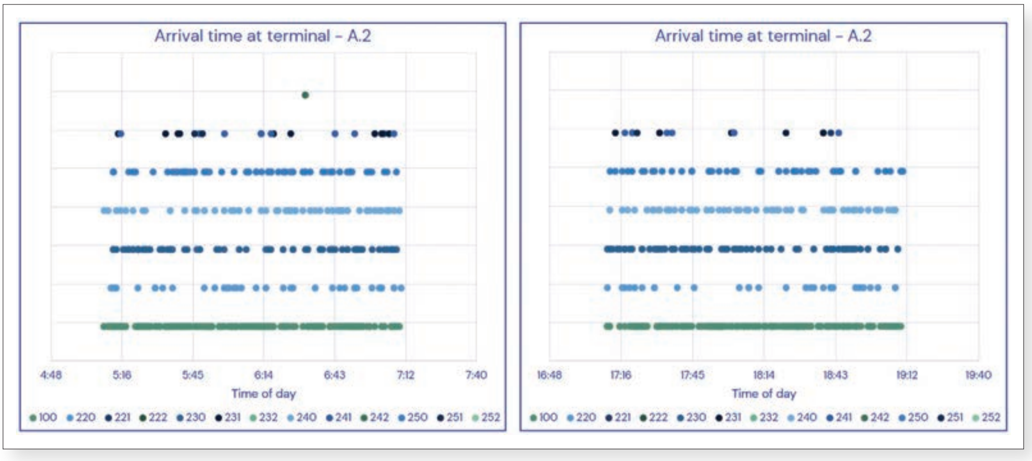
Appendix 8 – Arrival time scenario B.1



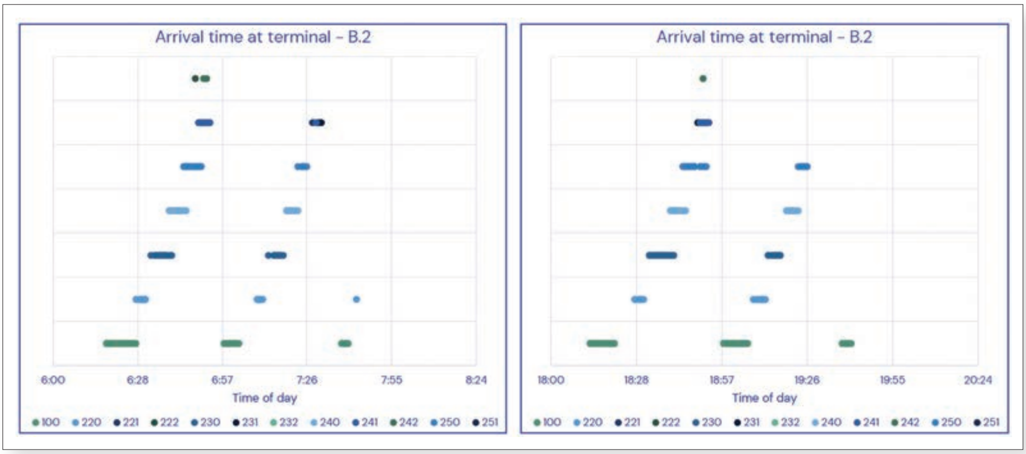
Appendix 9 – Arrival time scenario C.1



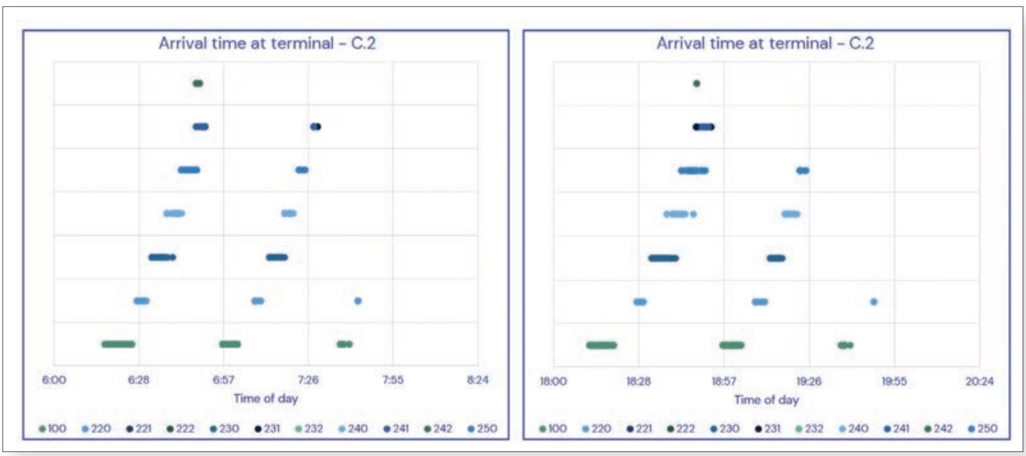
Appendix 10 – Arrival time scenario



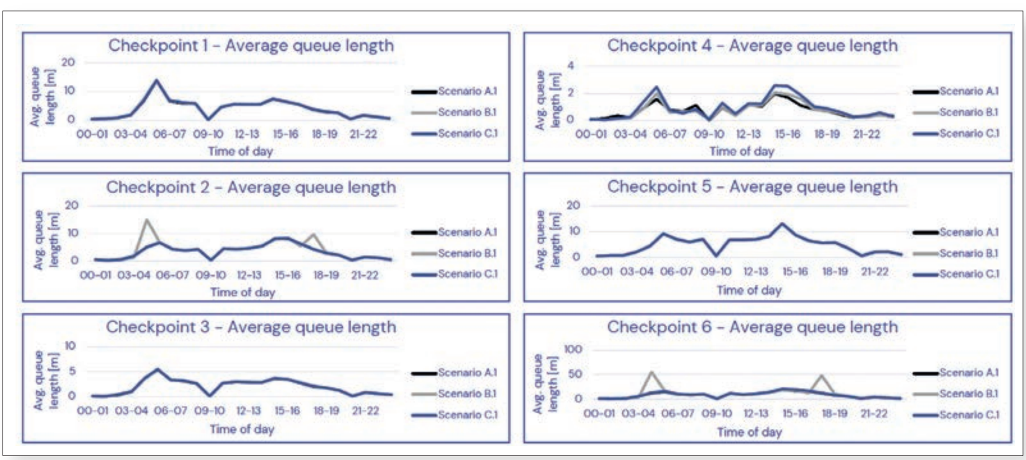
Appendix 11 – Arrival time scenario



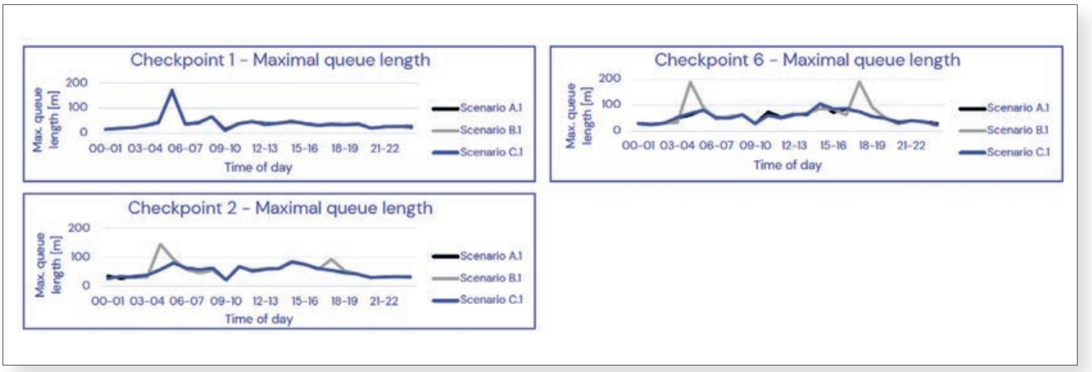
Appendix 12 – Arrival time scenario



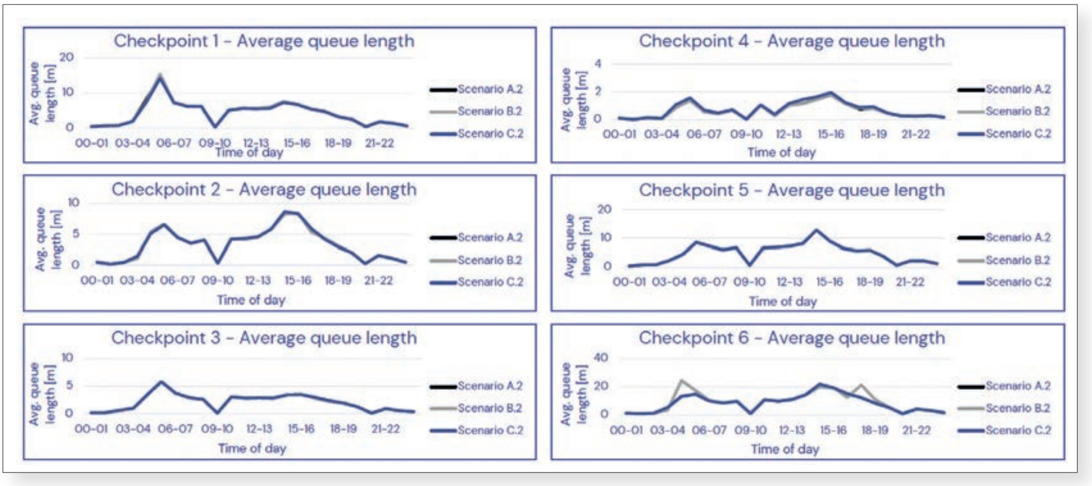
Appendix 13 – Average queue length



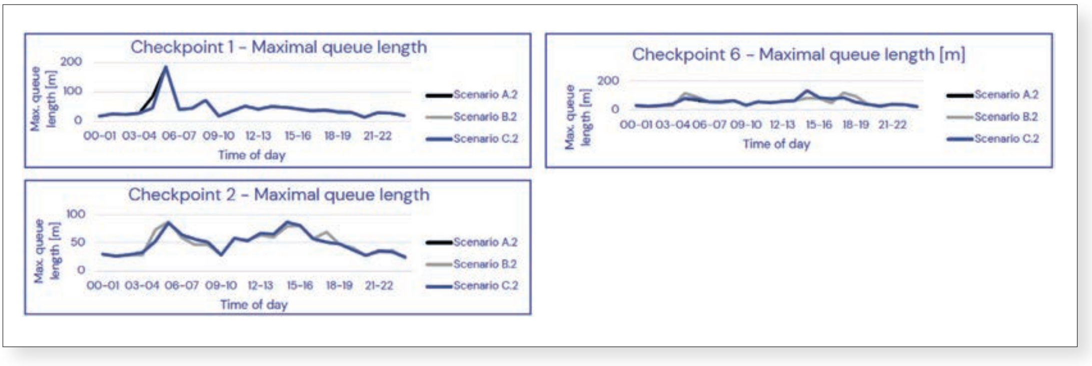
Appendix 14 – Maximum queue length



Appendix 15 – Average queue length



Appendix 16 – Maximum queue



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Ethical and trustworthy smart terminals

Contributors

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Ethical requirements in a narrative form are guiding AI system developers to create a trustworthy smart terminal environment with ethically aligned design methods.

Background

People using a port terminal with smart features should be able to trust the technology used there. In technology design, trustworthiness can be achieved by the developers utilizing ethically aligned design methods. When intelligent systems are discussed, it is important to emphasize what is being developed; the developers, in this context, are developing software that is enhanced with artificial intelligence (AI) or machine learning models. The developers are then software engineers or software development teams.

Software engineers are in a key role as they follow the goals set for them by the customer or stakeholders of the technology under development. Software engineers turn high-level goals into practical features or non-features, as quality features in the line of product development. As much as AI-related endeavors have raised issues lately, regarding the low quality of AI technology, implemented with biased data or creating unfair situations with the decisions made by the autonomous AI system, the practical tools for software engineers to solve these problematic development-focused issues do not yet exist. Software development teams are responsible for tuning AI software development into ethically sound and ethically aligned software product/engineering.

AI ethics is namely the field concentrating on the research of AI systems emerging in industry and society as a whole and the impact it is creating globally in different embodiments. AI ethics has developed from meta ethics, meaning the discussion and debate about the definition of AI ethics and its related terms, concepts, themes, and principles, which has emerged during the last decade, is applied ethics to some extent. The Ethics Guidelines for Trustworthy AI by the European Commission High-Level Expert Group on Artificial Intelligence introduce a framework for Trustworthy AI. According to the framework, Trustworthy AI is lawful, ethical, and robust, following four ethical principles and seven key requirements, and operationalizing the key requirements. The guidelines do not depart far from classical ethics, as they find that "AI systems should improve individual and collective wellbeing" (HLEG, 2019, p.11). However, AI ethics-related publications state that the guidelines are not an implementable means for practical AI ethics to follow.

Ethical framework implementation

Solution and method

In 2018, the University of Jyväskylä started its research on practical tools in software engineering for AI systems development. Since then, the research group has introduced a method called ECCOLA, which contains an ethical framework, "the code of ethics" for AI developers (Vakkuri et al., 2021). This framework contains a specific number of research-based ethical themes and principles for developers to consider during their development work, and it is built on agile software engineering practices. This framework educates software engineers about the themes and principles of AI ethics, calling it an ethically aligned design method. Using the method output and the product worksheets, the trustworthiness of a product can be measured.

The Smart Terminal project aims to create blueprints for the future smart terminal through research-based recommendations, and ethical requirements for smart terminals are one of the project deliverables. Practical tools for AI software practitioners that operationalize the key requirements are now being experimented with in the Smart Terminal project. Agile software engineering, and particularly agile requirements, engineering practices, and ethically aligned design together, generates the theoretical framework for the research, to investigate How to elicit ethical requirements for the Smart Terminal blueprints. A challenge that was highlighted earlier with AI ethics pragmatism, which we turned into an opportunity, was to create practicality in the workflow of software development covering ethicality by empirically exploring the case of the smart terminal. The focus point is on the research problem: How to make Smart Terminals Ethical and Trustworthy. Without prior studies on the subject, we investigated the theoretical framework to build a model to elicit domain-specific ethical requirements for future smart terminals.

This solution enables the stakeholders in the development team to concentrate on the ethical themes and principles that relate particularly to the studied domain. Ethics is context specific; the applicable themes or principles relate to the specific domain or industry in question (HLEG, 2019).

The Domain-Specific Ethical Requirements Elicitation Model

The model shares several data points that gradually build up the domain-specific ethical requirements, delivering a prioritized backlog of ethical requirements. The model and the ECCOLA method are built on gamification techniques. Gamification techniques are often used in non-game environments to engage customers and partners in cooperation, sharing and interaction (Pedreira, 2015). Smart Terminal project data is collected through the three use cases, each with a responsible leader, a use case owner, conducting the project work. In the model, the use case owner initiates the process by choosing the use-case-specific themes and principles from the ethical framework.

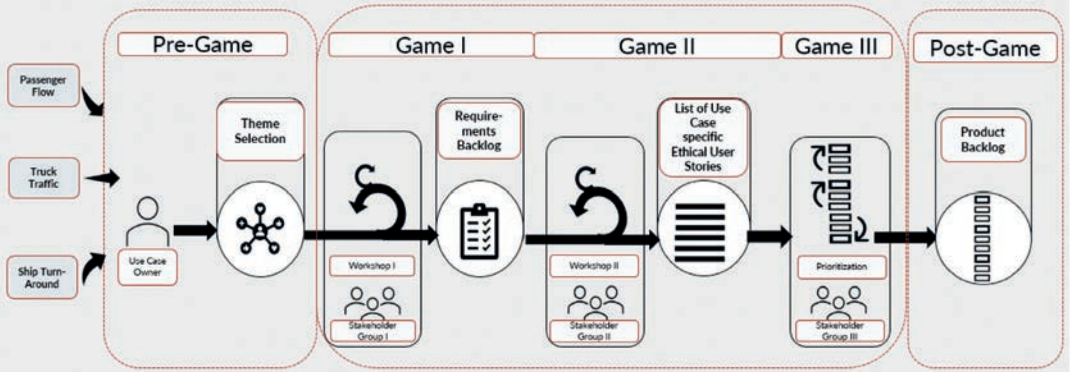

Figure 1. Ethical Requirements Elicitation Model.

The ethics of AI and robotics, according to Müller (2021), focuses on "concerns" of various sorts, in which the new technology challenges the current norms and conceptual systems (Müller, 2021). The ECCOLA method centralizes these concerns when the theme and principles are processed during the development. Table 1 shows the use-case-specific AI ethics themes and principles from the ECCOLA method.

Table 1. The use-case-specific AI ethics themes and principles from the ECCOLA method.

Data Variables					
Framework Content: ***21 cards in 8 themes (22 with instructions)***	***Original setting for the workshop sprints***				
Theme	***Card Topic (Principle)***	*Passenger Flow*	*Truck Traffic*	*Ship Turn-around*	Prioritized
Analysis	***#0 Stakeholder Analysis***				
Transparency	***#1 Types of Transparency***				
	#2 Explainability			x	
	#3 Communication			x	x
	#4 Documenting Trade-offs				
	#5 Traceability	x	x		x
	#6 System Reliability				
Data	***#7 Privacy and Data***	x	x		x
	#8 Data Quality		x		x
	#9 Access to Data		x	x	x
Agency & Oversight	***#10 Human Agency***				
	#11 Human Oversight				
Safety & Security	***#12 System Security***	x			x
	#13 System Safety	x			
Fairness	***#14 Accessibility***			x	x
	#15 Stakeholder Participation				
Wellbeing	***#16 Environmental Impact***		x	x	
	#17 Societal Effects				
Accountability	***#18 Auditability***	x			
	#19 Ability to Redress				
	#20 Minimizing Negative Impact				

In the case study, the pre-selected themes and principles were processed within focus groups in a use-case-based workshop. The workshop goal was to empower the participants in ethical thinking using the ECCOLA method cards, and to document the shared discussion and thoughts. A total of n=367 notes were documented in the requirements backlog. The focus groups were all from different stakeholders, forming three stakeholder groups according to the occurred model development phase. Smarter consortium members from institutions and industry took part in workshop I as stakeholder group I.

Stakeholder group II from the University of Jyväskylä's AI Ethics Lab met online in the next development phase to create ethical user stories from the workshop notes. The ethical user story is the focal point in this case study, as it turns the high-level requirements into an implementable format for the software programmer or coder. A user story is an agile requirement engineering tool to capture and communicate software requirements between the customer and the developer team. User stories are usually made on index cards or post-it notes, or in an electronic template, by the customer team or by a product owner. They usually follow a three-sentence form of <as a>, <I want>, <so that> and are followed by acceptance criteria to split the user story into practical tasks for coders/programmers (Cohn, 2004, a). Ethical user stories are requirements that are filtered through an ethical framework and written in the form of user stories (Halme et al. 2021). The user story practice was chosen for the ethical requirements research as it held characteristics optimal for the smart terminal development environment. User stories are characterized as a flexible, practical, and time-efficient hands-on communication tool between different stakeholders (Cohn, 2004, b). A low-threshold communication tool among experts from different fields was seen to be a suitable way to process the ethical requirements in the project. In addition, the guideline by IEEE Ethically Aligned Design directs AI practitioners to developed AI systems with tools familiar to them (IEEE Ethically Aligned Design, 2019). The three use cases produced n=253 ethical user stories.

In software development, products are developed incrementally. The first increment shares the most important features and qualities of the product. 253 ethical user stories with a plethora of features and non-features to be implemented are realizable only with prioritization (Cohn, 2004, a). An ethical requirements backlog, in the form of user stories, was prioritized in the final activity by the industrial partners, stakeholder group III. The outcome of the activity was an ethically influenced product backlog for future smart terminals.

Findings based on an analysis of the data set and data collection are listed below, followed by a summary of the findings and the conclusions.

Results, findings, output, and impact

Stakeholder participation and analysis

A smart terminal is characterized as a system-of-systems, with a stakeholder group or groups from different fields of expertise. Indirect stakeholders are also important and should be considered during the development, as well as the ways different groups of people are affected by this system-of-systems. The work transition affected by the smart terminal deployment creates changes in personnel training plans, or the role and aim of communication in and out of the terminal sphere take a different element in different operations, to mention just a few examples of how the smart terminal affects the different stakeholder groups, users, or end-users of the system. Stakeholders should be brought into the development loop, as well, as stakeholder analysis should be handled in the beginning of the development cycle. Stakeholder analysis and involvement are a part of ethically aligned design.

In the Smart Terminal project, the stakeholders were included from the beginning of the development by involving them in the requirement elicitation process. System users and possible end-users were included in the stakeholder group, also representing a particular user or end-user group of the system, called proxy users. In order to facilitate expedient software development, proxy users are representatives of real system users and their values, and they voice the needs of various user groups that cannot participate in the system development. A use-case-specific stakeholder analysis was also developed and presented before the ethical user story development workshop.

The model

1. All themes were observed and processed through the ethical requirements elicitation model, which indicates that the ethical elicitation process through the model provides a tool for industry use, to holistically and pragmatically manage ethically aligned design.
2. The theme *Traceability and Data* was processed in all the use cases, *Wellbeing* in two use cases, and *Safety & Security, Fairness,* and *Accountability* were processed in a single use case. *Agency & Oversight* was not processed in the sprints by stakeholder groups I and II. This division of theme selection indicates that ethics and ethically aligned design are context specific, and the model is compliant in different domains (in industry). The ethical framework and method used in ethically aligned design should be able to evolve with the ongoing development work.
3. The product owner (= the use case owner in the smart terminal) leads the discourse between the stakeholders all through the requirements elicitation process, until a product backlog is reached.

Key data points and pattern recognition

4. To make the vast number of ethical user stories implementable, we took the final stage in the process to prioritize the ethical user stories for the blueprints of the SMARTER project as ethical requirements. We used a technique called the MoSCoW method. The term MoSCoW is an acronym that refers to the first letter of each of the four priority categories that are *must-have, should-want, could-have*, and *will not have* (Achimugu, 2014). Organizations utilize the MoSCoW method as a tool to convey the significance and priority of the many needs being met in various projects (Waida, 2022). The final set in the prioritizing activity resulted in 177 ethical user stories from 7 ECCOLA cards and 4 themes. The 9 solution

providers (SMARTER industrial partners) in stakeholder group III prioritized 177 ethical user stories. The deviation between 7 card themes resulted in 1-6, meaning that one theme containing a specific number of ethical user stories was prioritized once, twice or six times, increasing the sum of prioritized ethical user stories to 340. Table 2 presents the deviation between the prioritized ethical user stories according to category and theme. The most valued themes for smart terminal ethically aligned design, based on the prioritization, were:

a. Data took over 70% of the prioritized data set, where card *#6 Access to Data* was prioritized 6 times.

b. *Access to Data* was valued on many levels in the prioritization, indicating that it shares the most knowledge during the AI development process.

c. *#3 Communication, #7 Privacy and Data* and *#12 System Security* were the most valued principles category-wise.

d. *#8 Data Quality* is also considered important, sparking nearly 90% of the principle-specific ethical user stories, but it was not considered as important in the *Must Have* category as the themes *Communication, Privacy and Data*, and *System Security*.

Table 2. **Outcome of the prioritization using the MoSCoW technique.**

Principles	Factor	EUS	SUM	*Must Have*	*Should Have*	*Could Have*	*Will not* Have
#3 Communication	1	18	18	*10*	*4*	*1*	*3*
#5 Traceability	1	42	42	*15*	*14*	*11*	*2*
#7 Privacy and Data	2	49	98	*56*	*21*	*11*	*10*
#8 Data Quality	2	14	28	*10*	*15*	*3*	*0*
#9 Access to Data	6	20	119	*35*	*30*	*31*	*23*
#12 System Security	1	24	24	*15*	*9*	*0*	*0*
#14 Accessibility	1	10	10	*4*	*3*	*2*	*1*
7	14	177	339	*145*	*96*	*59*	*39*

5. The content analysis gave similar results to the key data points, as well as additional information through pattern recognition. The *Must Have* category was at the center of the analysis. Codes that were clearly perceived through the material (below) were used for filtering the data for pattern recognition:

a. the stakeholder role as user and end-user

b. other ethical themes and principles that relate to the user story

In addition, the user story content often referred to training in smart terminal project concerns, reflecting the importance of communication and accessibility principles in future smart terminal development. These principles are grouped in the themes *transparency* and *fairness* in AI ethics.

Table 3. **Outcome of the content analysis.**

Principles	Stakeholder role - user	Stakeholder role - end-user	Relation to other themes and principles	Note
#3 Communication	9	1	#7 Privacy and Data #14 Accessibility #9 Access to Data #1 Types of Transparency #12 System Security	Together (#3 Communication, #7 Privacy and Data, #12 System Security)
#5 Traceability	13	2	Stakeholder participation #6 System Reliability #7 Privacy and Data #3 Communication	
#7 Privacy and Data	26	13	#8 Data Quality #3 Communication #12 System Security #11 Human Oversight #1 Types of Transparency #9 Access to Data	
#8 Data Quality	6	1	NA	
#9 Access to Data	11	6	#4 Documenting Trade-offs #6 System Reliability #10 Human Agency #11 Human Oversight #13 System Safety #7 Privacy and Data	
#12 System Security	9	6	#11 Human Oversight #7 Privacy and Data #3 Communication	
#14 Accessibility	4	0	Na	
7				

The ethics of smart technologies in port areas revolve around issues such as data (privacy, quality, and accessing), transparency, human agency & oversight, and security.

Data: Reflecting on the ethical user stories, the concerns in the theme *data* relate to system use and how system users, such as logistics operators, access the data and are affected by the data on the systems. *Privacy and Data* is a strong theme in the end-user context and calls for the concerns in related matters, such as personal or sensitive data, to be secured, communicated appropriately, accessed with a specific protocol, and regarded with human involvement. Data hierarchies are also in focus when the data is considered in terms of ***communication***; what data, how is it being communicated, and to whom? This finding indicates a relation to the theme ***transparency***, which is a major trend in ethically aligned smart system development, as transparency enhances trust.

Transparency: Transparency enhances trust when smart system explicability is observed during development. Transparency also enhances trust when all the stakeholders are informed fairly about the development of the "black box" decision-making (explicability) in deployment and use in the future smart terminal.

Security: The research indicates that the theme ***system security*** is involved with several themes, such as human involvement in ***human agency and oversight, privacy and data***, and ***communication***. The research data indicates that users and end-users are educated in GDPR-connected smart terminal questions. Users and end-users are educated about smart technology development, deployment and use in the terminal, and how the data and technology are secured.

Human agency and oversight: The human-in-the-loop concept was observed and regarded as a requirement in smart technology development, deployment, and use in the future smart terminal.

Ethically aligned design is striving for the wellbeing of individuals and groups of people. An ethically aligned and trustworthy future smart terminal is possible with the domain-specific requirements elicitation model, in which the product owner is responsible for keeping the project goals and the communication alive among different stakeholders during the project. The development should concentrate foremost on data, system security, and communication-related concerns and on being transparent with all stakeholders regarding the smart technology development life cycle. Human Involvement in the future smart terminal is required by smart terminal stakeholders and can serve as a pillar for transparent design that is in line with ethics.

Port terminal operators may make sure that the use of smart technologies is responsible, ethical, and consistent with the values of their stakeholders by putting these findings into place.

Summary

This research on ethically aligned design in the smart terminal project was looking for strategies to overcome key ethics-related concerns in building a trustworthy future smart terminal. The task was driven by analysis led by the ECCOLA method. The analysis was performed with the help of the domain-specific ethical requirements elicitation model. Smart terminal consortium members took part in the model processing in three (3) stakeholder groups with the lead of the conducting institution and the use-case specific product owner. The objective was to raise domain-specific ethical concerns in each use case through use-case-related ethical themes and principles. The outcome of the task was an ethically aligned product backlog that can be used to assess the trustworthiness of smart terminal development. The key findings of the research are the domain-specific ethical requirements elicitation model, 177 key ethical requirements for the future smart terminal, and the analysis of the key ethical requirements, in which data, transparency, human agency and oversight, and security concerns are the objects of evaluation in future smart terminal development, deployment, and use. The use-case-specific product owner is in a key role when ethical requirements are built for the future smart terminal product backlog, keeping the conversation alive with all the stakeholders of the system(s) throughout the process. Ethical concerns often create a spiderweb like effect, when analyzed, in which all themes relate to each other on some level. To holistically do ethically aligned design in creating trustworthy AI, we find that key ethical requirements are the starting point in the process, which internalizes other ethical requirements, as well. We find that in order to do ethically aligned design in a holistic and practical manner, It is necessary to bring up the concerns and involve various stakeholders in the process in order to consider their values in the development, deployment, and use of a trustworthy future smart terminal.

Publications

- **Halme, E., Vakkuri, V., Kultanen, J., Jantunen, M., Kemell, K.K., Rousi, R. and Abrahamsson, P.**, 2021, June. How to write ethical user stories? impacts of the ECCOLA method. In Agile Processes in Software Engineering and Extreme Programming: 22nd International Conference on Agile Software Development, XP 2021, Virtual Event, June 14–18, 2021, Proceedings (pp. 36–52). Cham: Springer International Publishing.
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More results from the work are still being published in scientific conferences and journals.

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Cyber-Security Architecture in the Smart Terminal Systems

Contributors

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Global maritime transportation logistics systems are essential parts of critical infrastructure in every society. Sea ports are crucial parts of maritime logistics processes. Digitalization makes it possible to increase the efficiency of terminal systems in the processes. In the best cases, this means reducing emissions by optimizing port operations and improving cargo and people flows, while improving the experience for all stakeholders. The improvement of port processes relies very much on the development of information and communication technology (ICT), as well as industrial control systems (ICS) or operation technologies (OT). At the same time, the cyber-security aspects of maritime logistics need to be addressed.

Introduction

In the cyber world, the most important threat centers on critical infrastructure (CI). CI encompasses the structures and functions that are vital to society's uninterrupted functioning. It comprises physical facilities and structures, as well as electronic functions and services. Critical infrastructure systems comprise a heterogeneous mixture of dynamic, interactive, and non-linear elements.

From the cybersecurity viewpoint, the functioning of a modern society is based on the cooperation of several critical infrastructures, whose joint efficiency depends increasingly on reliable national ICT and ICS/OT systems. Crucial in the cyber environment are functional data transmission networks and the usability, reliability, and integrity of system data in the operating environment, whose cyber-security risks are continuously augmented by threatening scenarios in the digital world. A modern society depends entirely on a cyber environment that provides dynamic services.

The cyber-security risk landscape is currently evolving toward the point when risks that were once considered unlikely began occurring with regularity. This ongoing trend can be attributed to higher maturity of attack tools and methods, increased exposure, and increased motivation of attackers. The change to the landscape forces us to include the previously excluded risks that are commonly referred to as cyber risks, in the focus zone. These very-high-impact risks will also force us to become better at protecting our assets and devising creative solutions to mitigate risks.

In the past, most attacks were conventional, and the attackers were individuals or small groups of hackers. Nowadays, we see a new breed of attacks, targeted and sophisticated, in which the attackers use advanced cyber weapons that are developed by intelligence, military, and terror organizations. These attacks are called advanced persistent threats (APTs), which usually refers to a group, such as a foreign government, with both the capability and the intent to target a specific entity persistently and effectively. Effective situational awareness is essential in defense against APTs.

Cyber-security architecture framework

In recent years, attacks against critical infrastructure, critical information infrastructure, and the Internet have become ever more frequent, complex, and targeted because perpetrators have become more professional. Attackers can inflict damage on or disrupt physical infrastructure by infiltrating the digital systems that control physical processes, damaging specialized equipment and disrupting vital services without a physical attack. These threats continue to evolve in complexity and sophistication.

Correctly implemented and appropriately functioning cyber-security architecture is the most important process behind all cyber security. The framework focuses on using organizations to guide cyber-security activities and consider cyber-security risks as part of the organization's risk management processes. The framework consists of three parts: the starting point of the analysis, the cyber threat intelligence process, and the risk management process.

1. The starting point of the analysis

There are currently several cybersecurity solutions and technical tools available to meet the needs of organizations. These also present challenges such as the fragmentation of technology, problems at the practical level of implementation and maintenance of new security elements, and measures that may lead to an increase in the complexity of the entire functional system and the difficulty of managing the whole.

The increasing complexity of technology and systems therefore requires the development of integrated security procedures that identify both external and internal threats. Therefore, appropriate security solutions and security breach detection procedures, and a comprehensive cyber security system, are needed to ensure the continuity of the organization's operations.

Systems thinking enables a holistic view of the organization's cyber security. A comprehensive view of cyber security is available through cyber-security systems thinking. The object of the research is the structure of the cyber-security architecture suitable for the target organization.

2. Cyber threat intelligence process

Cyber threat intelligence (CTI) is knowledge, skills and experience-based information concerning the occurrence and assessment of both cyber and physical threats and threat actors that is intended to help mitigate potential attacks and harmful events occurring in cyberspace. Strategic cyber threat intelligence informs the most senior decision-makers, operational intelligence is aimed at those making day-to-day decisions, and tactical threat intelligence is focused on units in need of instantaneous information.

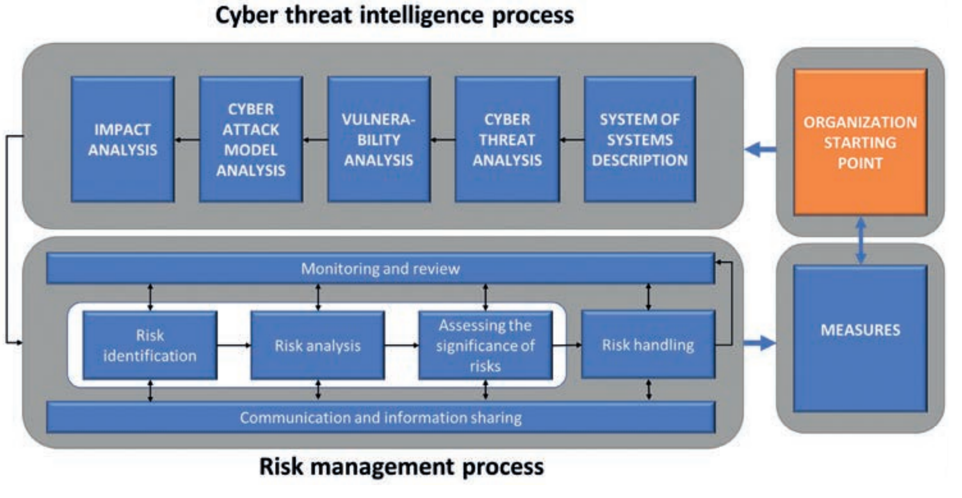
In this architecture, the cyber threat intelligence process consists of a system description, cyber threat analysis, vulnerability analysis, cyber-attack model analysis and impact analysis.

3. Risk management process

Correctly implemented and appropriately functioning risk management is the most important process behind all digital security, including data security, cyber security, and privacy protection. Risk management is increasingly important, as the need for improving the various areas of security has increased. The need for improvement has arisen from the digitalization of operations, the possibilities offered by new technologies, and the new threat and risk types that have evolved rapidly. Without appropriately functioning risk management, the organization may not be able to recognize the significant threats that could prevent the achievement of its objectives or that are related to its daily operations, and it will not be able to control these threats.

Risk management is also an excellent tool for the organization as it develops the processes, actions, and services to improve its security. Risk management helps achieve cost-efficiency, enabling development measures to be targeted at matters that have a significant impact on decreasing the probability or mitigating the impact of a recognized threat. In addition to risk management, the guideline discusses the recognition of opportunities. The failure to take advantage of opportunities could pose a threat to the improvement of the organization's operations or the achievement of its targets, for example. Increased digitalization of operations is a good example of such an opportunity; it should be seen as an important player in developing operations. However, the threats related to digitalization must also be recognized.

The following figure illustrates the holistic cyber-security architecture process.



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ADE digitalizes training in virtual reality. We cooperate with training and certification organizations.

ADE's Isoveli platform enables the management, delivery and update of virtual training, devices and equipment remotely. The platform enables remote monitoring of training sessions. Isoveli ensures delivery of the correct virtual training to trainees based on their individual usernames. The trainer can easily edit and revise the virtual training. Exercises from third parties can be imported. This enables the analysis, evaluation and comparison of data, and also skill gap analysis.

ADE has a training and simulation portfolio of 45 different training courses for logistics, health care, warehouse work, forestry, gardening, construction, and safety. Based on the eRequirements of the Finnish National Agency for Education, ADE licenses these training courses to vocational institutes, education providers and corporations for simulation training via ADE´s Isoveli training platform. Isoveli provides a whole library of 45 simulators for use through one innovative workstation.

Harbor virtual training

Contributors

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- Sami Tammio
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In the project, ADE researched and tested how harbor personnel can be trained digitally and independently. In the project, a model to carry out skills training digitally in harbor environments was created, and several types of training were tested. From these findings, a new platform for virtual training can now be created.

Background

ADE has an AI-controlled virtual-reality simulator platform for car, truck, bus, taxi and van driving. ADE also has lift and crane simulators, with full physical models for a ship crane, bridge crane, mobile crane, log crane and tower crane. This is why ADE was technologically in a good position to create a virtual-reality digital skills training solution for harbors.

Solution, method

ADE interviewed and listed different types of skills training done in harbor environments. The main training method is currently the classroom. Classroom training does not adjust to the individual needs of employees to obtain certification; it is expensive and time-consuming.

ADE carried out many different workshops with companies and schools. In these workshops, different training simulators where tested. From these, several factors were found that made it hard for the personnel to do the training by themselves.

From the research and pilot testing, a new model for digital training was created for harbors. This includes a platform attached to an easily transportable training device that can provide all the required training to personnel, test them, and record the training.

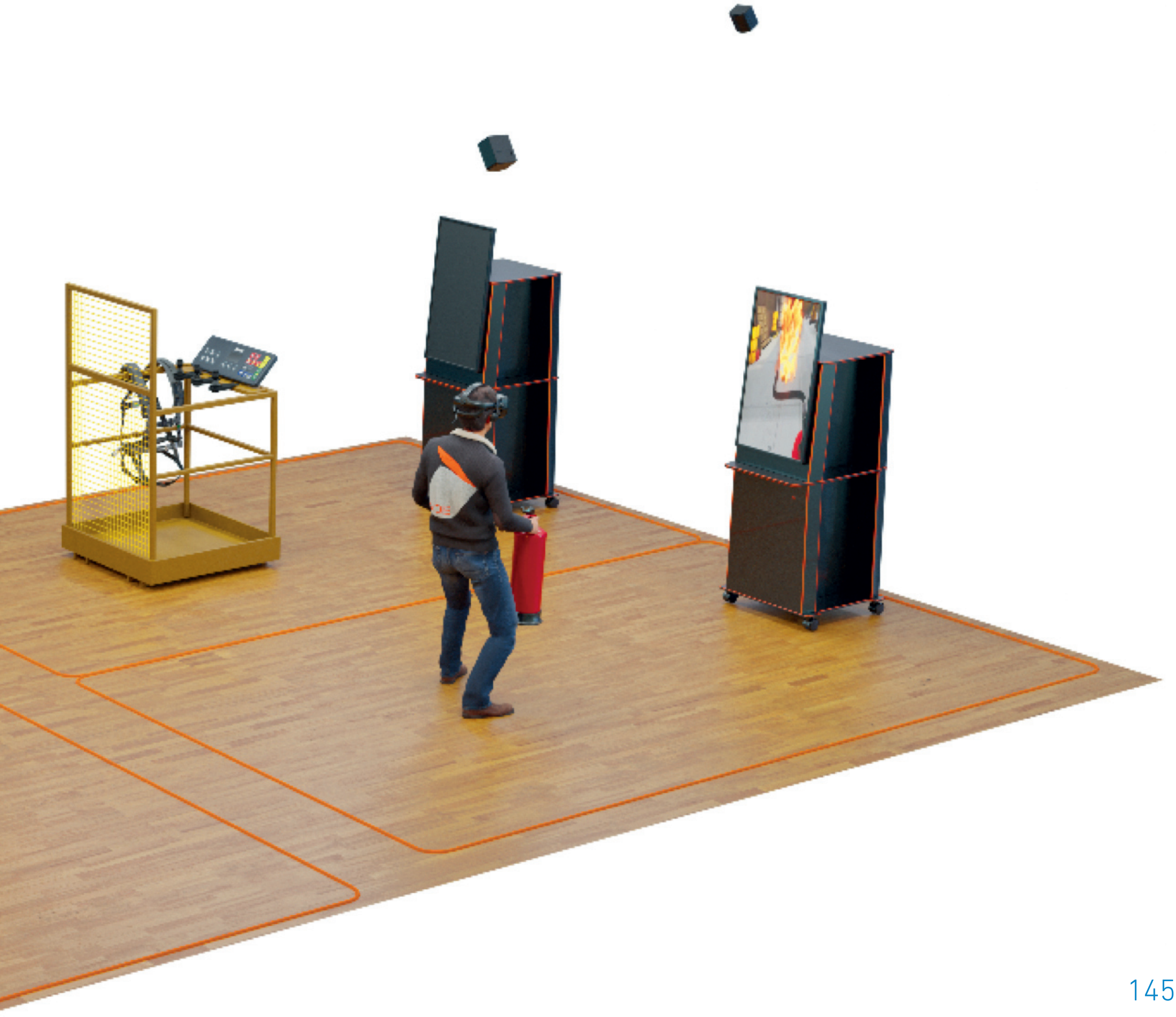
Figure 1. AI-controlled virtual-reality simulator platform.

Figure 2. Easily transportable training device that can provide all the required training to personnel.

Results, findings, output, and impact

For ADE, the main findings in the project were that current state-of-the-art simulators were technically sufficient to do certification, but the personnel were not able to use them by themselves. If using this digital training requires additional personnel, the new technologies won't be implemented in harbor environments. In addition, the mobility of devices was found to be a key factor.

From these findings, ADE has researched a new solution for skills training in harbors. It is a combination of current devices, new devices, and a specific training platform.



Brighthouse Intelligence offers a one-stop shop for building digital solutions for remote and autonomous applications. We provide intelligent situational awareness, reliable high-performance connectivity, and advanced cyber-security solutions. Our services cover the full R&D life cycle, from innovation and prototyping to development and maintenance. We have been developing remote and autonomous maritime technologies since 2015, but we operate elsewhere as well: indoors, outdoors, offshore. We work in close contact with our customers and build innovative solutions by combining industry knowledge and heavy hands-on experience in complex R&D projects.

We help public areas to improve the functionality of various activities by analysing the people behaviour and flows using an intelligent data collecting and sharing system, feeding data to advanced analysing algorithms.

Intelligent Data Collecting and Sharing System

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- Jyrki Alamaunu
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- Timo Saari
- Mikko Salokannel
- Samuli Hellberg
- Joel Isotahdon
- Peter Eriksson

Background

Our first target in the programme was to design, develop and build the technical concept for an intelligent and secure data collecting and sharing system that enables high-speed data flows in a harbour environment. In the programme, this technology concept formed a solid backbone and test platform, in which collected and generated data was accessible by other programme partners and used for various development purposes, such as image recognition and tracking algorithm development. In the core of the system was our intelligent data gathering and transmitting unit (SmartBox), which was further developed during the programme.

The second target was to develop the methods and algorithms for monitoring passenger flow in order to optimise the various activities in public areas such as terminals. All data for development purposes was gathered via our SmartBox system.

Solution Data collection was implemented using the Brighthouse SmartBox system. The system provides a transparent connection for partners for their data needs. System health and status monitoring was part of the SmartBox internal functionality.

SmartBox also has limited machine vision capabilities, which can be used for local edge calculation. An advantage of edge calculation is that sensitive data is analysed on the site, and only analysed metadata is transferred to the backend system. More accurate analysis can be done offline in the backend system.

SmartBox had four modems installed: three LTE modems (one for each major operator) and one 5G modem. With this solution, we had the possibility to further study the robustness of the LTE network. As there was good 5G coverage around the Tallink Silja terminal, this was seen as a good place for 5G studies.

Passenger flow analysis was done using machine vision. Both real-time analysis and offline analysis were implemented. Real-time analysis was done as edge computing (Figure 2) within the SmartBox, while back-office analysis was run on the server at the Brighthouse office (Figure 3).

In this exercise, three partners were connected to the SmartBox system:

- Teleste: video surveillance system
- TUAS: lidars and other sensors
- Brighthouse: reference camera for passenger flow machine vision and lidar studies

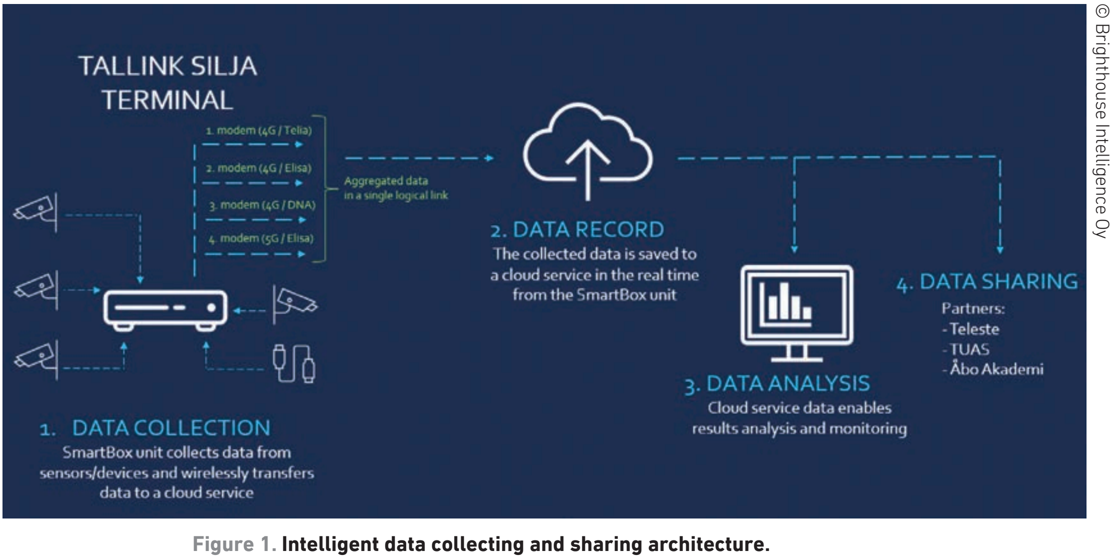

Figure 1. **Intelligent data collecting and sharing architecture.**

SmartBox provided a transparent IP-level interface for sub-systems over multiple carriers, for a secure and robust connection, to maintain the best possible connectivity all the time.

All relevant data was stored on the Brighthouse data server for online and offline analysis and for further data delivery. Data was stored encrypted and with usage monitoring.

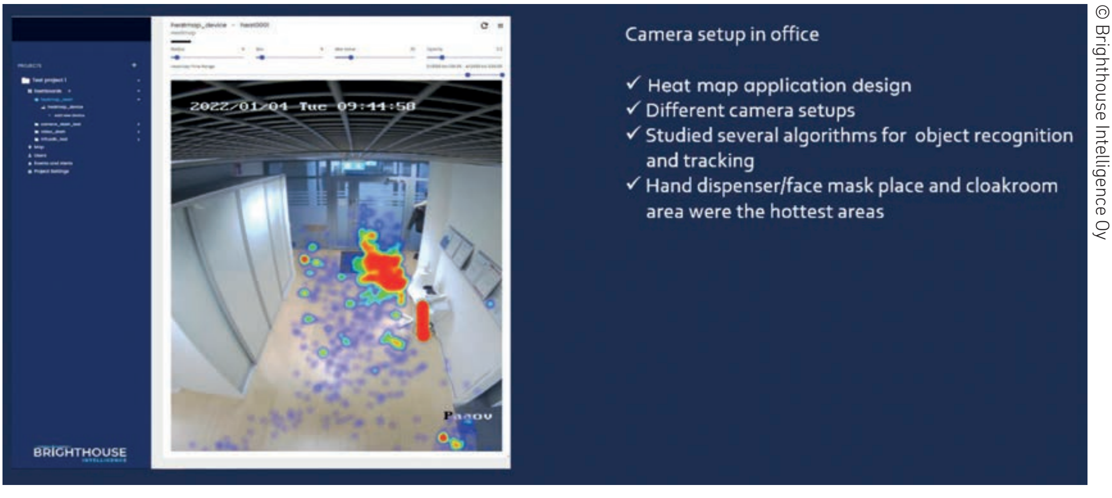

Figure 2. **Passenger flow study.**

Figure 3. **Object recognition and tracking in practice.**

Results and Findings

The results of the system testing for data collection and sharing were very useful and are used as a supporting element in our coming projects. Some findings:

- Data connection was stable throughout the project.
- The 5G uplink was not as reliable as the 4G network.
- New features (e.g. load-balance, fallback) were successfully tested in practice.
- Machine-learning algorithms proved to be useful.

Successful data sharing with other programme partners worked well after GDPR issues were solved.

GDPR caused some issues for collaborative R&D work:

- There were strict restrictions by port authorities on where to install cameras. → A test and development environment could be built only inside the terminal. All outer areas / use cases were left out, even though they were included in the original plan, and the existing camera data / network could not be used (which would have been useful for larger-scale development).
- No recorded data could be shared with other partners, but we survived with live data, as well.
- Sharing personal data caused challenges.

→ **Note to future programmes:** When sharing stored personal data, lawful contracts should be clarified and approved with all partners.

PUBLICATIONS

The list of publications that were developed by ÅA and partners within WP1 and WP3

Åbo Akademi University, WP1&WP3

- **Chen, Y., Tsvetkova, A., Edelman, K., Wahlström, I., Heikkilä, M., & Hellström, M.** (forthcoming) The Role of Digitalization in Changing the Business Models in Logistics: case of ROPAX Ports. Forthcoming.
- **Chen, Y., Tsvetkova, A., Edelman, K., Wahlström, I., Heikkilä, M., & Hellström, M.** (2023) The Role of Digitalization in Changing the Business Models in Logistics: case of ROPAX Ports. Paper submitted to e-BLED Conference 2023.
- **Tsvetkova, A., Chen, Y., Wahlström, I., Morariu, A., Iancu, B., & Hellström, M.** (2023) Digitalization in ROPAX Ports: the Typology of Available Solutions. Paper submitted to e-BLED Conference 2023.
- **Tsvetkova, A., Chen, Y., Wahlström, I., Morariu, A., Iancu, B., & Hellström, M**. (forthcoming) Exploring the Value Creation Potential of Digitalisation in RoPax Ports: A Typology of Digital Solutions. (forthcoming).
- **Långstedt, J., Wahlström, I., Chen, Y., Tsvetkova, A., Sundholm, M., & Hellström, M.** (2021) D1.1 Analysis of selected workflows in RoPax, RoRo and cruiseferry terminals. Internal project deliverable for SMARTER.
- **Wahlström, I., Hellström, M., Tsvetkova, A., & Chen, Y.** (2022) Ready to Roll? Greening Ferry Ports by Truck Flow Optimisation. Baltic Transport Journal 5/2022.
  Available at https://issuu.com/balticpress/docs/btj_5-22.
- **Iancu, B., Morariu, A., Chen Y., Wahlström, I., Tsvetkova, A., Lilius, J.** (2023) Data sharing in RoPax Ports: Challenges and Opportunities, FRUCT conference.
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- **Krueger, S., Willrodt, S., Tsvetkova, A., Wahlström, I. & Hellström, M.** (forthcoming) The applicability of pre-gate concepts in RoPax terminals. (forthcoming).

University of Turku within WP1

- **Heikkilä, M., Saarni, J., & Saurama, A.** (2022) Innovation in Smart Ports: Future Directions of Digitalization in Container Ports. Journal of Marine Science and Engineering, 10(12), 1925. URL: https://www.utupub.fi/bitstream/handle/10024/173645/jmse-10-01925.pdf?sequence=1&isAllowed=y.
- **Seppä, E.** (forthcoming) Evolving Automatic Identification System (AIS) in Maritime Future Developments of AIS Data. Master Theses. Turku School of Economics. University of Turku. – this thesis will be defended during this spring.
- **Edelman, K., Heikkilä, M., & Saarni, J.** (2022) The analysis of ports' digital transformation: with the focus of RoRo and RoPax ports. Internal project deliverable. Sea4Value SMARTER – Smart Terminals.

Port of Turku, Finland. Photo: Igor Grochev

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