# Trajectories and scenarios in port digitalization

Raffaele Pesenti

pesenti@unive.it

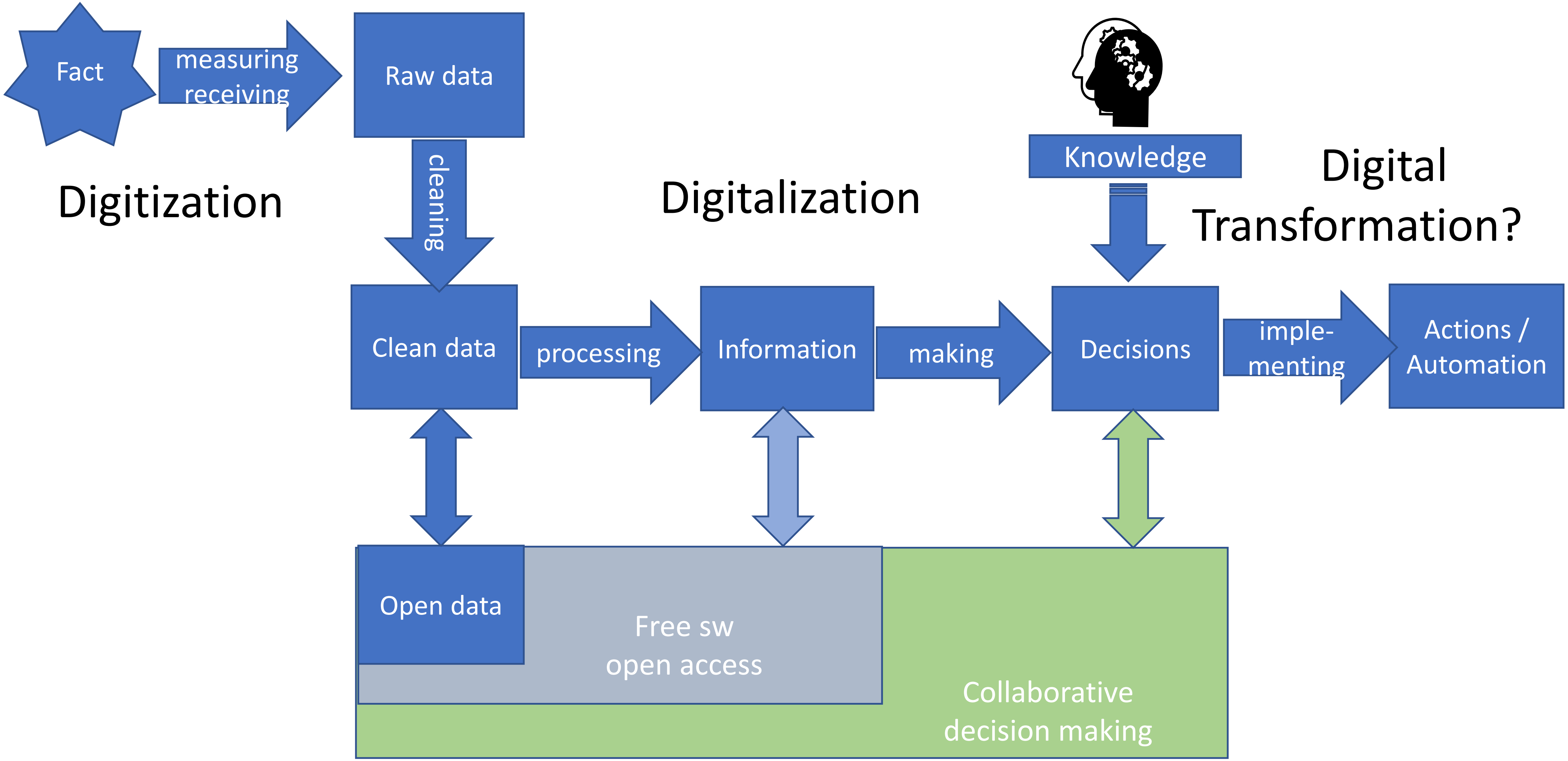
# Outline

- ✓ Digitalization and Port definitions
- ✓ Best in class ports
- ✓ Port integration and digitalization

# Two questions

- ✓ What is Digitalization?
- ✓ What is a Port?

# From raw data to decisions/actions

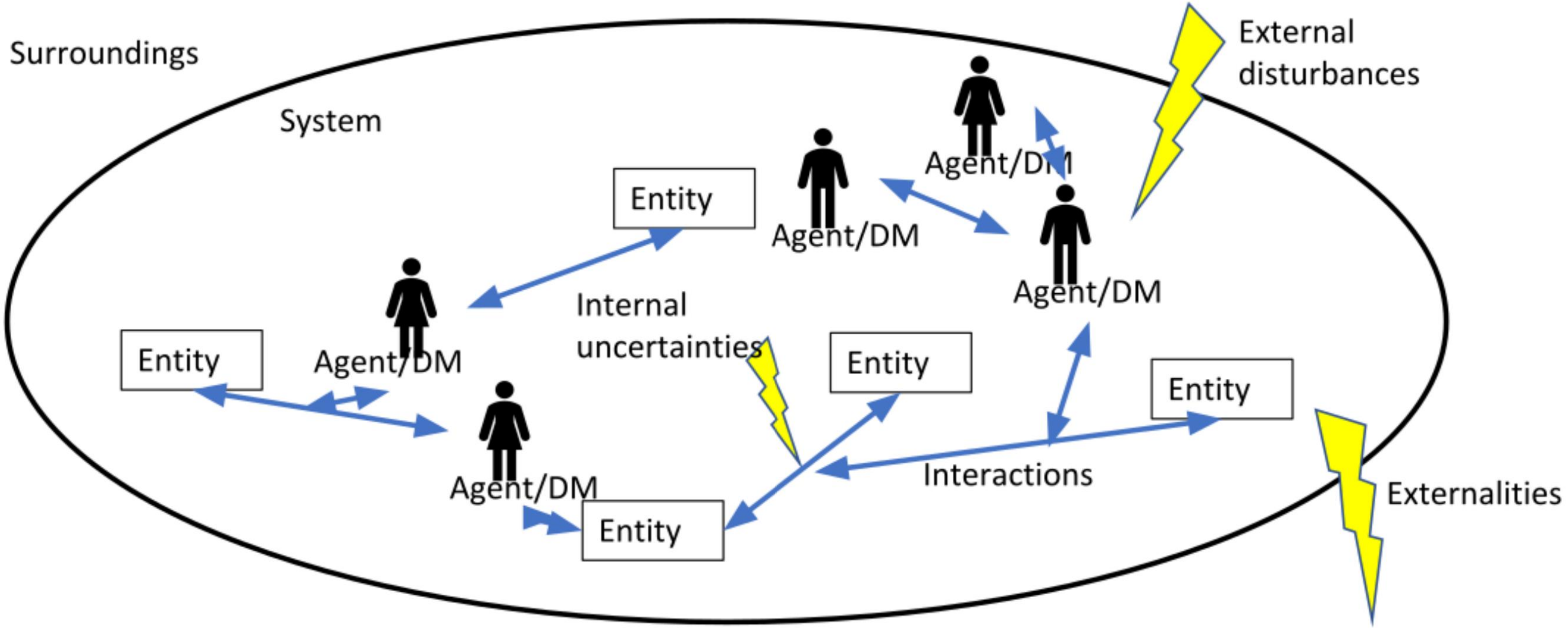


# Definitions

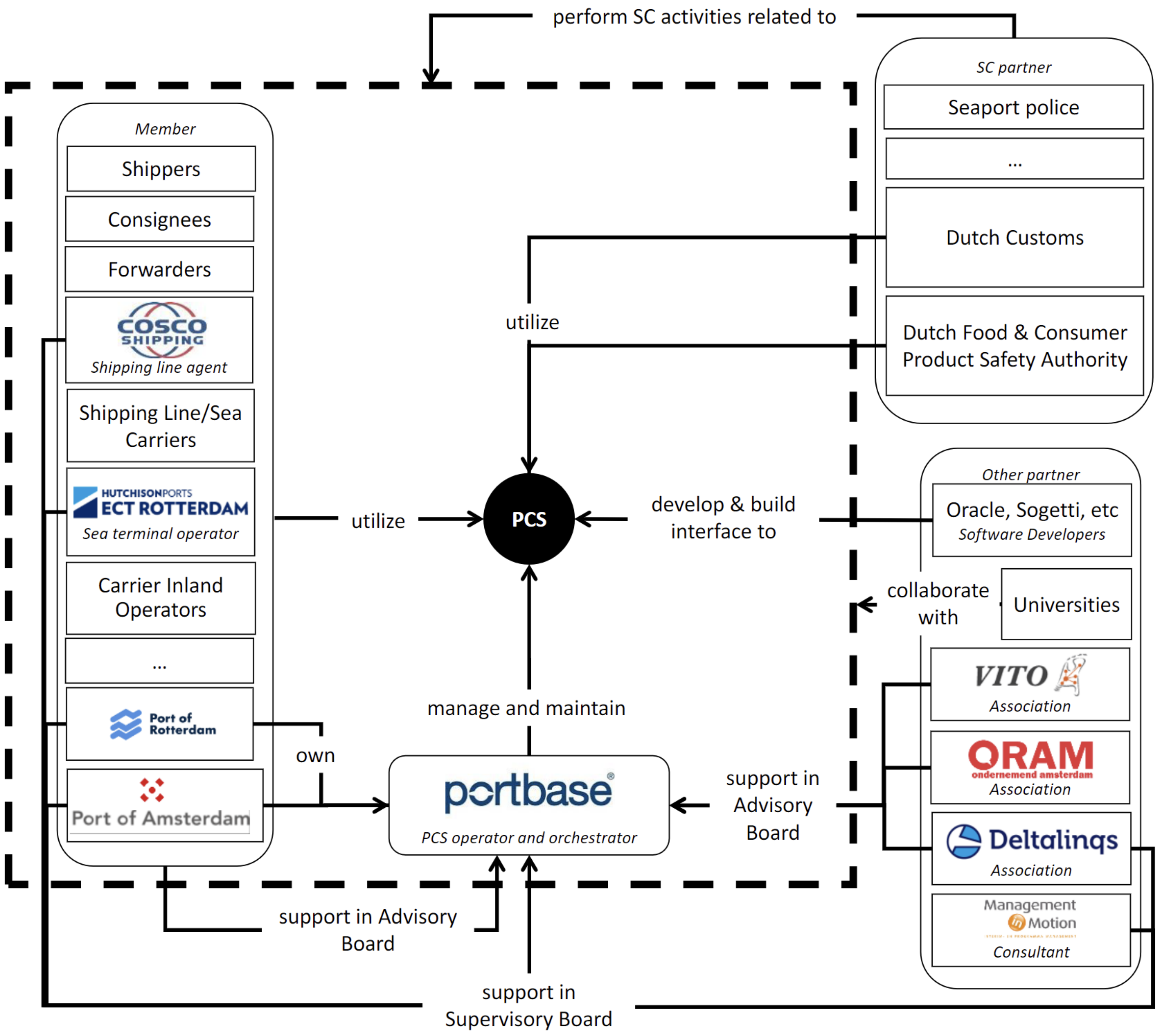
- **System:** A system is a set of interacting **elements** that form a **unified whole** delimited by spatial and temporal **boundaries** and it is surrounded and influenced by its environment
- **Model:** A model is an abstract (inherently approximate) representation of a system by means of logic and/or mathematical relations.
- In a system we distinguish:
  - **elements:**
    - **agents**, e.g., decision makers
    - **entities**, e.g., vessels, containers, $CO_2$
  - **interactions** among the system elements, e.g., through data/information
  - possible external **disturbances** and, vice versa, **externalities**

- **Ports as systems**
- **Digital twins**

# A system

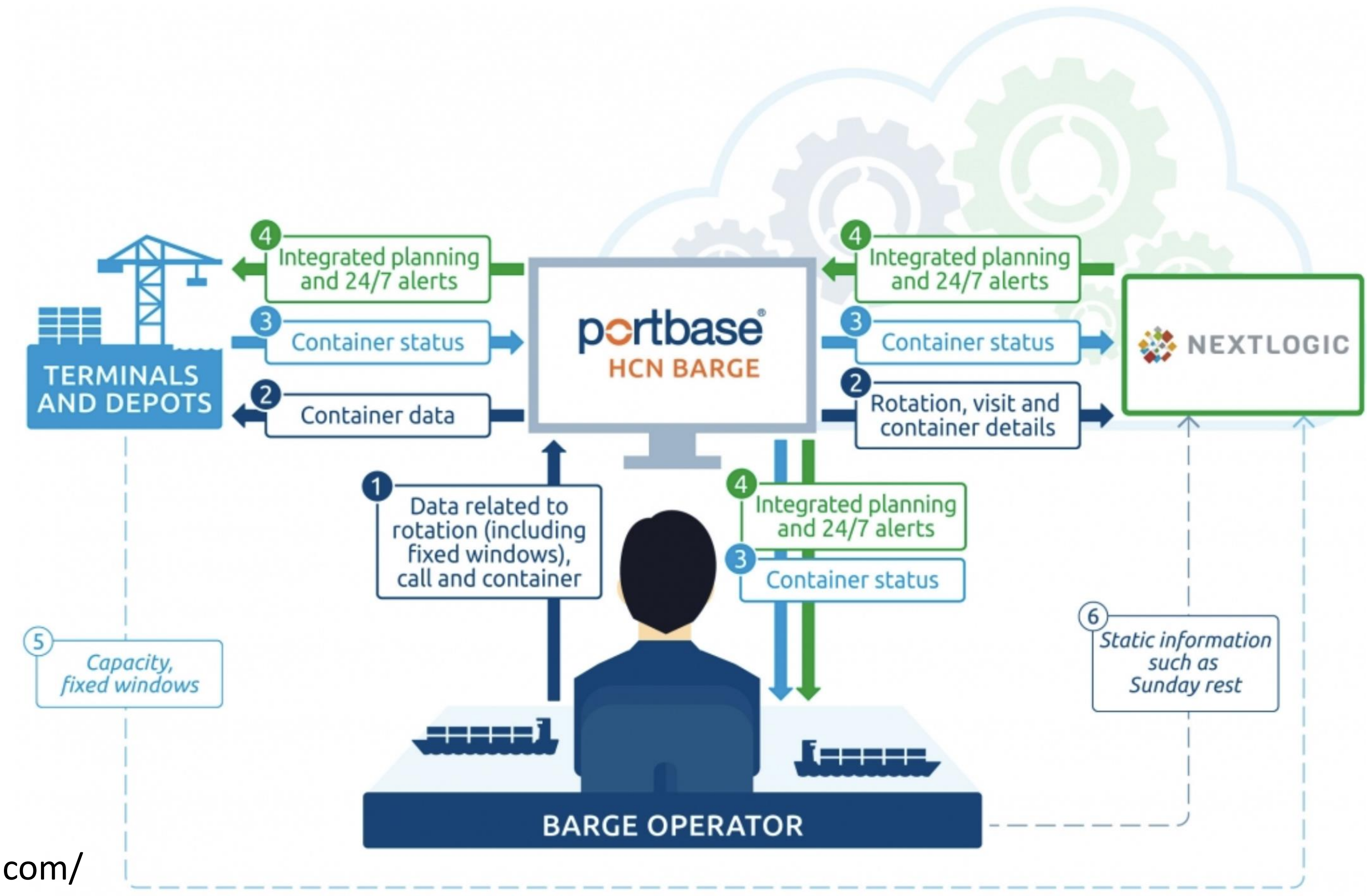

Surroundings
System
External disturbances
Agent/DM
Entity
Agent/DM
Agent/DM
Internal uncertainties
Entity
Agent/DM
Entity
Entity
Agent/DM
Interactions
Externalities
Agent/DM
Entity

# Rotterdam PORTBASE




https://www.portbase.com/

# PORTBASE and NEXTLOGIC




https://portbase-nextlogicconnect.com/

# Issues

A “port/system” includes many interlinked and interrelated actors, who may not always share the same interests, or their interests may not be achieved in the same way. Hence:

- ✓ Lack of collaboration with other actors, need for further integration along the maritime supply chain, uncertainty about legislation, and drifting apart of the local needs and the strategic decisions made by headquarters as a result of globalization.
- ✓ Benefits are not always readily visible, often resulting in a low willingness to pay. At the same time, concern about the cost elements definitely plays in a sector where margins are narrow.
- ✓ Innovation initiative fails or ends in endless discussions about data (ownership, availability, accessibility and modifiable).

# Issues – Human factors

Humans play a fundamental role in the success of the digitalization process (e.g., cyber-security)

- ✓ Digitalization and automation create new challenges and threats for port labor, given the increasing demand for new jobs focusing on high-skilled personnel.
- ✓ New capabilities for workers will require specific training schemes and certifications.

- ✓ Similar arguments hold for infrastructures and procedures

# Other two questions

- ✓ Should we digitalize our ports?
- ✓ Who are the “best in class” in port digitalization?

# European Commission roadmap (2019)[1]

- ✓ **Technological goals/drivers**
  - ✓ Safety
  - ✓ Efficiency gains through digitalization and interaction between technological business models
  - ✓ Environmental soundness
  - ✓ Human factors (behavior and activity)
- ✓ **Automation systems**
  - ✓ operational real-time monitoring systems
  - ✓ automated docking procedures
  - ✓ autonomous vessels used in short sea shipping (SSS)
- ✓ **Smart ports?**

[1]European Commission. (2019). STRIA roadmap on connected and automated transport: Road, rail and waterborne

# Port digitalization – drivers/needs

- ✓ A need for better (already existing) data use from dispersed sources that is not easily accessible. This leads to the combination and data management challenge.
- ✓ A need for better communications in data use and data storage identification between different actors within the supply chain.
- ✓ A need for individually identified technologies including e.g., block-chain, Internet of Things, data-transfer protocols, interoperability solutions, real-time weather data, open traffic data, location-based services, and identification technologies.
- ✓ A need for enhanced development of back-office data systems including financial monitoring and reporting.

Tommi Inkinen, Reima Helminen and Janne Saarikoski, Port Digitalization with Open Data: Challenges, Opportunities, and Integrations, J. Open Innov. Technol. Mark. Complex. 2019, 5, 30

# Port digitalization drivers/expectations

Digitalization can increase port efficacy and efficiency through improved port operations due to:

- ✓ process standardization
- ✓ increasing quality in port services
- ✓ effective strategic planning

| OPERATIONAL | COMMERCIAL |
|---|---|
| 1. Reduce access cost | 1. Less illegal transaction |
| 2. Reduce cost of communication | 2. Reduce labour quantity |
| 3. Decrease rate of operational errors | 3. Faster custom clearance service |
| 4. Reduce data inconsistency | 4. Assist logistics services |
| 5. Increase operational performance | 5. Support cargo distribution |
| 6. Avoid operational risks by early warning | 6. Provide business intelligent |
| 7. Simplify ship declaration | 7. Help to draft commercial contract |
| 8. Provide navigation assistance (tug+ilot) | 8. Provide plaform for collaboration |
| 9. Provide data security | 9. Less beraucratic procedures |
| 10. Reduce accidents and incidents | 10. Promote coordination among entities |
| 11. Assist the route planning | 11. Assist tariff prediction |
| 12. Electrical and internet failures | 12. Lower operational expenses |
| 13. Better tracing and tracking | 13. Require higher capital expenses |
| 14. Enchance the function of GIS | 14. Faster booking service |
| 15. Better dangerous good management | 15. Complex claim handling |

# Port digitalization expectations – Example

Port of Rauma – medium port Finland

**Added Value**

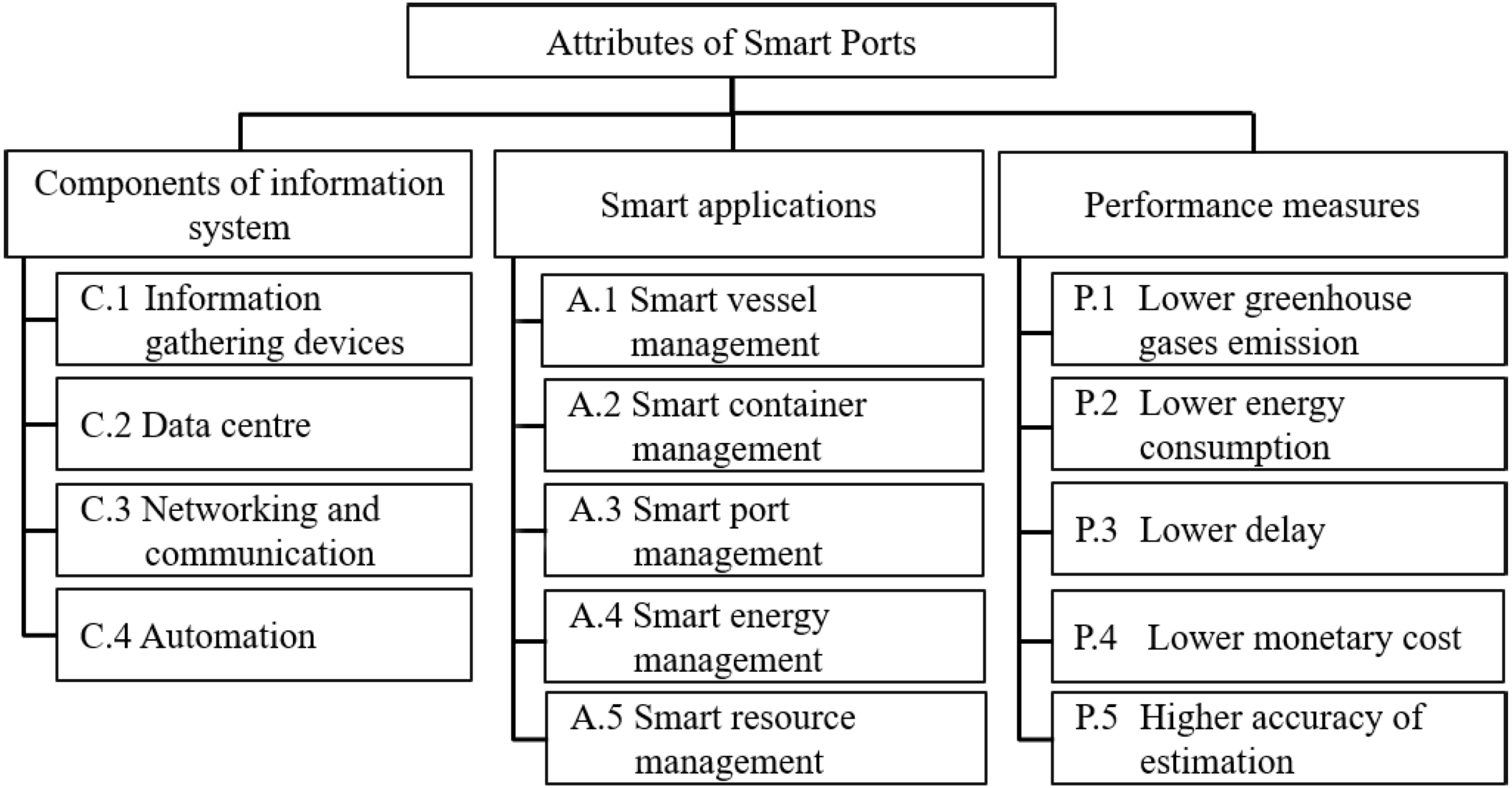
- Improved port information flow and accuracy
- Improved terminal planning
- Improved port call efficiency
- Improved port service planning

- Just in Time arrival possibility
- Plausible reduced emissions
- $CO_2$ reduction follow up and record

- Enhancing the port local governance and collaboration

de Andres Gonzalez, O.; Koivisto, H.; Mustonen, J.M.; Keinänen-Toivola, M.M. Digitalization in Just-In-Time Approach as a Sustainable Solution for Maritime Logistics in the Baltic Sea Region. Sustainability 2021, 13, 1173.

# Smart ports




KOK-LIM ALVIN YAU, SHUHONG PENG2, JUNAID QADIR, YEH-CHING LOW, AND MEE HONG LING, Towards Smart Port Infrastructures: Enhancing Port Activities Using Information and Communications Technology, IEEE ACCESS

# Best in class

| Country | Port | Features |
|---|---|---|
| USA | Los Angeles (TraPac Terminal) | Integrates shipping data from across port ecosystem with data analytics to enhance supply chain performance through real-time data. |
| France | Le Havre | Embarks on projects which address mobility issues (i.e., traffic monitoring and coordination), energy management (i.e., energy production and collection), data management (i.e., data processing and analytics), and environment issues (i.e., air quality improvement). |
| The Netherlands | Amsterdam | Improves management of assets, and develops unique expertise in waste management. |
| The Netherlands | Rotterdam | Uses IoT to create a digital twin and data analytics to determine optimal conditions and timing for the berthing and passage of ships. |
| Spain | Barcelona | Implements storm forecasting system and enables quantification of its customers' cargo environmental footprint. |
| Spain | Seville | Uses IoT-based system for intermodal transshipments, and mobile network technology for supply chain management. |
| Germany | Hamburg | Monitors navigation in real-time, sources shore power supply from renewable energy, and uses mobile GPS sensor for intelligent fleet management. |
| Belgium | Antwerp | Uses blockchain technology to enhance security in digital exchange for transfer of rights between competing parties, digital cameras, and sensors to ensure ships moored at the correct berth, and optimizes preventive maintenance via automatic image recognition. |
| China | Shanghai (Yangshan Port Phase 4) | Implements automated container terminal with remotely controlled bridge cranes, rail-mounted gantry cranes, and auto-guided vehicles. |
| Singapore | Tuas Megaport | Will implement (to be completed by 2040) automated wharf and yard functions, and full-electric automated guided vehicles. |

KOK-LIM ALVIN YAU, SHUHONG PENG2, JUNAID QADIR, YEH-CHING LOW, AND MEE HONG LING, Towards Smart Port Infrastructures: Enhancing Port Activities Using Information and Communications Technology, IEEE ACCESS

# Best in class

| Technology ⇓ \ Application ⇒ | **Port of Rotterdam (see also Portbase)** | **Port of Antwerp** | **Port of Shanghai** |
|---|---|---|---|
| **Internet of things** | Internet of things platform based on sensors, prediction models, etc., such as collaboration platform with IBM for ship tracking and meteorological prediction, berthing conditions; administration data in SAP; spatial data in GIS. | Internet of Things platform to simulate, monitor and optimize a variety of port activities by creating create a port digital twin system based on integration of cloud and sensors. | Information systems based on Internet of Things including logistics information system, shore management system; Internet of Things platforms; intended eastablishing of underwater data acquisition and data transmission |
| **Big data** | Automatic Identification System based on big data for tracking and information exchange, such as ShipTracker and Portxchange. | Establishing of digital data platform for port community system to promote the sharing of big data, such as acquiring of Nxtport for the demand of data processing in smart logistics | Establishing of automatic identification system and digital data platform |
| **Cloud services** | Permission for users to Management Information System by cloud application, such as access to M2Hamis via laptop or tablet. | Cloud-based platform and cloud-empowered digital twin of port widely used in the port logistics to collect and process data, improve adaptability and sensitivity | Cloud-based datasharing platform including both private cloud and public cloud |
| **Blockchain** | Supply chain integrated blockchain platform, such as DELIVER; combination with other technologies including artificial intelligence and high-frequency trading for energy efficiency, such as Distro. | Application of blockchain technology for simplify the cargo processing process, paperless port, collaboration with other technologies including artificial intelligence to solve issue such as, carbon dioxide emissions, port logistics and more | Paperless port under blockchain technology, the collaboration of different platforms such as electronic EIR platform , realizing process collaboration and data penetration between customers, shipping companies and ports authority, etc. |
| **Automation** | Use of drone for delivery of packages and robots, automation administration of data, such as M2Hamis for local waste collection activities’ administration | Automatic equipment, such autonomous sounding boat | Fully automated terminal including AGV |
| **Digital camera and sensors** | Installation of cameras in the port and industrial area for surveillance of the Port of Rotterdam, such as installation agreement of 227 cameras positioned and connected to optical network for processing and storing of optical information | About 600 installed digital cameras and automatic analysis of optical information for inspection, preventative maintenance | Digital camera sensors installed in the port |

Xuyuan Sun, Digitalization in the port industry from the perspectives of bibliometric analysis,
The Maritime Commons: Digital Repository of the World Maritime University, Malmö, Sweden

# Smart ports – 5 maturity stages

| Maturity stage | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Capability level | Optimization | Automation | Digitization | Connectivity Expansion and Orchestration | Knowledge Creation |
| Key action plans | • Value stream mapping<br>• Value analysis<br>• Task simplification<br>• Task standardization<br>• Sustainable port development including emission control systems and waste management implementation<br>• Energy consumption control and monitoring at the port (or by containers or by fleet)<br>• Port worker safety | • Self-configuration of port logistics infrastructure<br>• Port-wide real-time locating system (RTLS) via RFID and a geographic information system (GIS)<br>• Automated quay, stack, and lift<br>• Automated yard and gate management with sensors<br>• Automated yard space/parking management<br>• Customs process automation<br>• Self-environmental protection | • Maritime logistics plan digitization through wireless and mobile technology<br>• Data collection from every piece of equipment at the port<br>• Compliance with the Smart Port Security Act and International Ship and Port Facility Security Code (ISPS)<br>• Quality control digitization<br>• Remote monitoring<br>• Creation of a digital twin (a virtual representation of the entire port) | • Information and communication technology (ICT) integration<br>• Strategic alliance<br>• Big data storage and monitoring<br>• Data visualization<br>• Data/information sharing<br>• Real-time, broadband communication | • Error/malfunction detection<br>• Early warning system<br>• Rule-based expert system<br>• Business intelligence development through organizational learning |

Hokey Min, Developing a smart port architecture and essential elements in the era of Industry 4.0, Maritime Economics & Logistics (2022) 24:189–207

# Smart ports – 5 maturity stages - KPIs

| Maturity stage | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Key measuring attributes (including performance indicators) | • Asset utilization rate (e.g., percent equipment utilization, yield rate)<br>• Customer response time<br>• Uptime/downtime<br>• Cost-saving<br>• Overall Equipment Effectiveness (OEE)<br>• Berth productivity<br>• Frequency of port calls<br>• Port energy consumption level<br>• Renewable energy usage<br>• Port congestion level<br>• Wastewater level<br>• Air/water/noise pollution level<br>• The level of intermodality (e.g., percentage of goods moved by railway)<br>• Accident frequency/severity | • Robotic usage<br>• Automatic Guided Vehicle (AGV) and Automatic Guided Cart (AGC) usage for material handling<br>• Housekeeping standards<br>• Workload reduction<br>• Human error reduction<br>• Carbon footprint reduction<br>• Labor productivity | • Data visibility<br>• Data accuracy<br>• Data integrity level<br>• Data query time<br>• Real-time data access capability<br>• Cyber security assessment<br>• Mobility<br>• Capital expense saving | • Supply chain resiliency level<br>• Breadth and length of partnerships<br>• Port network level<br>• The level of sharing information regarding port and hinterland traffic flows | • Learning through quality circles<br>• Organizational learning through knowledge externalization (collective group knowledge) and transfer<br>• Mutual trust level<br>• Process innovation |

Hokey Min, Developing a smart port architecture and essential elements in the era of Industry 4.0, Maritime Economics & Logistics (2022) 24:189–207

# Smart ports - next

- ✓ New applications
  - ✓ Smart marine traffic management
  - ✓ Smart logistics
  - ✓ Smart security service
- ✓ Collaboration platform for different ports
- ✓ Enhanced terminal operating system
- ✓ Collaborating with smart ships
- ✓ Autonomous smart ports
- ✓ Big data analytics for smart ports
- ✓ Optimization, AI, blockchain for logistics

KOK-LIM ALVIN YAU, SHUHONG PENG2, JUNAID QADIR, YEH-CHING LOW, AND MEE HONG LING, Towards Smart Port Infrastructures: Enhancing Port Activities Using Information and Communications Technology, IEEE ACCESS

# Final question

- ✓ Can Italian ports compete?

# Port integration and digitalization – four maturity layers

1. Single ports are striving to develop and digitalize their own processes;
2. Port communities and companies operating in the vicinity of the port integrate their operations and data sharing that is a fundamental part of digitalization;
3. Logistic chains integrate other logistic companies and operators working outside of ports are integrating their systems with ports. Digitalization has expanded beyond the vicinity of ports;
4. Global port data exchange processes as parts of global logistic chains: ports are networked with each other creating highly detailed on-demand transport chains.

# Issues

- Smaller ports have more difficulties and resource limitations in implementing digitalization
- Data exchange and transfer is not often considered as a competitive advantage
- Port digitalization should embrace port-city interfacing and traffic management close to ports
- One of the drivers for port cooperation, if not mergers, is to avoid duplication in facilities necessary to handle larger ships and more and more complex supply chain. Public port authorities are more likely to cooperate with each other than a public and private authority (drawback of privatization?)

# Key technologies for port digitalization

- Technologies
  - Artificial intelligence (AI), Optimization, (big) data analytics and blockchain
  - IoT, sensor technologies and 5G
  - Robotics and automation, autonomous shipping, drones and, possibly, cyber physical systems
  - Cyber-security
  - 3D printing and laser scaling
- Scenarios
  - Digital supremacy
  - Business as usual
  - Digital failure

Tommi Inkinen, Reima Helminen, Janne Saarikoski, Technological trajectories and scenarios in seaport digitalization, Research in Transportation Business & Management 41 (2021) 100633

# Drivers

| Main drivers | Digital supremacy | Business as usual | Digital failure |
|---|---|---|---|
| Authoritative collaboration (Governing driver) | Standardization has been succesfull globally. Several breakthroughs in technological interoperabilty. | Collaboration and standardization has progressed but only slightly. Several national interests and conflicting situations exist. | Standardization has decreased and national/ organization specific system developments dominate. |
| Logistical hubs and market development (economic driver) | Convergence of general e-commerce plaforms and logistic platforms. large IT companies dominate logistics management. Maturization of the market e-services. | Large IT and e-commerce companies have become a part of the logistics market as competitors to traditional logistics companies. Market has consolidated but not there are plenty of development areas in IT integration. | Logistics market is not growing. Significant amount of partial optimization and lack of collaboration. IT integration not progressing due to divergence. |
| Port impact in society (Societal driver) | Digitalization aids planning processes efficiently and participatory methods are used in order to integrate ports into their surroundings. Ports have become more significant locations within cities. | Ports are competing with other forms of land-use. The role of ports is considered as a silo in society (transport industry). Traditional planning causes residential are-port area conflicts. | Other forms of land use are prioritized before port areas. Extensive problems with congestion. IT solutions are unable to ease traffic management and flow control in port vicinities. |
| Carbon neutrality (Environmental driver) | New energy and engine solutions provide significant reductions in port emissions. IoT and sensor technologies widely applied in monitoring and real-time reducing emissions. | Small steps in order to reduce carbon and other emissions from ports. Diverging interests in environmental management and partial solutions for emission control. | Environmental conflicts are increasing and even current levels are not hold. Lack of collaboration and partial optimization of costs lead to use of non-efficient solutions and technologies. |

Tommi Inkinen, Reima Helminen, Janne Saarikoski, Technological trajectories and scenarios in seaport digitalization, Research in Transportation Business & Management 41 (2021) 100633

# Technologies

| | Digital supremacy | Business as usual | Digital failure |
|---|---|---|---|
| AI & big data | All parts of supply chain are IT embedded.<br><br>AI is the new ‘normal’ in ports.<br>Port management and key-decisions rely extensively on data analysis and AI decision making. | AI helps and gives efficiency gains in daily operations.<br>All key-decisions and management remain human driven.<br>Data analytics are used as a supportive addition in decision making. | Resistance to change (including employees, governing bodies, employers) causes that the use of data analytics are limited.<br><br>AI is not used as a supportive tool.<br>Adoption of non-interoperative support tools that are port specific. |
| Block-chain | BC technology is widely used in all transactions related to supply chain and port operations.<br><br>BC covers practically all domains of transport documentation. | BC is driven only by the largest companies.<br>Transaction chains are done within company blocks.<br>Number of closed systems. | BC is virtually non applied due to diasgreements and lack of collaboration between companies.<br><br>The lack of general concensus is causing BC to remain marginal. |
| IoT and sensor technologies | The use of sensor techologies and IoT is widely accepted.<br>Efficient use and optimization of flow data enables decreases in accidents, congestion and maintence. | These technologies are used but only by the largest and the most resourced ports.<br>Sensor networks produce raw data for data-analysis and AI. | Problems in data security and confidentiality limit the use of technology integration.<br>Reliability problems are causing that majority of port organizations remain using old methods in their operations. |
| Robotics and automation | Extensive adoption of robotics and automation in all ports.<br>Increasing use of drone technologies and applications. | Robotics are used only in largest ports.<br>Scaling benefits towards smaller ports are emerging slowly. | Employees and interest groups are not ready for massive changes. Robotics are considered expensive and investments remain low. |

# Technologies

| | Digital supremacy | Business as usual | Digital failure |
|---|---|---|---|
| 3D printing | 3D Printing impacts core transport business.<br><br>Transportation of raw materials increases.<br>Selected ports invest in production facilities for 3D production. | 3D printing and production offers business potentials for some ports.<br>The impact on transport business is limited.<br>Investment levels are small but provide niche potentials. | 3D printing and production remain marginal in ports.<br>Their potential is not considered significant and they wither away from port agendas. |
| Laser scaling | Remote sensing data is widely applied in port planning and decision making.<br>Real-time 3D monitoring is used in maintenance and decision making. | Some applications of laser scaling are used in the largest ports.<br>Limited impact and disagreements of benefits. | 3D models and remote observation are considered insignificant and too expensive.<br>The development plans depend on speficially ordered mappings on the need basis that does not provide constant platform for renewal of practices. |
| Cyber-security | New secure solutions have increased trust towards AI decision making. BC technologies are widely applied enabling these developments.<br>Cyber-crime numbers are dwindling. | The constant competition between criminal activities and cyber-security tools continous.<br>Acceptance levels and privacy debates continue to exist as they have done thus far. | Adopted new technologies pose great security risks causing limitations in their use.<br>Severe trust issues towards technology use in private data management. |

# Smart ports - applications

Tommi Inkinen, Reima Helminen and Janne Saarikoski, Port Digitalization with Open Data: Challenges, Opportunities, and Integrations, J. Open Innov. Technol. Mark. Complex. 2019, 5, 30

| Theme | Decided and Planned Solutions for the Theme |
|---|---|
| Road, rail and waterborne traffic channels: | • Intelligent guidance of traffic and parking (1, 2, 3)<br>• Special haulage/outsize load routing (1)<br>• Intersection safety (3)<br>• Rail monitoring with sensors (2)<br>• Operation information of security devices on water areas (2, 3)<br>• Depth data (2)<br>• Port's weather station (1, 2) |
| Buildings and areas: | • Conforming map coordinate system use in different parts of a port (2)<br>• Resource dividing between/with user segments (1)<br>• Infrastructure service dividing between/with organizations (maintenance, winter conditioning) (1, 2)<br>• Technical data portal in a port (2)<br>• Vessel automated mounting (automooring) (1, 2)<br>• Automated vehicle scaling system (2) |
| Technical networks: | • Anticipating maintenance with sensor data (2)<br>• Intelligent lighting guidance (2)<br>• Intelligent camera and image recognition systems (2)<br>• WLAN for port customers and organizations (2) |
| Port management (whole): | • Enhanced data and information distribution: Port snapshot system (2)<br>• 3D port models (2)<br>• Interaction improvement (1)<br>• Mobile applications on defects reporting (2)<br>• Close call and deviation messaging information distribution to all stakeholders (1, 2)<br>• Hazardous situation informing for port community employees (3)<br>• Port related industries integration with port operations (1) |
| Dynamic traffic data: | • Mobile application for travelers, enhanced travel experience (2)<br>• Tugboat visibility (physical) to ports (1)<br>• Information delivery of traffic conditions/obstacles on the paths leading to ports (2) |