# MARITIME INFORMATICS AND DECISION MAKING

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## ABSTRACT

Maritime informatics takes a holistic approach to shipping, noting that information requirements are strongly influenced by the self-organising nature of the industry and the spatial-temporal data needed to manage operations pursued during sea transport as an integrated part of the global transport chain. It follows that the many actors involved must share data in real-time to organise the many associated activities effectively and efficiently. Strong voices in the shipping industry are now pushing for a digital transformation that will result in higher levels of transparency, predictability, and visibility of all transport operations connected with shipping. There is a drive for enhanced situational awareness across the full spectrum of activities in the movement of goods from origin to destination. In this paper, we explore how maritime informatics may empower decision-making pursued among involved actors.

**Keywords**: *Maritime Informatics, Standardization, Smart Operations, Short-Sea Shipping, Financials Decisions*

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# 1. DECISION-MAKING IN THE SELF-ORGANISED ECOSYSTEM OF THE MARITIME INDUSTRY

Informed by system sciences, informatics takes a holistic view to change human practices, usually for the better. It applies digital technology to enable people to collect, process, and distribute information. From an organisational point of view, it seeks to empower decision-making through information systems. As one of the founders of informatics claims, information systems is to serve the object system, where the object system is the practice in focus (Langefors, 1973). In the 1960s, when informatics was introduced as an enabler for efficiency, the organisation was conceived as the object system, which changed later by introducing e-Commerce, thereby focusing on the customer. More recently, the inter-organisational aspects of multi-organisational collaboration have been embraced by informatics.

The maritime industry is a self-organising ecosystem, constituted by many participants and stakeholders acting in self-interest, loosely held together by information for centuries. The information enables traders and shippers to overcome national differences and the myriad actors in the worldwide maritime system to request and receive the necessary services to transit oceans, rivers, and lakes, and handle cargo in a multitude of ports of varying size and resources (Watson et al., 2021). The time has now come for ecosystems within the maritime sector to be empowered by connectivity and data sharing to deliver integrated ecosystem performance.

In this paper, we visit several applicational areas where Maritime Informatics has and could empower decision making in the shipping sector. For each of the areas, the focus is on how information can raise the quality of decision making and thus improve capital productivity.

# 2. APPLICATIONAL AREAS FOR EMPOWERING DECISION MAKING BY MARITIME INFORMATICS

## 2.1 Digital Data Sharing for Enhanced Decision Making

Digital Data Sharing for Enhanced Decision-Making covers how Maritime Informatics provides a foundation for the maritime aspects of the so-called fourth industrial revolution (Maritime 4.0) (Bergmann et al., 2021). Building upon the notion of digital data streams (DDSs) attention is paid to the maritime domain's need to define and standardise the *When*, *Where*, *Who*, *What*, *Why*, and *How* dimensions when capturing an event's circumstances. Through standardised digital data sharing affected actors can gain the necessary situational awareness to make coordinated decisions to enhance resource utilisation and increase the safety and efficiency of operations to create value for individuals and society.

Digitalisation is the key process of what is now termed 'the fourth industrial revolution', or 'Industry 4.0'. It is about developing an environment utilising new and disruptive technologies like artificial intelligence (AI), robotics, virtual reality, and the Internet of Things (IoT) and is changing how we work and live. To some, the maritime industry has been lagging, but the pace of adoption of digitalisation has grown in recent years, focused on the term 'Maritime 4.0', sometimes also called 'Shipping 4.0' (Fraunhofer, 2018). In this arena, Maritime Informatics plays an important role as it brings maritime digitalisation into the broader maritime technology space, as well as marine biology and other related maritime aspects of computer science.

In the advent of the age of digitalisation, data standardisation has become paramount in support of the tremendous changes along the whole chain of information processing. Digitalisation and Maritime Informatics create opportunities for new structures for capital creation and how data sharing enables new opportunities. Along those lines, sharing data increases the "of new perspectives for situational awareness, and as such can strengthen the foundations for decision making. In this realm, it is important to differentiate between 'data' and 'information'. Data is the uninterpreted fact. Information provides the facts in a digestible way (Bergmann, 2012).

One important implementation of Maritime 4.0 is the Port Collaborative Decision Making (PortCDM) concept. Here, timestamp data on port calls is gathered and shared in a standardised way, as valuable information to increase port calls' efficiency and safety (Lind et al., 2019). From the Maritime 4.0 perspective, the data streams coming out of systems of records, such as PortCDM compliant tools, are growing in diversity, scope, and scale. Thus, it is reasonable to think that a vast number of digital data streams will be available to players across the maritime ecosystem.

In the digital era, data streams are often identified as static or dynamic data streams. Static data is characterised as data which is compiled and then used over a long period. The integration of both static and dynamic data, be it real-time or semi-real-time, can provide additional situational awareness as it provides both knowledge about less volatile baseline data as well as data with high volatility (Pigni F et al., 2016). With more and more data streams becoming available, both static and dynamic, and the growing importance of IoT to the maritime industry, the need for harmonisation and standardisation is recognised by many to be critical. However, the maritime domain, due to its global character, needs to ensure worldwide adoption of the necessary standards and needs to foster open data streams so all can benefit from the data explosion fed by Maritime 4.0 and enabled by Maritime Informatics.

### 2.2 Decision Support for Port Visits

Maritime Informatics provides decision support for port visits, both for visiting carriers and for operators at ports providing services to the carriers. Decision Support for Port Visits (Lind et al., 2021c) considers the important role that ports have in global trade as transhipment hubs and inter-modal connection points between sea-based and land-based transport. In order to function efficiently, a well-coordinated port needs to be informed about when ships and hinterland carriers, as episodic tightly coupled actors, will use the port to make sound decisions about reserving appropriate resources and infrastructure to serve visiting ships. Sharing this information to achieve a common situational awareness of forthcoming and ongoing port calls among all the involved actors enables them to align their plans concerning others.

Data from systems of production channelised as data to record systems (Watson, 2019) permit distributed coordination of port call operations among the various involved actors. One of the key foundations for establishing such a system of record is to share and aggregate spatial-temporal data as the foundation for making well-founded decisions on the timing of the different events related to each other. Such records also form the foundation for an elastic approach to time slot allocation allowing for slot reservation systems that can enhance the timely interaction of episodic tightly coupled actors.

Thus, ports have an important role in global trade. They serve as locations for transhipments to be made and as inter-modal connection points between sea-based and land-based transport. Some ports also offer additional services of refinement of goods that pass through them. For ports of today, there are great challenges to balance between a large degree of flexibility and having a solid structure of plans for forthcoming visits by ships and different types of hinterland carriers.

Consequently, the well-coordinated port needs to be well-informed about when ships and hinterland carriers, as episodic tight coupled actors, intend to use the port and, consequently, make sound decisions about reserving appropriate resources infrastructure to serve them. It needs a good understanding of the status of goods and passenger flows and to be able to track carriers' movements to predict and coordinate the different types of events in the port. The Port Collaborative Decision Making concept, the sharing of timestamps, i.e. a digital message with details of a planned or actual event, for an emerging common situational awareness among involved participants, has been designed specifically to enable this.

In order to achieve global harmonisation, the establishment of standardised message formats, communication channels, and interaction procedures are thus foundational capabilities. Based on such standardisations, data derived from different areas of operations and related systems of production in the ecosystem may be used to optimise the overall ecosystem's performance. Increasing its information richness through digital data sharing, the maritime transport sector can improve resource management and its overall efficiency. Ship movements can be conducted with a reduced carbon footprint and a port's resources more fully utilised.

### 2.3 Decision Support for Voyaging

A ship is now increasingly both a consumer of data originating from different sources and a provider of data. Most ships are now sources of some level of information that can be remotely monitored, collected, analysed and acted upon. Many onboard information systems support decisions for the officer on watch during a voyage. This includes position, engine and machinery monitoring and increasingly, the condition of the cargo. This level of monitoring is only likely to increase in the coming years. Data recorded at sea can be distributed upon return to port, if not previously communicated in real-time and now forms an important source of data for maritime informatics – assisting future voyage planning and execution.

An important aspect of the increasing availability of digital data at sea is its presentation in a standardised form because both ships and their crews often rely on information received in languages they might not master. The digital data also needs to be compatible with the variety of systems and equipment fitted in different ships. An example is the standardisation of the nautical chart and supporting information publications achieved by the International Hydrographic Organization (IHO). Any mariner in the world can recognise and use a nautical chart (paper or digital) produced by any country in the world. Work to standardise all data streams across all aspects of maritime digital data exchange is now high on the international agenda to ensure that data is available, understandable and compatible across the range of different information systems in ships and ashore.

A key development for ships is the International Maritime Organisation's (IMO) e-navigation concept which is defined as "*… the harmonised collection, integration, exchange, presentation and analysis of marine information on board and ashore by electronic means to enhance berth to berth navigation and related services for safety and security at sea and protection of the marine environment*" (IMO, 2018). E-navigation envisages the provision of information required for safe and efficient navigation being provided digitally as streamed services. The various data and information requirements are grouped under sixteen Maritime Services.

| Maritime Service | |
|---|---|
| **1** | VTS Information Service(IS) |
| **2** | Navigational Assistance Service(NAS) |
| **3** | Traffic Organization Service(TOS) |
| **4** | Local Port Service |
| **5** | Maritime Safety Information Service(MSI) |
| **6** | Pilotage service |
| **7** | Tug Service |
| **8** | Vessel Shore Reporting |
| **9** | Telemedical Assistance Service(TMAS) |

| Maritime Service | |
|---|---|
| **10** | Maritime Assistance Service(MAS) |
| **11** | Nautical Chart Service |
| **12** | Nautical Publications Service |
| **13** | Ice Navigation Service |
| **14** | Meteorological Information Service |
| **15** | Real-time Hydrographic and Environmental Information Service |
| **16** | Search and Rescue Service |

### 2.4 A Smart Grid in Container Terminals

Empowered by Maritime Informatics, the shift from conventional fuel-powered vehicles to electric vehicles as one possible step for a sustainable transformation in the logistics sector, such as at container terminals, where heavy-duty vehicles are essential when moving containers around the terminal is a promising area for a smart grid application (Harnischmacher et al., 2021). Here, idle vehicles' batteries can be used during less busy times to provide a primary control reserve (PCR) and potential boost capacity for the energy grid. The need for energy reserves has increased with the integration of intermittent renewable energy sources, which need to be carefully managed to provide a stable power supply.

The publicly funded electric mobility project FRESH (Flexibilitätsmanagement und Regelenergiebereitstellung von Schwerlastfahrzeugen im Hafen) serves as a business case to integrate the battery capacities of automated guided vehicles (AGVs) into the energy network as flexible storage units for a contribution to grid stability and power supply. All container terminals include the transport of the containers from the cranes that move them to the shore to the storage area (Kemme, 2013). This is generally done by the AGVs that transport one or two containers per vehicle depending on the containers' size and weight. Electrification of these vehicles massively reduces the greenhouse gas emission of the terminal. Furthermore, due to the implementation of a virtual power plant (VPP), a vehicle's battery can be connected to charging stations during idle times to provide primary control reserves for the energy market. The ecological and economic outcome of such an undertaking heavily depends upon the interplay of the information system (IS) involved at the logistical level as well as on the replicability and adaptability of the project.

As a container terminal is an extensive and complex setting, it often presents a barrier of implementation. Therefore, to facilitate novel IS implementations, IS research should remove this barrier and investigate the individual information needed for decision making, e.g. analysing the strength, weaknesses, opportunities and threats (Johnson et al., 1989) of smart grid applications. Most importantly, cost driver analysis is an essential first aspect for the operator's decision process to ensure economic benefits and prevent unprofitable outcomes. In order to make economically beneficial decisions, the operator has to gain insight into total costs that arise in the context of implementation, usage, and constructions that have to be weighed against the benefits and revenues. Commonly, analyses that include considerations like these are referred to as Life-Cycle Cost Analysis (LCCA) models (Rapaccini et al., 2013). In the information technology (IT) industry, the specific LCCA approach of the total cost of ownership (TCO) method is used as a suitable tool for this purpose (Ferrin and Plank, 2002). It is defined as "*a purchasing tool and philosophy which is aimed at understanding the true cost of buying a particular good or service from a particular supplier*" (Ellram, 1994). In the TCO model framework, one essential step, outlined by Ellram (1993), is the identification of these costs.

To determine all the relevant costs that occur in providing a PCR through AGV batteries in an electrified container transport system, a three-phase research approach was followed. Firstly, a review of existing work on cost analysis in electrified systems to find a systemised scheme for the cost analysis and to identify relevant costs that were addressed in similar settings. Secondly, experts from different relevant fields experienced in the port and electric industries evaluated the described project setting's cost. Finally, the results were aggregated to identify a cost model that is based on a systemised scheme and holds for the specific use case that was examined.

To enhance the implementation of such systems and provide a practical example that can be used to transfer to other domains, a model was developed to establish an overview of the cost drivers relevant to the specific scenario studied. Firstly, cost drivers can be distinguished in terms of the project stage at which they occur (Ellram, 1993): pre-transaction, transaction and post-transaction. Furthermore, the cost drivers can be allotted to different overarching cost areas (Ellram and Siferd, 1993): management, delivery, service, communication, quality and miscellaneous.

The transition from a container terminal with fuel-powered AGVs through electrification of its vehicles, up to the generation and trade of PCR by a smart electrified system was demonstrated. Several cost drivers were consistent over the process while other cost drivers were added or deleted as they are no longer relevant. The results show that general cost drivers also hold for a non-electrified container terminal that uses fuel-powered AGVs. These cost drivers include, for example, the purchasing cost of AGVs, and the maintenance of software and hardware. Due to the change from fuel-powered to electrified vehicles, the following cost drivers arise: purchasing of batteries and conversion of AGVs, the cost to change software from fuelling management to electric charging management, costs connected to the disposal of fuelling stations and the purchase of electric charging stations, installation and investment costs, maintenance costs of for the new charging stations.

Nevertheless, the costs regarding battery lifetime and degradation are difficult to estimate, and the fuel costs are eliminated, and environmental costs are reduced. Moreover, when using the batteries to generate PCR during idle times by connecting the AGVs with the charging stations to energy reserves in the market via a VPP the following cost drivers need to be considered: cost to change the battery administration system, so the AGVs drive to charging station when not used for transport, purchasing costs VPP (hardware and software), maintenance of VPP, VPP costs to interact with market and get exact estimates and costs for the prequalification necessary to participate in the PCR market.

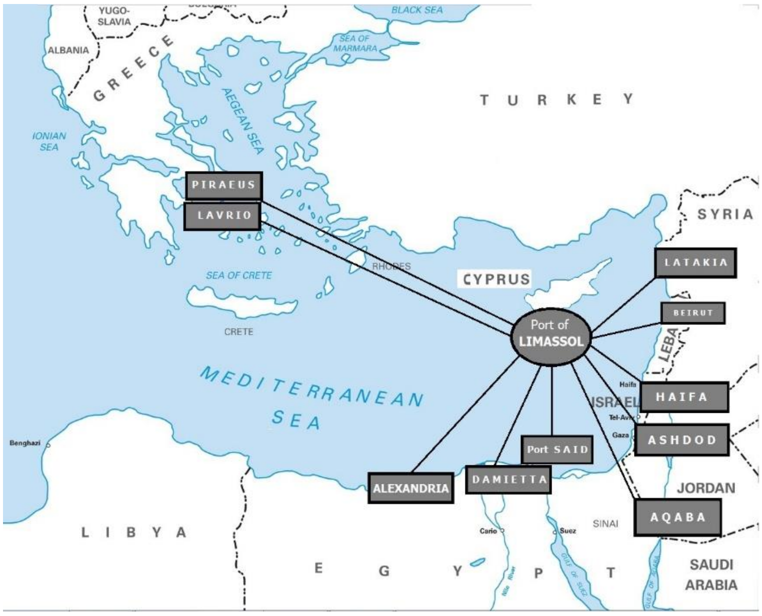
All identified cost drivers are based on the relevant literature and expert evaluations. The results promote implementation and thus serve as a pioneer for other industries with mobile energy sources and access to the electricity market.

## 2.5 Decision Support in Short Sea Shipping

Shipping of today is arranged in Short Sea Shipping and Deep Sea Shipping patterns, having the consequence that different ports have specialised in different ways (such as feeder ports and larger gateway ports into different regions of the world). Short sea shipping (SSS) is a commercial waterborne transport that does not transit an ocean. SSS can be a cleaner, safer and efficient transport system well-suited for areas such as the Mediterranean. The authors identify reliability, quality and safety, and reduce costs and delays in ports as some main challenges and look upon how Maritime Informatics, through digital data sharing and proactive collaboration between nearby ports, can improve SSS efficiency within a region. Building upon Watson et al. (2021), short sea shipping is concerned with glueing together port nodes, as self-organised entities, by the movements of episodic tight coupled actors made between those nodes. As the term "short" implies that the relative distance between the nodes is small, so downstream ports need to be updated on the progress made for serving the arriving ship in the upstream ports to secure that foundational basis for planning is established in the downstream port. Achieving connectivity between ports through means of standardised digital data sharing, therefore, becomes crucial.

The validation of PortCDM (Lind et al., 2018) shows that standardised digital data sharing and enhanced collaboration can reduce unnecessary waiting times during port visits and inform about the port visit's expected time with a high degree of predictability. As the focus has been placed upon just-in-time shipping lately, it is to be expected that ports informing about when operations are to be finished with high predictability, would become a part of the value proposition. SSS offers a set of advantages that no other mode can provide, especially concerning the environment. However, the ecological sustainability of SSS relies on port efficiency and the time spent in ports for realising its advantages compared to other modes of transport. In the related literature on port efficiency, there is a gap in quantifying the different waiting and idle times during a port call process and identifying their root causes. In Michaelides et al. (2019), the effect of time in port is considered by investigating the factors influencing the various waiting times at the Port of Limassol (see Figure 1), both from a quantitative and a qualitative perspective. The qualitative results are based on the views of key people involved in the port call process. The quantitative analysis relies on data from over 8000 port calls during 2017-2018, which are analysed with respect to ship type, the port of origin, and shipping agent. The calculated key performance indicators (KPIs) include arrival punctuality, berth waiting, and berth utilisation. The analysis clearly reveals considerable variation in agent performance concerning the KPIs, suggesting a lack of attention to the social aspect of a port's socio-technical system.

**Figure 1: Limassol EU Port in the Eastern Mediterranean**




Source: Michaelides et al., 2021

The sustainability of Short Sea Shipping is central to a clean, safe, and efficient transport system. For shipping, and particularly for SSS, there are obvious and immediate benefits from improving efficiency by enabling all those involved in the port call process to engage more easily. In particular by equipping shipping companies, port service providers, and ships' agents with information sharting and decision support systems to boost their efficiency and that of their port (Lind et al., 2019). In particular, an analysis of recent port call statistics for the Port of Limassol, Cyprus, indicates an opportunity to improve port call data sharing by applying the Port Collaborative Decision Making concept. Better data are essential for better decision making. The Cyprus port experience is not unique; it is just an example of a phenomenon that exists all over the world. It follows that every port should become connected to other ports to provide the basis for an efficient SSS. Many of the world's ports, large and small, are confronting the same issues concerning making SSS more efficient - this applies equally in developed and less well-developed countries. Better data sharing based on the

PortCDM concept is a key way forward. This, in turn, will make shipping more efficient and sustainable, thereby contributing to meeting the important climate and sustainability goals advocated by the United Nations.

### 2.6 Maritime Informatics for Recreational and Fishing Vessels

To sail or navigate recreational vessels, you have to prepare what are required from the beginning to the end of a voyage. You may need to choose a yacht dock to call, check weather forecasts, plan a route, share the planned route with your family, check safety before departure using the checklist, report departures, receive marine meteorological information, report on dangerous obstacles, and report ship entry. Maritime informatics for recreational vessels is a generic term for information services that enable these activities more efficiently and effectively by using ITC technologies.

Concerning Maritime Informatics for fishery vessels, the information that helps to identify the fishing grounds is important. On the market, you could find a variety of apps for fisheries. They provide sea surface temperatures (SST), altimetry, chlorophyll concentration, currents, fish species, hot spots, fishing bank, artificial reefs, shipwrecks, fishing records, and sea weather forecasts. In addition to the information service leading to catch more fish, illegal fishing surveillance system/service is another type of Maritime Informatics system for fisheries. As sustainable fishing governance faces great challenges, illegal fishing undermines the ability of fisheries governors to make sound and informed decisions (Österblom, 2014; Sumaila et al., 2006) and for food. Since both fishing vessels and fish are mobile, spatially referenced data on the location of fishing vessels, equipment and catches should be collected to minimise illegal, unreported and unregulated fishing activities (Toonen and Bush, 2020). For this purpose, technologies include drifting fish manoeuvres, onboard cameras, drones, and satellite vessel monitoring systems.

Although Maritime Informatics for Recreational and Fishing Vessels is not dealing with containers or with goods which are normal to merchant shipping, the purpose of applying Maritime Informatics to the field is same as for merchant shipping: efficiency and productivity which can be interpreted as safer navigation and more fish caught while also making it sustainable. This means advantages from the application of Maritime Informatics are not limited to merchant shipping but extended to non-merchant shipping. As these ships use the same water infrastructure as merchant ships, they should all have access to the same digital infrastructure and services to enable complete situational awareness and thus improve safety, environmental sustainability, and efficiency for all at sea.

### 2.7 Support for financial decision making

Forcellati et al. (2021) explore key financial processes where Maritime Informatics could make a difference by enhancing existing practices. They acknowledge the different types of costs associated with maritime transport, such as capital expenditure, operational expenses including environmental, social, and running costs including management. Building upon Maritime Informatics's role to achieve control, mitigate risks, and reduce the costs within each of these cost segments, different opportunities are identified. The economic advantages and resilience emerging from transparency in financial processes through data sharing are considered.

Maritime Informatics and data sharing activities are increasingly relevant for financial decision making. They enable the understanding and mitigation of present and future risks along with facilitating the assessment of existing and future costs in terms of resiliency, compliance and sustainability. For example, from a sustainability angle, climate change and the increased pressure on the shipping industry to decarbonise will impact the future costs associated with maritime transport as already observed with the recent sulphur cap enforcement making bunker procurement processes more complex and costly.

Furthermore, considering the systemic nature of climate change, Maritime Informatics and data sharing will facilitate the assessment and quantification of the interconnectivity and socioeconomic impacts and therefore increased costs associated with climate change. Rising sea-level, coastal erosion and changing sedimentation patterns are potentially impacting port infrastructures and supply chains around the globe. Maritime Informatics tracking re-routing activities, increased transit time and several ports visited during a voyage, are great data indicators for future financial decision making.

## 2.8 Green supply chain management and environmental control and regulation

Panayides et al. (2021) examine the importance of green supply chain management (GSCM) and its relationship to the shipping industry, referring to the regulatory framework and several existing enforcement mechanisms and how these impact and enhance green shipping. GSCM adds value through socially responsible management of logistics processes by connecting stakeholders within a corporate structure to promote collaboration and preserve the environment.

Shipping firms complying with the ISO 50001 international standard for energy management systems, can increase their environmental performance and decrease their costs, by reducing their energy consumption and CO2 emissions and fuel costs, by using energy-efficient systems and engines. These performance improvements eventually lead those environmentally proactive shipping firms to competitive improvements.

Several key regulatory mechanisms in place may lead those in the maritime industry to adopt ethical and socially responsible practices for protecting the environment and being crucial for GSCM, environmental performance, and competitiveness within the shipping industry. For a sustainable and profitable industry, shipping companies need to implement GSCM effectively and cost expediently and go beyond compliance with environmental regulations by adopting proactive internal and external green practices. The introduction of digitalisation within the maritime industry should make compliance easier to achieve and to monitor. GSCM, which adds value through the socially responsible management of logistics processes, by connecting stakeholders within a corporate structure to promote collaboration and preserve the environment, uphold a crucial role within the industry.

Shipping firms need to collaborate with their supply chain partners to achieve common environmental goals. External green collaboration helps the integration process between internal and external proactive environmental management practices. The main focus of green collaboration among supply chain members is to achieve more proactive and environmentally sound operations that prevent or limit pollution and improve the supply chain's overall green performance. Maritime informatics plays a role in regulatory compliance and monitoring and promoting a proactive GSCM strategy and practices.

## 2.9 Global Data Exchange Standards: The Basis for Future Smart Container Digital Services

Becha et al. (2021), acknowledge the importance of global international standards to support the future of global trade. Particular focus is placed on the United Nations Centre for Trade Facilitation and Electronic Business (UN/CEFACT), promoting smart container solutions. Physical supply chains for shifting goods need a parallel digital supply chain that moves data describing the goods and their progress through the supply chain. As data are the raw material of Maritime Informatics, smart container data flows are key to ensuring that the physical flow is well synchronised with the required documentation flow.

In today's complex intermodal transport markets, it is difficult for any single player to gain total visibility of door-to-door cargo transport activities and the required trade data to answering business questions or making a fully informed operational decision. Also, many supply chain stakeholders are constantly enhancing their processes as they try to reach logistics excellence. Smart containers are an essential building block to meet the emerging requirements for end-to-end supply chains (e.g., Voorspuij and Becha, 2021; Lind et al., 2021b, 2020b). A "smart container" is generally considered to be a marine shipping container; which is fitted with a permanently installed monitoring device.

The smart container solution could be based on various technical pillars:

1. an active smart device fixed on a container;
2. a platform collecting the data, processing it and sharing with the different stakeholders;
3. a catalogue of APIs for easy integration of the physical data; and
4. various wireless communications technologies.

A "smart device" has an embedded set of sensors enabling it to send out near real-time information on such things as location, door opening and closing, vibrations, temperature, humidity, and any measured physical parameters of the surrounding environment of the asset to a data collection centre. These tracking and monitoring devices can also be used to equip other types of assets, such as wagons and trailers. Extra remote sensors could also be added/paired with the main smart device to address a given cargo consignment's specific needs. When smart container trip plans, cargo information, and other information are shared with smart container service providers, smart containers can differentiate business-as-usual conditions during the journey versus out-of-bounds conditions when certain measures exceed the configured thresholds, alerting stakeholders to take action (Becha, 2020b). For example, if a container is sealed before shipping, the smart container solution would alert the stakeholder if a door was opened during a journey. Besides, Smart Container solutions empower supply chain stakeholders to enhance their operations using reliable physical data to provide door-to-door visibility and AI-based predictive services for deriving such things as estimated time of arrival (ETA) at any point along the route of the container. Smart container solutions increase the efficiency, safety, and ecological sustainability of the whole shipping industry.

As leading carriers adopt smart container solutions, they gain valuable data that can be shared with shippers and other supply chain stakeholders. However, generating and collecting data is not enough to make smart container solutions or supply chains "smart.". A smart container solution must deliver data that matters, in a standard format for easy integration into different systems. It must enable unambiguous data interpretation and empower all involved stakeholders with actionable information. Clear semantic standards are essential for effective smart container data exchange, ensuring that all stakeholders understand the same information in the same way. Only then can smart containers truly become part of digital data streams (Lind et al., 2020b; Pigni et al., 2016).

Adoption of global multimodal data exchange standards is a win-win situation since these standards guarantee interoperability. Smart container standardisation effort (Becha, 2020a; Becha, 2020c) is one of many standardisation initiatives (Lind et al., 2020b) supporting global trade. Standards enable stakeholders in the logistics chain to reap the maximum benefits from smart container solutions while enabling them to share data and associated costs. Standards-based data exchange usage increases the ability to collaborate, which in turn increases efficiency. Additionally, such standards reduce development and deployment costs and cut time to market for the Internet of Things (IoT) solution providers. Data exchange standards developed in an open process offer a useful aid to all parties interested in the technical applications and implementation of smart container solutions.

The risks of not developing or not following standards include:

1. Proprietary technologies with significant deployment limitations,
2. Lack of interoperability among systems and devices,
3. Reduced capability for the international validation of technology deployment,
4. Costly and time-consuming integration and
5. Risk of vendor lock-in.

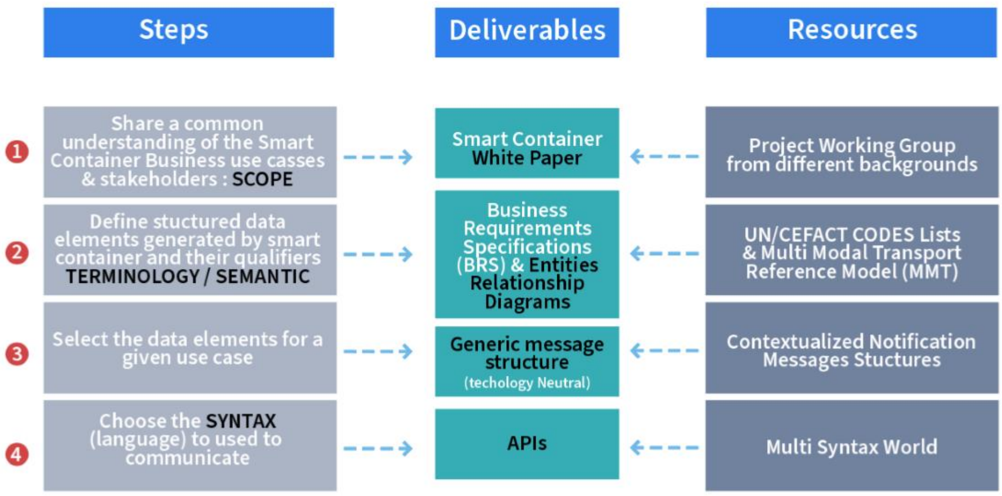
The UN/CEFACT Smart Container project, launched in 2017, has developed the first global, multimodal, Smart Containers data exchange standards, a key accelerator of adopting smart container solutions by the logistic chain stakeholders. The UN/CEFACT data model provides the basis for the Smart Container standard messaging and Application Programming Interfaces (APIs). The standard API definitions are be based on the standardised data elements' semantic descriptions (defined meanings of objects or information) and on a syntactic description, that captures the functional behaviour of API operations.

The UN/CEFACT, Smart container project, has delivered the following:

1. The UNECE "Trade Facilitation White Paper on Real-time Smart Container data for supply chain excellence" where decision-makers in different organisations will find answers to questions such as "What is in it for me?" and "Why should I care?" (UNECE, 2019).
2. UN/CEFACT Smart Container Business Requirements Specification (BRS) ensuring that the various ecosystem actors share a common understanding of smart container benefits by presenting various use cases. (UN/CEFACT, 2019).
3. The smart container data model (UN/CEFACT, 2019) defining the different data elements and their attributes based on the Core Components Library (CCL).

The methodology of the Smart Container project is detailed below in Figure 2.

**Figure 2: UN/CEFACT Smart Container Project Methodology - From data elements to APIs definition**




Source:

Physical supply chains that move goods need a parallel digital supply chain that moves data describing the goods and their progress through the supply chain. The smart container data flows to ensure that the physical flow is well synchronised with the required documents flow. Data are the raw material of Maritime Informatics. Without data streams emanating from operations, there can be no data analytics. As we digitalise, we improve operational productivity and lay the foundation, through Maritime Informatics, for another round of strategic and operational productivity based on big data analytics and machine learning.

## 3. FINAL REMARKS

As the maritime sector becomes more connected, more data streams will surface. They will create more opportunities for empowered decision-making and allow maritime transport stakeholders to become more aligned than they are today. Further, digital collaboration enables the adoption of technologies for sustainable operations, through movements such as in just-in-time shipping and in environmentally sound operations provided by the transition to renewable energy.

Importantly, more and more physical objects, such as the smart container, are becoming digitally connected providing additional situational awareness, both for actors within the maritime ecosystem, such as those within the port, and stakeholders outside the ecosystem (Haraldson et al., 2021).

Such a connected environment also provides opportunities for digital twinning, allowing for advising the maritime manager to make decisions based on the combination of historical data, real-time data streams, and simulations. A digital twin is a generic model of a situation that can be tailored to a specific situation by specifying relevant parameters to provide answers to '*what happens if …*' or '*what happens if this does not …*' to support decision-making (Lind et al., 2020a). As more digital data streams become available, many opportunities are offered for efficient and sustainable maritime operations emerging from empowered decision-making enabled by maritime informatics.

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