Intelligent container terminals - ITS solutions for seaports

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ABSTRACT

Maritime container traffic has been the fastest-growing part of the world transport market for years. Building global supply chains requires the involvement of many actors, both operating within the area of maritime transport as well as hinterlands. Seaports are the focal points of all parties engaged in the transport process, determining their effectiveness. For this reason, dedicated intelligent systems are increasingly used in container terminals to improve their capacity and performance. ITS solutions for seaports should therefore be defined as a four-layer model - port sector, seaport, terminal and cargo/mean level. Obviously, these complex systems need to work together to generate significant synergy effects. For this purpose, it is necessary to use modern technology for identification (RFID, OCR, X-ray), transfer, communication, processing and data sharing. Of importance is that container terminals are also equipped with fully automated transport (AGV) and lifting (ASC) equipment. Therefore, seaports and container terminals demonstrate an interesting example of an intelligent node for the intermodal transport system.

KEYWORDS: seaport, ITS, container terminal, logistics, supply chain

1. Global challenges to the development of seaports

1.1 Maritime container traffic and its importance in the global economy

The globalization process observed in the last two decades, based on the liberalization of world trade, has created a huge demand for transport services. Relocation of the global production of manufactured goods from Europe and North America to Asia (outsourcing & offshoring), as well as a rapid growth of the emerging and developing economies, have increased maritime traffic on the oceans. The crucial technology, suitable for the valuable goods transport, is containerization. So, world container traffic has been growing for years at an average speed of 10%. As a consequence, a total number of about 160 million TEU (20-foot equivalent unit) was transported in the global scale in Year 2012 (approx. 1.5 billion tonnes) [1].

In order to cope with increased transportation volumes and to benefit from the economies of scale, ship owners are continually increasing the capacity of their deep-sea container vessels, recently culminating in the projected 16,000 TEU (CMA CGM's Alexander von Humboldt) or 18,000 TEU (Maersk's Triple-E class) container ship generation. Similarly, the total capacity of the world container vessels reached a level of 17,103 thou. TEU in April 2013 [2].

At the same time, the number of boxes served by seaports reached a level of 426 million TEU all over the world (2012). Operators of seaport container terminals have primarily responded to this development by increasing their terminals in size and making use of more efficient transportation and handling equipment. There are, however, a great number of existing terminals, which have already reached their limits and can no longer expand.

Hence, a new, intelligent solution based on existing infrastructure has been implemented in container terminals as well as in seaports as a whole.

1.2 ITS in maritime transport

According to the European definition, intelligent transport systems (ITS) are an advanced application which, without embodying intelligence as such, aim to provide innovative services relating to

different modes of transport and traffic management by enabling various users to be better informed and make safer, more coordinated and 'smarter' use of their transport network [3]. The above presented attitude refers to road transport (urban areas or high capacity road infrastructure) in majority (see the title of Directive 2010/40/EU). In the case of other modes, the following solutions respond to traffic management systems as identified in Figure 1.
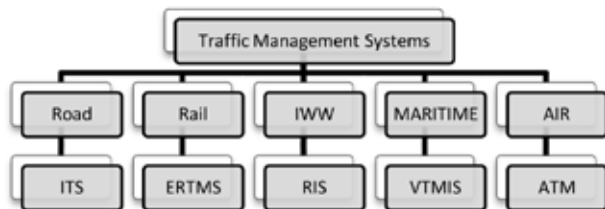

Fig. 1. Modal structure of the European classification of the TMS.

In the maritime transport sector a vessel traffic monitoring and information system (VTMIS) is regarded as a crucial element of ITS [5]. The system consists of such elements as an automatic identification system (AIS), a long range identification and tracking system (LRIT) [6] as well as it being coherent with the SafeSeaNet (SSN) European initiative [7]. Despite the wide range of elements of maritime ITS, seaport solutions are not included in the EU transport policy as a based area of ITS implementation. However, the business practice confirms the common utilization of ICT and telematic systems in seaports and terminals.

A seaport represents a complex system of highly dynamic interactions between various handling, transportation and storage units and incomplete knowledge of future events. As a transport node, a seaport focuses on a number of different means of transport (maritime, road, rail, IWW, pipe), as well as renders a variety of services (stevedoring, handling, forwarding, logistics, etc.) and operates in different dedicated facilities (e.g. bulk, ferry, container terminals; storage areas and warehouses, land and sea infrastructure connections). It should be emphasized that the wide external interconnections between a port and its surroundings need proper coordination and control. The international environment of a port's operation, concerning mostly safety and security issues as well as the border crossing requirements (customs, immigration), is the next crucial step in sharing information and coordination. Seaport development should also take into account the specifics of a port's activity (e.g. ISPS code, regulation of IMO, ISO, ADR).

Growing competitiveness and increased security requirements need to be improved in order for a seaport to be effective. This includes improving the following areas:
- optimization of cargo, ensuring that containers, personnel, ships, trucks, and rail traffic move in and out of ports as efficiently as possible,
- maximization of the mobility and productivity of personnel by enabling them to access data and communicate with each other from any point in the facility,
- monitoring all security issues throughout a seaport by screening its perimeter, as well as containers and other means of transport that enter or leave the facility,

- compliance with governmental regulations and communicate efficiently with the coast guard, customs office and other control services,
- promoting tenants' satisfaction by providing an efficient operating environment and value-added service,
- unification and upgrading the facility's communication system for greater operational efficiency [8].

Special attention should be focused on container terminals where a significant number of boxes is flowing through the facility (see Table 1).

Table 1. Container traffic in the top global, European, Baltic and Polish seaports.

Scale	Seaport	Container traffic
World	Shanghai	32.5 million TEU
Europe	Rotterdam	11.8 million TEU
Baltic	St. Petersburg	2.5 million TEU
Poland	Gdańsk	929 thou. TEU

For this reason, on a terminal level, the following kinds of areas with particular decisions should be supported by dedicated ITS systems [13]:
- operate planning (empty container distribution, storage and stacking policies, crane assignment and split, berth allocation, stowage planning),
- real-time control (landside transport, quayside transport, slot assignment, crane scheduling and operational sequencing).

The last field for improving a seaport's operation is service and management of the means of transport (vehicles, vessels, trains, handling equipment) as well as the cargo units (or passengers). This refers mostly to booking systems and cargo scanning (security seals).

Again, the complexity of a seaport's transport system should be emphasized. Therefore, an intelligent system of planning, coordination and control of a seaport's activities must outline and define the function (or set of functions) and its goal(s). The core of the system should therefore be a database solution interconnected with a dedicated application used in particular fields and levels of a seaport's activity. Last, but not least, it is necessary to integrate various parts and processes occurring in a seaport, its terminals as well as financial, institutional and social environment. Finally, the crucial benefits from implementing the ITS can be presented [14]:
- integration - the ability to combine different technologies, hardware and software in order to obtain a more efficient flow of information,
- flexibility - the ability to create new structural configuration in order to better accommodate the needs,
- efficiency - ability to increase and promote the benefits,
- intelligence - as the ability to make independent decisions in changing circumstances.

2. ITS solution for seaports and container terminals

2.1 ICT and telematic systems in the seaport sector

Utilization of information and communication technology in the transport sector could be investigated on the following levels [15]:
- micro-level: company processes support systems,
- mezzo-level: improving data exchange between the partners/companies/organizations/agencies,
- macro-level: coordination and efficiency improvement of the transport systems.

Table 2. ITS systems used in seaports

Medium	Objective	ITS technology
Freight traceability / security		
Freight	Security Freight quality Dangerous freight	Electronic seals, tampering Temperature, humidity, vibration sensors Electronic identification Fleet management system
Transport mode	Mechanical condition monitoring	Sensors: fuel level, tire status, speed, mechanical alerts
Infrastructure	Monitoring traffic conditions Weather conditions	Traffic management systems Weather stations monitoring rain, fog, precipitation, atmospheric pressure, wind conditions, etc.
Driver	Identification Route conditions Driving times	Automated identification systems Traveller information systems Fleet management systems
Equipment (cranes, trailers, other)	Depending on the type of freight	Automated identification systems
Infrastructure efficiency		
Tolls	Free-flow	Electronic payment
Weight station	Non-stop	Non-stop weighting
Port terminal access	Shorter stops	Automated identification systems
Border crossings, customs procedures	Shorter stops Less paperwork	Automated identification systems One-stop counter Electronic bill of lading
Terminal logistics management	Efficient use of space and resources Reduced operating costs	Terminal operating systems Automated identification systems Automated machine guidance
Inspection	Selective Freight verification	Automated identification system Image processing system
Planning	Reliable information	Freight management system
Operations	Real-time information	Electronic data transmission Port community system
Trade	Electronic	Electronic data transmission Port community systems

In the case of maritime transport and seaports, the development process of ITS systems occurs at each listed level. To be more precise, a list of ITS solutions for seaports is presented in Table 2. Two main challenges to seaports' ITS is freight traceability & security as well as infrastructure efficiency. Similarly, the crucial application/technology can be counted. These are: the port community system, terminal operation system, automated identification system and fleet management system. It should be emphasized that this kind of application is dedicated to a particular seaport terminal, so in multi-terminal seaports (common practice) such kinds of the systems should be multiple as well as integrating. On the other hand, because of competing terminals with highly sensitive business information located directly next to each other, special confidential solutions should be implemented into the system.

2.2 ITS solutions model for seaports

Implementation of telematic solutions and building intelligent systems in seaports strongly affects not only their efficiency, reliability and safety of port operations, but also integration between the ports and their environment. The environment of a port system includes cargo owners, shippers, passengers, and carriers of all modes of external transport available in a port [14]. Because of the wide selection of ICT and telematic systems implemented in seaports, a base model of a seaport's ITS has to be structured. Taking into account the objectives of the system activity, a four-level model can be defined and described (Fig. 2).
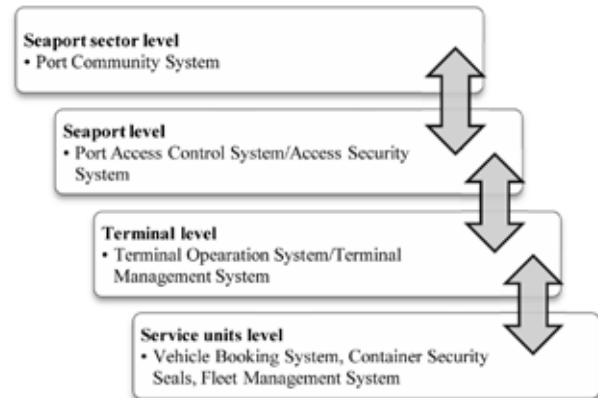

Fig. 2. The layer model of ITS for seaports.

Despite the presented division of the seaports ITS application, interaction between the particular levels is necessary. On the one hand, the higher-rank systems consist of lower-rank systems; on the other hand, the lower-rank systems feed the higher with information [18].

The Port Community System (PCS) is placed at the top of the model. PCS integrates international trade, public agencies and transporters. Such kinds of the systems can be regarded as external ITS solutions. Port Community Systems have played a major role in facilitating a more efficient movement of goods while allowing customs and other governmental agencies to maintain effective control.

The following list of documents can be replaced through the use of PCS: manifests and associated amendments, customs release notes, ship's out-turn/discharge reports and amendments, bonded removal documents (for example, inter port, ICD, CFS, etc.), local transhipment documentation, lines' commercial release, acceptance of rent/storage charges, delivery instructions to transport operators (road/rail), export delivery advice, export arrivals, export load list, loading reports, customs scanning/examination/sealing requirements, port health/quarantine and other governmental departments' activities, requests to out-turn in sheds/warehouses (devanning), shed/warehouse out-turn reports and amendments, customs declarations for exports, ship planning notifications and amendments, dangerous/hazardous goods reporting [19].

The PCS solutions operate in numerous seaports around the world. Examples are listed below [20]:
- *DAKOSY* in Hamburg,
- *PORTNET* in Singapore,
- *INTIS* in Rotterdam,
- *ADEMAR PROTIS*+ in Le Havre,
- *PROTIS* in Marseille,
- *HIT* in Hong Kong,
- *EDI* in Kobe,
- *PACE* in London,
- *ORION* in Charleston,
- *Tradegate ECA* in Sydney,
- *SEAGHA* in Antwerp.

What is important, the PSC systems from the different seaports can be integrated into one solution like in case of the *EurotransPortnet* system (Antwerp, Le Havre, Rotterdam, Bremen/Bremerhaven, Hamburg and Felixstowe) or *EUROMAR* (Marseille, Genoa and Valencia) [21].

The second layer of the model is constituted by access control systems. As they border the seaports, the external - internal nature of the solution could be indicated. Because of the variety of the available application with the different scope of activity, there are a number of system examples: The Port Access Control System (PACS), Gate Operating System (GOS) or Access Security Systems (ASS). The main features of the access systems are as follows [22]:
- data (imaging) collection,
- recognition (e.g. license plate, container number),
- high-resolution damage inspection imaging,
- measurements (cargo units, means of transport),
- access / area control and alarms,
- storing of all vehicle, train, container, trailer and personnel traffic data.

Gate access systems [22] exist in many global, European and Baltic seaports (e.g. Helsinki, HaminaKotka, Cuxhaven, Tallinn, Gioia Tauro, Tilbury).

The next level of ITS in seaports is the Terminal Management System (TMS) or Terminal Operation System (TOS). The system focuses on optimizing maritime freight processes, loading and unloading of ships, and logistics planning, including operations and location, human resources, equipment and warehousing. According to market players, TOS needs to be [23]:

- reliable, built on a dependable technology platform;
- flexible and adaptable so it can be configured to local operating needs;
- scalable so it grows with the needs of the operator;
- seamlessly integrated with other systems and backed by dependable support.

Under a single umbrella of TOS, the following features should be available: EDI, DGPS positioning, activity charging, vessel planning, intermodal rail planning, networked multi-terminal management, resource planning, gatehouse security and vehicle booking [24].

There exists a selection of the TOS systems available on the market. As was mentioned before, TOS systems are dedicated solutions for a terminal (terminal operator), offered by IT companies. Similarly, complete and standard TOS applications are offered (e.g. *COSMOS*, *NAVIS*, *Autostore CTMS*, *MES CTMS*, *Mainsail TMS*).

Last, but not least, elements of ITS are systems prepared for particular and specific issues of items of a seaport's operation. As examples of the leading application, the following solutions can be listed:
- Container Security Seals (CSS),
- Fleet Management System (FMS),
- Vehicle Booking System (VBS),
- Vessel Planning Module (VPM),
- Container Positioning System (CPS).

In practice, all the above mentioned systems are included and coordinated within the TOS system.

3. ITS technology in seaports

3.1 Technology solutions for ITS

ITS solutions for seaport and maritime transport are equipped with common tools and technologies like in other modes of transport. The core element of the system is IT hardware and software with database storage.

The second element of the architecture is communication and information transfer technology and devices. Both wired (e.g. optical fibre) and wireless (Wi-Fi, GSM, GPS) solutions are available.

A very important element of a seaport and maritime transport's ITS system is the Automatic Identification System (AIS) and Automatic Positioning System (APS). In this case, a specific solution has been developed.

On the one hand, AIS can be regarded as an automatic tracking system used on ships and by vessel traffic services (VTS) for identifying and locating vessels by electronically exchanging data with other nearby ships, AIS base stations, and satellites. What is important, the system uses different satellites networks (*Globalstar, Iridium, Inmarsat*) equipped with a special application for maritime traffic monitoring. Thanks to this, proper planning of a seaport's operation can be prepared.

A slightly different sort of automatic identification systems should also be recognized in a seaport area. In this case, utilization of the following technologies is necessary:

- Optical Character Recognition (OCR) - gate systems, container number identification, damage inspection;
- License Plate Recognition (LPR) - special feature and application based on OCR technology;
- Radio Frequency Identification Devices (RFID) - identification of: container, vehicle or storage area;
- ID card system with PIN code readers - drivers, port workers;
- Sensors, X-ray and radiation detection units, biometric devices - cargo scanning and sealing.

3.2. Automated equipment for fully controlled ITS in a container terminal

A special feature of the seaport ITS system, different from other modes of transport, is the automatic seaport equipment in a container terminal. The technology solution for improving the overall productivity of a container terminal and to reduce the berthing times of vessels is to enhance the degree of automation of the handling and transportation equipment. Such attitude is fully coherent with the ITS development in container terminals. Elimination of the drivers or operators increases the reliability of the terminal operation while improving the dependence on ICT. Since a container terminal represents a complex system with various interrelated components, computerized logistics control systems recently gained considerably more attention [25].

Three types of automatic equipment in a container terminal can be listed (Table 3).

Table 3. The range of services of automated terminal equipment

Equipment	Transport	Lifting
AGV	+	-
ALV	+	+
ASC	-	+

The most common solution is the Automated Guided Vehicle (AGV). These types of terminal operations are provided in Hamburg, Rotterdam and Singapore. A vehicle serves container transport between a quay (STS crane) and stackyard [27]. An ITS system, based on the AGV technology system, has to include fleet management and navigation applications as well as control of the AGV fleet [28].

The benefits offered by Automated Guided Vehicles for ports can be elaborated as follows [30]:

- they are cost-efficient and time-efficient,
- they increase the efficiency of the overall processes in a terminal,
- traffic pertaining to the transportation of the cargo internally in the ports is well regulated,
- potential accidents and consequent injuries are reduced substantially because of the absence of human traffic.

Fig. 3. AGV in the HHLA Container Terminal Altenwerder, Hamburg/ Germany (CTA).

Today, the AGV development process is directed towards capacity and flexibility development or increasing the functional scope (ALV). The concept of C-AGV offers a load capacity of 61 tonnes. A vehicle can carry cassettes with double-stacked 40-foot containers or two 20-foot containers in a single tier. Major improvements to manoeuvrability have been made by incorporating individual electrically-driven and steered bogie axles which enable the C-AGVs to be moved in any direction and turn 360 degrees [31]. An Automated Lifting Vehicle (ALV) is another way of AGV development. The vehicle mostly engaged in transport services (horizontal movement) is also fitted with the possibility of lifting a container up from the yard. So far, this kind of equipment is still in its infancy stage.

The second type of terminal equipment is an Automated Stacking Crane (ASC). It performs fully-automated housekeeping and management of container stacks. It also forms the link between quayside and landside equipment such as ship-to-shore cranes, transport vehicles and trucks [32]. The crucial benefits from ASC implementation are defined as follows [33]:

- high stacking density, optimum use of space,
- high working speeds, high handling rates,
- crane and system software, maximum efficiency,
- drive technology that makes efficient use of resources.

Implementation of automatic transport systems in a terminal creates an Automatic Container Terminal (ACT). So, integration of the ITS applications and ACT can radically improve the efficiency and effectiveness of a seaport and make its implementation into the supply chain management process easier.

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