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AI PORT INITIATIVES

- POSSIBLE MODERNIZATION OF PORT OPERATION AND MANAGEMENT THROUGH CUTTING EDGE ICTs -

by

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ABSTRACT

Improving port productivity may be currently one of the most common and prioritized agendas for international container terminal operators. This paper highlights and discusses possible application of modern information and communication technology (ICT) such as the internet of things (IoT), big data and artificial intelligence (AI) to the container port operation and management. An importance of creating a port big data based on the daily operations for fostering AI, as an artificial port manager, is concluded. Difficulties and issues of port communities to invite and include the AI into their daily operations and business practice are also addressed.

1. INTRODUCTION

Port productivity may be one of the key issues for the global container terminal operators, which are competing each other for surviving in the global and regional container trade market. This situation is more and more accelerated by reflecting recent changes in business environment at ports, which are strongly requested by clients to be a more efficient logistics service provider among the global supply chain networks. There is no doubt that the modern world economy fully depends on the global production network and sophisticated supply chain management. Nowadays, materials, parts and components for automotive assembly lines, for example, are gathered across oceans in a regular basis, hence ports, as essential connecting nodes of waterborne and land surface transportation networks, are one of key players of global production activities. In this context, commitment to the extremely sophisticated but complicated and fragile supply chain management requires the port community more time and cost consciousness, with resulting in introduction of recent cutting-edge information and communication technology (ICT) for improving port operation efficiency and productivity. The global port operators are now facing the client’s strong requests to renovate their business practice for providing more quality logistics services with less port charges.

2. APPLICATION OF THE RECENT CUTTING-EDGE ICTS

2.1 Automatization of container port operations

In 2005, Tobishima Container Terminal of Nagoya Port, Japan, commenced its operation, which involves automated guided vehicles (AGV) and remote controlled rubber mounted yard gantry cranes. Toyota Motor Company’s car assembly line technology was applied to the terminal operation system. This was the first challenge to a mechanization and automatization of container terminal in Japan. In those days, there were only few terminals which adopted such a cutting-edge ICT for container terminals, among which the port of Rotterdam was also another icon of automatized container port.

More than ten years later, an automatization of container terminal operation has become a main stream of global mage-container ports. Table 1 highlights global top ten ports and their introduction of

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automation technologies into container terminal operation. Among the top twenty container hub ports, fifteen have had or will soon have at least partially automatized one or more terminals.

Rank	Ports	Container Throughput ('000 TEU)	Automatized terminal operation
1	Shanghai	36,540	**Yes**
2	Singapore	30,920	**Yes**
3	Shenzhen	24,200	No
4	Ningbo - Zhoushan	20,620	No
5	HongKong	20,110	**Yes**
6	Busan	19,450	**Yes**
7	Qingdao	17,510	**Yes**
8	Canton	16,970	No
9	Dubai	15,590	**Yes**
10	Tianjin	14,100	**Yes**
11	Rotterdam	12,240	**Yes**
12	Port Klang	11,890	No
13	Kaohsiung	10,260	**Yes**
14	Antwerp	9,650	**Yes**
15	Dalian	9,450	No
16	Xiamen	9,180	**Yes**
17	Tanjung Pelepas	9,100	**Yes**
18	Hamberg	8,850	**Yes**
19	Los Angels	8,160	**Yes**
20	Long Beach	7,190	**Yes**

Notes: i Container throughputs are statistics in 2015.
ii "Yes" means automatized terminal operation has been introduced or to be introduced soon in some of terminals of the port.

Data: Ports and harbor Bureau, Ministry of Land,Infrastructure, Transport and Tourism, Japan

Table 1: Introduction of automatized terminal operation in the global top 20 ports

2.2 Recent challenges for ICT application at ports

In 2011, the government of Germany launched a new ICT policy, Industry 4.0, which aims at introducing automation and data exchange in manufacturing technologies. It focuses on digitization and interconnection of industries, value chains and business models, which are all likely depend on the recent development of ICTs including cyber-physical systems, Internet of things (IoT), cloud computing and cognitive computing. (EU, 2017) An artificial intelligence (AI) based on deep learning programing, accurate sensor technology and big data is also rapidly attracting a big attention of the world business community. In line with these recent trends, the global port community is gradually going to step in the more ICT based and client oriented port operation and management.

An example of the ICT driven operation and management in the port sub-sector may be the smart-PORT logistics (SPL) concept initiated by the port of Hamburg, Germany, which includes IT based traffic management system and real time information transmission on the port traffic and infrastructure situation along with the demand-oriented networking via a central public cloud. While the services have been just started after several years pilot phase, the SPL is considered a pioneer to pave the way of dramatically changing the future port operation scene.

It has become a common business environment for shipping lines, terminal operators, shipping agencies, forwarders and other port service entities to be connect each other for providing more efficient and speedy port logistics services and trade processing. Challenges were mainly undertaken by shipping lines, among which Nippon Yusen Co. Ltd., for example, has initiated to build up new ship operation and management information system by connecting ship navigation and landside arrangement information through IoT technique. These challenges strongly request port administration offices, terminal operators and other port logistics service providers to prepare integrated and seamless data and information exchange and processing system for more smoothly sharing shipside information among port business colony with less cost and time consuming manners.

Considering the above mentioned global trend of creating more smart and competitive port operation and management, the government of Japan have decided to launch, as a part of its recent port policy reforms, a new ICT based port concept, namely “AI terminal initiatives”, for improving port operation productivity and port traffic traceability through employing AI for port terminal operation system configuration. The new terminal system is expected to enable AI independently to operate container yard cranes for minimizing crane movements. AI controlled terminal operation system is also expected to manage container dray traffic at port for realizing quick container check-in and release.

3. POSSIBLE ICT-DRIVEN PORT MANAGEMENT AND OPERATION

3.1 Port traffic and big data generation

Daily operations of port terminals involve a variety of administration, management and business oriented information in association with ship accommodation, trade processing, cargo handling, storage and delivery, taxation, quarantine clearance, port facility management, border control and cargo dray. The information is essential for daily port logistics activities, therefore, are generated day and night at port, and transmitted from/to port. Figure 1 schematically illustrates, by showing an example of container importation, the system of port logistics administration and business flow, which generates a variety of related data and information.

When container ship arrives at port, the ship and maritime information are transmitted to the port authority, CIQ offices, container terminal operator and marine service providers by ship itself or through shipping agent for their processing ship arrival and departure, customs clearance, quarantine inspection, and other commodity importation and delivery related procedures. In modern ports, shipping lines, port authority and terminal operators are generally equipped information and data processing systems for implementing these procedures. These systems are, however, not necessary well linked each other. Some of data and information are automatically duplicated and transmitted, but many are still to be manually fed and transmitted among these systems for storing and processing. Furthermore, the parties involved are not always cooperative to mutually being connected, because of their own tradition, practices and business secret. As such, there are long continued many difficulties to develop a common architecture to share business data and information among the port business colony.

On the other hand, modern container terminals are mostly under tough port competition, therefore, the terminal operators are normally keen on improving terminal competitiveness including berth window efficiency, and terminal yard and dray productivities. Reducing terminal lead time and check-in gate waiting time is also big concerns extended by consignees. Border control for preventing terrorism and intrusion of alien species is among basic requirements in the modern port terminals.

The above mentioned policy agenda for creating more effective, efficient and secured terminal may be common issues in modern ports, thus needs to be addressed accordingly. In this context, building properly designed data and information exchange and processing platform is considered of a great importance for all port terminals to survive the global container port competitions.

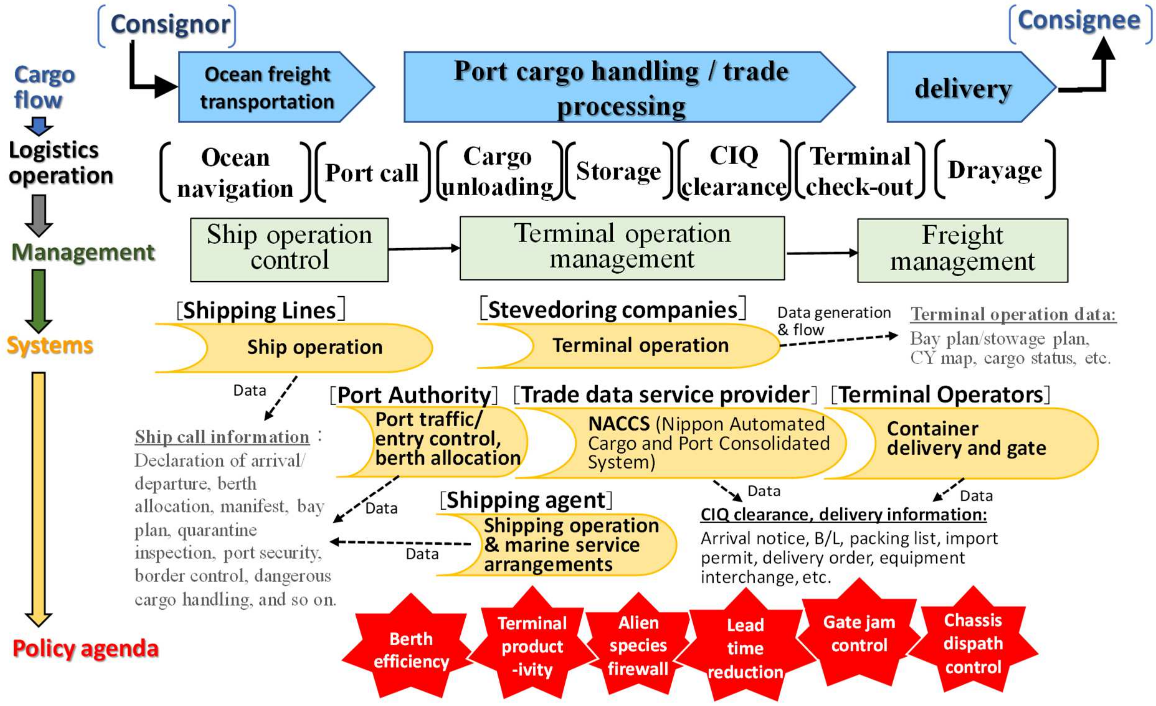


Figure 1: Typical port procedures, and involved data and information processing
（An example of import containers）

3.2 Possible solutions for the port policy issues by adopting cutting-edge ICTs

Among key elements for building the data and information exchange and processing platform as referred in Section 3.1, big data is rapidly attracting an attention of port and shipping sub-sector community. Big data is defined as data set with a size beyond the ability of commonly used software tools to capture, curate, manage, and process within a tolerable elapsed time. (Snijders et al., 2012) An appearance of AI supported by deep learning programing has dramatically increased a significance of big data. Now big data is strongly believed to have an unlimited potential as a gold mine of AI driven economic and social developments.

Introducing IoT techniques into container terminal operations enables port terminal operators and other port related entities to collect, process and store a bulky digitalized data from daily terminal operations on 24 hours and 365 days per year basis without no terminal staff intervention. Rapidly improving sensor technologies, in combination with IoT, are another development for creating port big data in an effective and efficient manner.

Artificial Intelligence (AI) is also expected to become a newly emerging player of port operation and management. AI will learn port operation skills and practices by analyzing the big data. Deep learning is a recently highlighted programing technique for realizing more efficient and effective AI controlled operation and management capacity, which will assist the terminal staff in all over daily operations and management works. For example, AI will provide terminal planners with an indicative optimum solution and best practices including best stowage and yard plans for assisting prompt decision making based on the past experiences included in the big data. It may enable terminal operators to undertake quick control and processing of container cargo traffic in the fully automatized container terminal yard.

Table 2 identifies possible innovations in the area of port operation by mobilizing cutting-edge ICT. Targeted terminal operation innovations and results of ICT applications are discussed and summarized. Challenges currently being and to be undertaken by the Japanese ports are also shown on the table.

As a sensor technology for generating port big data, image analysis techniques, global positioning system (GPS) and automatic identification system of ships (AIS) are identified as well as traditional electric and mechanical sensor systems. Progress in these sensor technology is considered an epoch making event for facilitating recently observed rapid development of port business data digitalization.

Cutting edge ICT		Terminal operation Innovation	ICT Applications	Current challenges
Sensor tech -noligy	Image analysis	Digitalizing all date and information generated by movements of things and persons within terminals.	• Generating cargo status digital data based on motion picture and still image of the yard operation scene. • Identification of freak incident in container yard through monitoring camera. • Monitoring gate check-in queue	➢ Automatic detection of container and vehicle identification numbers. ➢ Automatic container damage check.
	GPS /AIS		• Monitoring port traffic, ship arrivals, berth window situation, location and traffic lines of cranes and yard chesses .	➢ Berth window control based on AIS data.
	Others		• Detecting alien species in container. (odor sensor, thermal sensor, etc.)	N.A
IoT		Automatically collecting, storing and shearing digital date of generated, input or transferred in terminals without any manual control. (Port Big Data)	• Creating Port Big Data by automatically collecting: i) ship data, terminal operation data, trade data and CIQ clearance data, and ii) digital data and image data generated by sensors equipped in terminal.	➢ Quay crane data collection through IoT for mobilizing to undertake facility maintenance and life cycle management. ➢ Delivery of check-in waiting time and cargo clearance information.
AI		Implementing highly complex analysis and decision making based on the port Big Data.	• Automatically applying CIQ clearances, documenting delivery order, and informing cargo status at port. • Assisting in: i) controlling cranes, ii) preparing optimal stowage and bay plans, and iii) managing berth window. • Controlling automatic operation of yard cranes, including safety management. • Predicting container release time and check-in waiting times.	➢ AI driven yard crane semi-automatic remote control operation. ➢ Preparation of optimal stowage plan for minimizing container yard marshalling works.
Automatic Vehicle operation technique.		Undersupply of port workers incl. crane operator and truck driver.	• Vehicle platooning for container delivery.	N.A

Table 2: Possible innovations of port operation by mobilizing cutting-edge ICTs

3.3 Examples of big data application at port: AIS data

As stated in this paper, generating big data is probably one of the most important elements of AI controlled port operation and management. Then, what does the big data in ports look like? The authors consider that AIS (Automated Identification System) may provide one of most up-dated examples of viable big data application in the area of port and navigation cannel planning, design, operation and management, thus demonstrate it in this section.

AIS is an automatic tracking system used on ships. AIS was initially introduced to improve navigation safety, and to increase search and rescue capacity for ships. AIS integrates a standardized VHF transceiver with a GPS positioning system, with other electronic navigation sensors such as a gyrocompass or rate of turn indicator. AIS equipped ships can be tracked by AIS base stations located along coast lines or, when out of range of terrestrial networks, through satellites. The International Maritime Organization's International Convention for the Safety of Life at Sea (IMO SOLAS Convention) requires AIS to be equipped for international navigation ships with 300 or more gross tonnage, and all passenger ships regardless of the size.

While AIS information including unique identification, position, course, and speed of ships originally intends to assist the watch standing officers in avoiding ship collision, it is recently found useful for maritime authorities and port operators to track and monitor ship movements, and to identify suspicious ships.

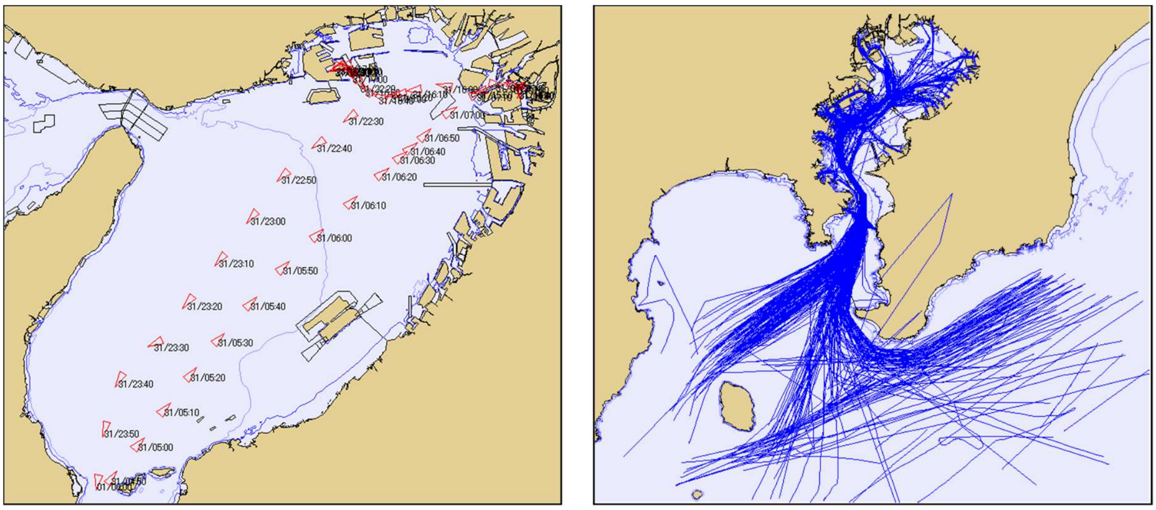


Figure 2: Track chart created based on AIS data

A figure in the left-hand side shows a ship track which entered ports of Osaka and Kobe. At 4: 50 in the early morning, the ship passed the mouth of Osaka bay and it arrived at offshore Osaka port at 7:00. In the afternoon of the day, the ship transferred to the port of Kobe and departed the port at 22:00 at night. By superimposing these track charts of ships, the right figure visualizes navigation situation in Tokyo Bay, where intensive traffic control is essential for ship security and navigation safety, and maintaining port logistics capability. (Takahashi et al., 2007)

Figure 3 demonstrates possible visualization of ship turnaround and berthing at Hirara ports, Okinawa, Japan. The figure provides information of detailed ship movement in the port waters therefore, port engineers, for instance, can easily identify an actually used water area by the ship.

In the quay side, AIS based data identifies an exact location of GPS antenna which shows location of ship berthing. As such, AIS-based big data is currently being expected to assist in more detailed and sophisticated planning and designing works. AIS data also enables us to visualize an actual berth window situation as a chart shown in Figure 4.

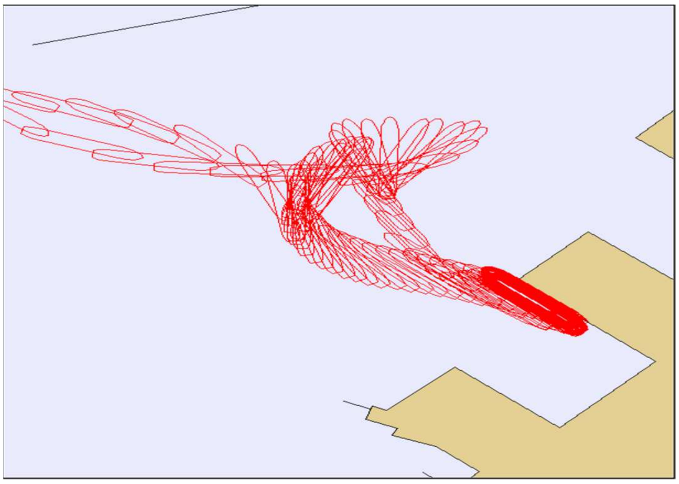
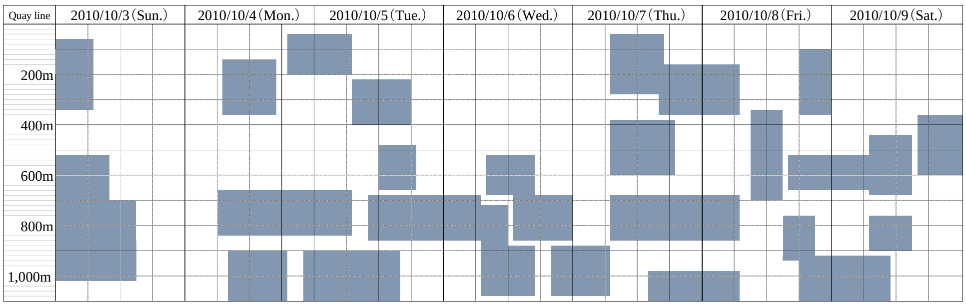
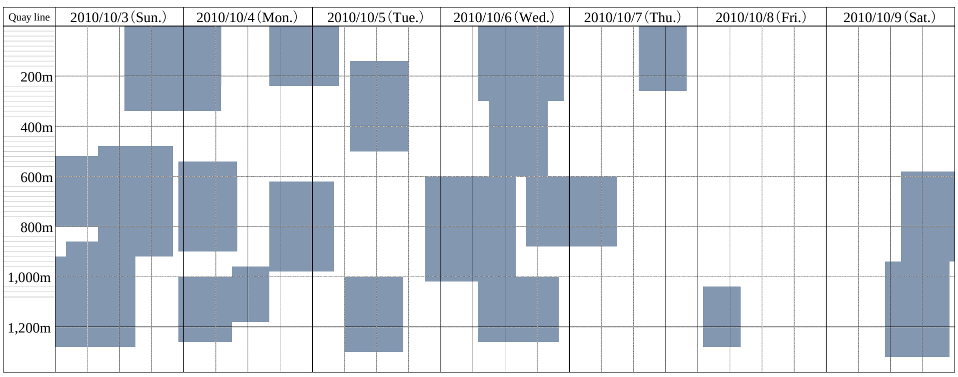


Figure 3: Visualization of ship turnaround and berthing

Figure 4 visualizes berth windows of Dream Island International Container Terminal (DICT), Osaka, Japan and Kwai Chung CT 8 (CT8), Hong Kong, China. Terrestrial AIS data of one week period from 3th to 9th October 2010 was used by Akakura et al. (2012) for preparing the berth window charts. DICT has a quay length of 1,100 meters and annual throughput of about 2 million TEUs, and CT 8; 1380 meters and 4 million TEUs.



Dream Island International Container Terminal, Osaka, Japan (Oct. 3-9, 2010)



Kwai Chung CT 8, Hong Kong, China (Oct. 3-9, 2010)

Figure 4: Berth window charts drawn based on AIS data

Berth window chart looks like a table with time line in the horizontal axis and occupied quay line in the vertical axis. Occupied berth window is defined as product of occupied quay length and occupied time period by ships, which is shown in the chart in figure 4 as light gray areas. It is noted that DICT has a space for accommodating more ships on Wednesday, and CT8; from Thursday afternoon to Saturday morning. Controlling berth windows may be one of the most important operations for the port terminals to increase in berth utilization, therefore, to obtain more incomes. Visualizing berth window charts may become a powerful tool for terminal operators to improve berth widow productivity.

4. AI PORT CHALLENGES

4.1 Possible system configuration

As discussed in Section 3.2, the ICT based management and operation system at ports are considered notably promising to provide with attractive solutions for the currently requested port policy agenda. There are many possibilities to dramatically increase terminal operation efficiency and competitiveness, contribute to the global logistics innovation, and improve business profitability and working environment at ports. AI will play a key role for the overall port operation and management through accurate and tireless data processing and analysis, self-sustained judgments and recommendations, and appropriate communications. Figure 5 illustrates a schematic view of AI-led terminal operation and management system.

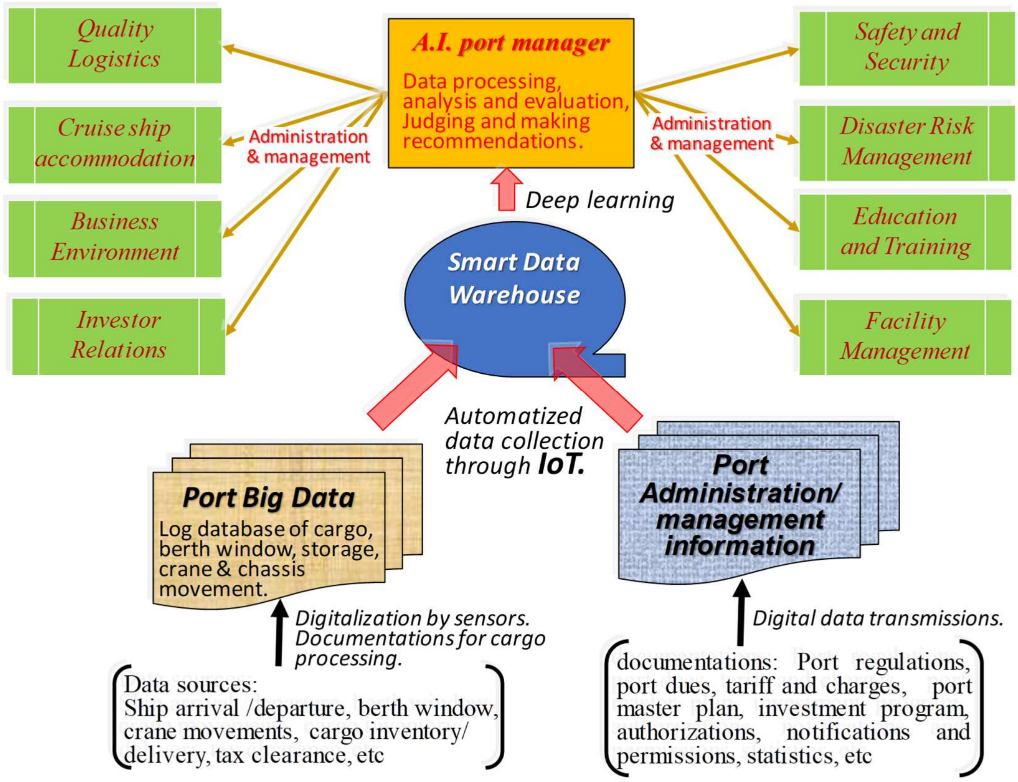


Figure 5: Basic configuration of AI-led port system

For cultivating terminal operation and management AI by mobilizing deep learning programming technique, big data creation is an essential and vital challenges.

As discussed in Section 3.1, possible sources of port big data should be a daily port operations and management procedures such as ship operation, port traffic control, terminal operation, cargo storage/delivery, and check-in/out gate control. From these procedures and operations, a bulky data is generated in terms of arrived ship specifications, arrival and departure details, berth window situation, quay and yard crane movements, cargo location and inventory, consignee/consigner information, delivery time and final destination, tax clearance status, quarantine inspection, safety, security and environment protection information, and any other notifications, authorizations and permissions. Some of these data and information are transmitted from outside port, and others are directly typed in or digitalized through sensors embedded in the terminal facilities and equipment. Smart data warehouse have a function of collecting and storing these data and information in a fully digitalized form. As such, properly employing IoT coupled with sensor technologies will be a key skill for automatically digitalize, glean, process and store the balky port operation related information, which is generated from daily port activities in 24 hours and 365 days basis.

Another important information sources for AI as a port manager may be port statistics and administration and management related documentations which include rules and regulations, port dues, tariff and charges, port master plan and investment program, and authorizations, notifications and permissions of port traffic. Availability of these information directly affect to the quality of port business practice and environment, thus, profitability of the port. In this context, the information must be also digitalized and stored in the data warehouse for contribution of AI to support port administration, operations and businesses.

4.2 Challenges

The above mentioned AI led port operations and management are still on the way of technical development and institutional arrangement.

Major challenges however may include: i) smooth introduction of the newest sensor technologies for efficiently and effectively collecting all terminal operation related information as digitalized data, ii) materializing an accurate big data transmission between on-site sensors and the terminal control host computer through IoT channels, iii) developing man-machine interface for assisting operator’s prompt decision making, iv) renovating current terminal operating system by employing AI based architecture, and v) introducing appropriate countermeasures against computer virus and hacking. A variety of deep learning software including many open software is currently available. Mobilizing these existing software resources may save the project time and cost, and enable to input more human and financial resources for developing AI loaded terminal operation system. Most advanced sensor technologies such as image processing techniques also may contribute, as eyes of AI, to the system development.

Legal and social aspects of current port systems will be also requested to make necessary adjustment for adopting these ICT-led port operation and management reforms. Particular issues to be address may include: i) increase in a vulnerability of port logistics in association with employing highly sophisticated ICT for port operation and management system, ii) ambiguity of legal responsibility for the third party liability at the AI controlled port, and iii) infringement of information ownership in association with creating big data. AI port manager may have a big operation and management capability much beyond human capacity, but is not the Omnipotent. Once AI port manager lose its function due to natural or human made disasters, it may not easy humanly to recover it. When AI port manager make a misjudgment or has a serious malfunction resulting in causing damages or violating rights of the third party, who supposedly will take a responsibility for it?

It must be carefully consider and discuss how is the best course to invite AI into our ports as a good partner. The port community are not always welcome to build a robot port. What needed in a practical viewpoint may be how to create a well-designed human-AI collaborative system for making our port operation and management smart. AI controlled terminal may be a common business interest of the port community and also a common challenge, therefore to be discussed globally. Some of the cutting edge technologies are just waiting for the application at ports.

5. CONCLUSIONS

This paper was prepared for inviting an attention of conference attendees to the recently developed cutting-edge ICT, in particular artificial intelligence (AI), Internet of things (IoT) and big data at ports, in the context of possible application to the port operation and management.

Considering continuously intensifying international port competition and recent diversification of port uses, global mainstream ports have started their consideration of further involvement of cutting-edge ICT into the port operation and management. Remarkable development of sensor technologies, coupled with IoT, has been enabling us to create a big data at port, which may lead to employment of AI at port. Actually some of global ports have already been tackling to introduce AI, IoT and big data into their ports. On the other hand, inviting cutting-edge ICT to the ports may raise many issues and new challenges from technological, legal and social aspects. In this context, starting discussion about this emerging agenda, and sharing data and information among PIANC community will surely benefit not only the conference attendees but also the whole member port community as well. The authors are pleased to have this opportunity of 34th PIANC world Conference to raise this hot topic for our PIANC colleagues.

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