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CONSTRUCTION AND PERFORMANCE ESTIMATION OF SHARING-BASED VIRTUALIZATION LOGISTICS SYSTEM

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Abstract. *An improvement in port logistics systems is required for the Fourth Industrial Revolution. To satisfy this need, much effort is being invested in developing technologies to improve the performance and increase the efficiency of port logistics systems. The goal of this study is to construct a sharing-based port logistics system and virtualization port and to integrate cloud systems and big-data technology to estimate performance through analysis. Improvement in the overall efficiency and stability of ports is anticipated, because the constructed port logistics system enhances the overall efficiency of port logistics, and the simulation model can estimate the performance of port logistics systems by verifying the stability and efficiency of logistics systems.*

Keywords: Sharing system, Port logistics, Logistics, Design & simulation

1. **Introduction.** The Port of Busan is a major port of Korea with an annual container-processing volume of more than 20 million twenty-foot equivalent units (TEUs), which is the sixth largest in the world. The cargo throughput of the Port of Busan is increasing by 2%-3% every year, so the port is under consistent development [1]. Because construction of the Busan Newport is planned, construction of a logistics system and estimation of the facility scale for harbor productivity is needed. While many of the major ports in the world are striving to construct a smart harbor using technologies of the Fourth Industrial Revolution, including blockchains, the Internet of things (IoT), and clouds, there is insufficient support for the Port of Busan [1]. The container throughput of the Port of Busan in 2018 was 21.66 million TEUs, and the expected throughput for 2019 is approximately 22.50 million TEUs. The throughput is expected to increase by 2%-3% every year. However, the yard occupancy ratio of the Port of Busan exceeds the proper value of 60%, and overcrowding is observed frequently when the occupancy ratio increases to 80%-90% temporarily, causing congestion of the entire port. To address this issue, a virtualization port for performance estimation needs to be designed to improve the current logistics system of the Port of Busan and estimate the facility and proper scale of the Newport [2-4]. This study presents a sharing-based logistics system. A virtualization port was constructed based on current facilities in the Port of Busan, and its performance was evaluated. Improvements are suggested and analyzed from the evaluation results to propose a performance estimation method for the Newport. This study presents a sharing-based logistics system. A virtualization port was constructed based on current facilities in the Port of Busan, and its performance was evaluated. Improvements are suggested and analyzed from the evaluation results to propose a performance estimation method for the Newport [5]. The shared-based virtualized logistics system improves the existing port logistics system so that Port-MIS, terminal operation system (TOS), and stakeholders can use the cloud system to resolve delays in information sharing in Figure

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1. In addition, the purpose of the project is to construct an appropriate port through assessment of facilities and equipment by drawing and analyzing the results through data related to the port using a CHESSCON simulation program for performance evaluation [6]. In Figure 1, information exchange by electronic data interchange causes information delay in the case of delayed information processing, and it ultimately leads to a delay in the overall logistics flow.

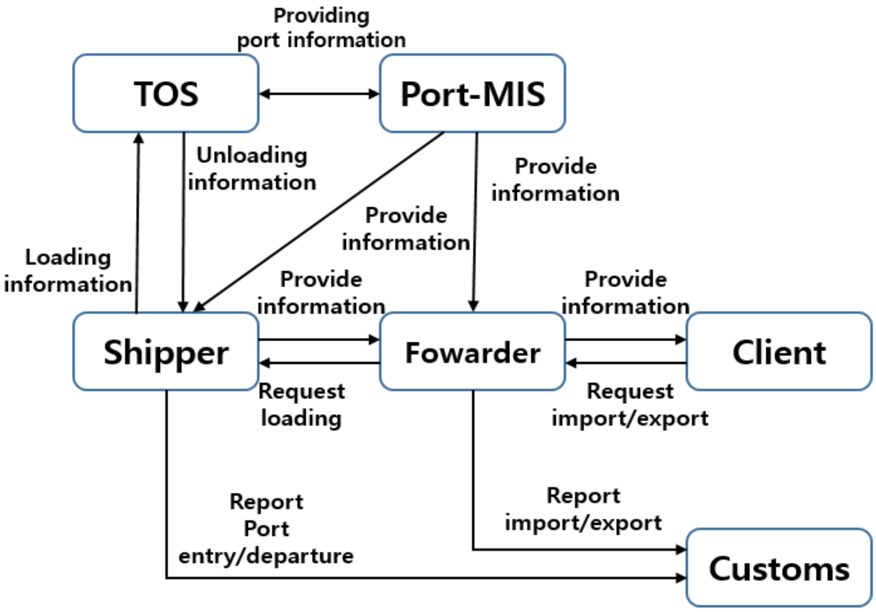

Figure 1. Operation process for export and import logistics system

2. Sharing-Based Logistics System.

2.1. Logistics system process. In the existing port logistics system for the Port of Busan, all data for cargo processed in the port, including gate pass, yard storage, transfer and vessel loading, is collected and processed through the terminal operation system (TOS). PORT-MIS, a shipping and port logistics information system, collects and discloses integrated information about the port. However, the current logistics system shows its limits in real-time information sharing by multiple users. Information exchange by electronic data interchange causes information delay in the case of delayed information processing, and it ultimately leads to a delay in the overall logistics flow. A prior study to improve the logistics system is presented in various forms, which noted the globalization of port operations and the expansion of the scope of business, arguing that cooperation in port competition can serve as a strategic option in port industry development through the analysis of joint works between Hong Kong and South China ports [7]. Analysis of the case of port co-operation and integration in China paper suggests improvements in the port logistics system through cooperation and integration among ports in China [7]. SEO proposed improvements to the operating system through the study on operating system implementation to the competitiveness of busan port paper by preparing valuation criteria for integration, preparing roadmaps for integration timing, participation of BPA, and setting scope and role [8]. The advanced study mainly presents improvements in the logistics and operating system through integration and cooperation, and in this paper, the focus is on enhancing efficiency through improvement of sharing and verification of simulation, not through conventional methods.

2.2. **Concept of sharing (cloud) and sharing-based logistics system.** A cloud stores countless data and moves them to multiple terminal environments, acting similar to a cloud. It is a system in which tasks are shared among smart devices and PCs independent of time and place. As files are saved to and loaded from a datacenter server storing big data without using a separate storage medium, software for data management can be conveniently installed on servers instead of installing it separately in devices or PCs. The availability of simultaneous storage and sharing in conventional storage media and cloud servers in a cloud prevents possible data loss, and it can be applied to various industries. Constructing the sharing-based logistics system illustrated in Figure 2 makes use by multiple users possible with real-time information transfer and sharing and improves information flow by allowing real-time information sharing and processing, all leading to a better logistics system overall. Port efficiency can be increased with a fusion of cloud and big-data technology, and identifying issues by storing and analyzing integrative container and task information processed in a port makes it possible to establish an improved port operation plan including savings in vessel waiting time, crane rearrangement, and vehicle rescheduling. Information generated at the port is backed up in real time for increased stability, and operation consistency is secured and damage is minimized with swift recovery in the case of a disaster or an accident [9,10].

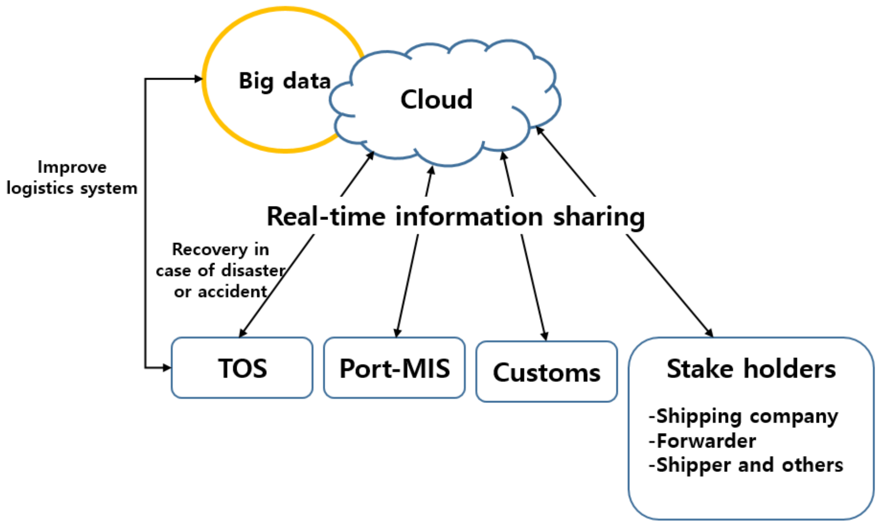

FIGURE 2. Cloud-based port logistics system

3. Construction and Operation of Virtualization Logistics System.

3.1. Concept and application of virtualization logistics system.

1) Concept of virtualization logistics system. "Virtualization system" is a term with a wide range of use referring to abstraction in a computing system, and it means constructing a virtualization layer between the user and system resources to simplify access to computing resources and infrastructure management. The technology integrates different systems into a single logical system or divides a single physical system into many logical systems. A preliminary investigation can minimize post-design errors in task, facility, etc. Virtualization systems can be applied to various fields, and, in this study, a simulation model is designed to estimate the facility and proper scale of the Newport. A port design simulation program is used to construct a virtualization port, issues are analyzed through resultant values, and a proper scale is estimated for application to the Newport.

2) Application of virtual logistics system. A simulation model was designed using CHESSCON, a simulation program specialized for ports, result values were derived by inputting data and input-output data, and experiments were conducted for different StSCs

and expected throughputs. Layout data become the first input data as the data input uses CHESSCON capacity, and yard classification, berth length, and water depth are configured. The names for yard types are Full, Empty, DG, PG, and PTI, which respectively refer to loaded container yard, empty container yard, dangerous-goods container yard, yard for plant quarantine, and yard for pretrip inspection before export of refrigerated or freezer containers. The total berth length was set to 1050m with three berths of 350m each, and all berths have the same water depth of 18m, so that a 20,000 TEU vessel can be berthed. These values are listed in Table 1. Input data associated with containers are set in Table 2, with ratios in each category.

Table 3 lists vessel-related data. Vessel scale was estimated separately for Jumbo, Medium, and Feeder types based on the maximum container loading volume, independent of vessel dimensions. StSC is a quay crane used when loading to and discharging from vessels. The processing capacity of StSCs is configured in units of boxes regardless of their TEUs with minimum value ranging from 28 to 32 box/h. The number of StSCs for a vessel can be set to a value from 1 to 5, depending on vessel scale.

Table 1. Layout input data

Item	Value
Yard scale	- Full: 39,754 TEU - Empty: 16,584 TEU - DG: 1,204 TEU - PQ: 144 TEU - PTI: 234 TEU
Berth length	- 350m × 3 berths
Berth depth	- 18m

Table 2. Container input data

Item	Value
Ratio of import and export versus transshipment	- Deepsea shipping: 48.5% - Transshipment: 48.5% - Shortsea: 3%
Ratio for each container type	- Full: 68.57% - Empty: 28.71% - DG: 2.08% - PQ: 0.24% - PTI: 0.4%
Ratio for each container size	Size 1 (20ft): 44.6% Size 2 (40ft): 55% Size 3 (45ft): 0.3%

Table 3. CHESSCON capacity simulation input/output data

Item	Vessel type	Data
Vessel scale	Jumbo	7,000 TEU $\sim$ 20,000 TEU
	Medium	1,000 TEU $\sim$ 7,000 TEU
	Feeder	400 TEU $\sim$ 1,000 TEU
StSC processing capacity	28 box/h $\sim$ 32 box/h	
Number of StSCs per vessel	Jumbo	$3 \sim 5$
	Medium	$2 \sim 4$
	Feeder	$1 \sim 3$

The mean stack period on yard was subdivided into export, import, and transshipment days based on the mean stack period of the Port of Busan. Empty was set as a criterion in Table 4, because there are no yard distinctions between Empty, DG, PQ, and PTI.

Table 4. Mean stack period of containers

Item	Export (day)	Import (day)	Transshipment (day)
Full	3.7 ~ 9.6	6.2 ~ 10.3	2.4 ~ 5.8
Empty	1.2 ~ 21.1	5.2 ~ 19.6	3.5 ~ 10.2
DG	1.2 ~ 21.1	5.2 ~ 19.6	3.5 ~ 10.2
PQ	1.2 ~ 21.1	5.2 ~ 19.6	3.5 ~ 10.2
PTI	1.2 ~ 21.1	5.2 ~ 19.6	3.5 ~ 10.2

3.2. **Construction and analysis of virtualization logistics system.**

1) Construction of virtualization logistics system. We used a system for construction of virtualization logistics system which is a CHESSCON layout design for the construction of simulation. The layout design needs to be completed before simulation is performed, and port limits, yard scale, berth length, and water depth were configured using the data in Table 1. The variables used in the simulation experiment, which are the number of StSCs and expected throughput, are listed in Table 5. Twenty different simulations for one year were tested 10 times each.

Table 5. CHESSCON capacity simulation experiment

Manipulation variables	Cases
Number of StSCs	4 cases (8, 9, 10, 11)
Expected throughput (Unit: million TEUs)	5 cases (1.7, 1.75, 1.8, 1.85, 1.9)

2) Analysis of virtualization logistics system. The occupancy ratio with additional StSCs and the mean occupancy ratio of the yard were measured and analyzed through a simulation in this study. The duty cycle of StSCs declines when its number exceeds a certain value for the given berths, and the proper number in terms of cost and efficiency was estimated when estimating the proper logistics system. The processing ratios for different expected throughput and number of StSCs are listed in Table 6. Case 4 had the highest processing ratio when the expected throughput was 1.7, 1.75, or 1.9 TEUs, and Case 3 had the highest processing ratio when the expected throughput was 1.8 or 1.85 TEUs.

Table 6. Processing ratio of expected throughput for different number of StSCs

Expected throughput/number of StSC	Case 1 (8 StSCs)	Case 2 (9 StSCs)	Case 3 (10 StSCs)	Case 4 (11 StSCs)
1.7 million TEUs	96.49%	99.23%	99.32%	99.41%
1.75 million TEUs	96.07%	98.81%	99.05%	99.41%
1.8 million TEUs	95.53%	98.6%	99.27%	99.22%
1.85 million TEUs	95.46%	98.16%	99.12%	99.06%
1.9 million TEUs	94.11%	97.41%	98.28%	98.95%

We show the ratio of the added StSC upon its deployment. The duty cycle of the nth StSC was estimated when one StSC was added to $(n-1)$ to make a total number of n. The mean duty cycle of the ninth StSC was 9.43% when it was added. In contrast, the 11th StSC showed a mean duty cycle of 0.83% when it was added. Table 7 summarizes the mean occupancy ratio of the yard for differing throughput represented as the number of StSC, with a margin of error of ±0.51%. The proper mean occupancy ratio for a yard is 60%, and the scale of Full yard was larger than needed, with minimum and maximum occupancy ratios of 37.40%∼41.48%, whereas the scales of Empty, DG, PQ, and PTI yards were smaller than needed as the ratio exceeded 60%. From the simulation result, it was concluded that efficiency decreases abruptly when the number of StSCs in the three berths exceeds 10, and the port can process up to 1.9 million TEUs of throughput with no difficulty. However, the scale of the Empty, DG, PQ, and PTI yards needs to be expanded while reducing the scale of the Full yard, because there are large discrepancies in yard occupancy ratio.

Table 7. Mean yard occupancy ratio for different throughputs

Items	Full	Empty	DG	PQ	PTI
1.7 million TEUs	37.40%	69.29%	69.08%	66.94%	68.56%
1.75 million TEUs	38.58%	71.49%	71.22%	69.28%	70.74%
1.8 million TEUs	39.53%	63.29%	73.11%	70.90%	72.58%
1.85 million TEUs	40.86%	75.80%	75.54%	73.41%	75.21%
1.9 million TEUs	41.48%	77.01%	76.72%	74.30%	76.23%

4. **Conclusion.** Ports are important facilities, serving 99.7% of Korea's exports and imports. Improvement of port logistics systems is necessary considering the large amount of value they create and the advent of the Fourth Industrial Revolution. A sharing-based port logistics system increases the efficiency of a port and improves the overall process in a port by reforming the existing system. Preliminary performance estimation is possible before port construction when improving the port logistics system with CHESSCON, reducing errors in actual port design. A simulation model using CHESSCON was constructed in this study, and the performance of the existing logistics system was estimated, enabling an estimation of a port logistics system for ports to be constructed in the future. Assuming a random vessel schedule resulted in a processing ratio of expected throughput lower than 100%, which is a limitation of this study. A schedule-sensitive operation plan is established in an actual port, and failure of vessel entry does not happen. An accurate quantitative estimation also becomes difficult, because each port has a different mean stack period. It is planned to construct a simulation model using the actual data from each port in a future study and to analyze it to improve the efficiency of port logistics systems. Issues of existing systems will be identified and corrected, and improvements in yard occupancy ratio and the efficiency of each equipment and establishment of an operation plan for actual ports will be of interest in the study.

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