THE OPERATIONAL SYSTEM OF CONTAINER LOADING-UNLOADING IN JAKARTA INTERNATIONAL CONTAINER TERMINAL AND PORT OF LAMONG BAY SURABAYA

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Abstract

Indonesia is a maritime country since approximately 67% of its area is ocean and has the 2nd longest coastline worldwide. In fact, its maritime facilities aren't well operated, therefore Indonesia has to improve its operational system to increase the efficiency. This study would provide an approach of analyzing operational system design of container loading-unloading in JICT and TTL, land transportation proposed system combined with magnetic technology used by the ports, and its economical and technical impacts of this maritime infrastructure. To achieve the goal, study of literature, qualitative and quantitative analysis will be the proper method to use. The system proposed in this study is 69-83% faster with its operational cost is 24-40% cheaper compared to JICT and TTL. Moreover, this system is environmental-friendly and will work safer. Overall, it is expected that this system will provide broad insight as well as a consideration for the use at Indonesian ports.

Keywords: Indonesia, ports, magnetic technology, maritime infrastructure, operational system design of container loading-unloading

Abstrak

Indonesia dikenal sebagai negara maritim sejak sekitar 67% wilayah negara Indonesia adalah laut dan memiliki garis pantai terpanjang ke-2 di dunia. Faktanya, fasilitas maritim di Indonesia belum cukup optimal sehingga membutuhkan perbaikan sistem operasional untuk meningkatkan efisiensi kegiatan bongkar-muat kontainer. Penelitian ini akan memberikan pendekatan analisis potensi desain sistem operasional bongkar-muat kontainer di pelabuhan dengan studi kasus JICT dan TTL, sistem transportasi darat usulan yang dikombinasikan dengan teknologi magnetik dalam terminal pelabuhan, serta dampak ekonomis dan teknis dari infrastruktur maritim ini. Untuk mencapai tujuan tersebut, studi literatur serta analisis kualitatif dan kuantitatif menjadi metode yang tepat untuk digunakan. Sistem usulan pada penelitian ini memiliki waktu 69-83% lebih cepat dengan biaya operasional 24-40% lebih kecil dari JICT dan TTL. Selanjutnya, sistem ini bersifat ramah lingkungan dan lebih aman secara teknis. Secara keseluruhan, diharapkan penelitian ini akan memberikan wawasan luas mengenai sistem bongkar-muat kontainer serta menjadi pertimbangan untuk digunakan di pelabuhan Indonesia.

Kata-kata kunci: Indonesia, pelabuhan, teknologi magnetik, infrastruktur maritim, desain sistem operasional bongkar-muat kontainer

INTRODUCTION

Indonesia has known as a maritime country since approximately 67% of the country's area is ocean and Indonesia also has the 2nd longest coastline in the world.

Blessed with its geographical location, the opportunity to build cooperation with another ASEAN countries also widely open, especially in economic sector development through maritime infrastructure development. The formation of AEC (ASEAN Economic Community) 2015 aims to transform ASEAN into a stable, prosperous and highly competitive region with equitable economic development. Considering this AEC 2015 progress, Indonesia must have a great plan to face AEC 2015 challenges to improve its competitiveness value within the logistics movement area compared to the other ASEAN countries. One area to improve is maritime facilities. The President of The Republic of Indonesia declared that Indonesia currently has a committed ministry that will establish coastal and marine areas of Indonesia through the support of science and technology, as stated in “Nawa Cita Jokowi-JK 2014”. Currently maritime facilities in Indonesia are not well operated to enhance the power of trade flows from and to Indonesia, especially on its operational system design of container loading-unloading activities. In order to improve the condition, Indonesian ports require a well-established system for moving goods from land transport mode to sea transport mode (and vice versa) with the most efficient way.

Container terminal is a link between different transport modes in the global logistics chain; therefore container terminal is all-important to the efficiency of the whole chain. Generally, efficiency in terms of container loading-unloading activities can be expressed by the ratio of number of TEUs over the operational time and cost. TEU is a unit of cargo capacity to describe the capacity of container ships and container terminals. It is based on the volume of a 20-foot-long (6.1 m) intermodal container, a standard-sized metal box that can be easily transferred between different modes of transportation. Land transport mode requires amount of land area, which is one of the key factors to determine the capacity of the port itself and how the operational system could be implemented. To meet the efficiency, spatial planning needs to be done in the land area to intensify safety of container loading-unloading activities.

Table 1 Loading-Unloading Container Activities in Indonesian Ports

No.	Activities	Explanation
1	Shipping	Ships sail from port of origin to the destination port by sea. This process will stop when the ship docked in the harbor at the time and specific position that have been scheduled before.
2	Stevedoring (Business Process I)	A process when containers being allocated from vessels to berth (and vice versa) using Quay Cranes (QCs) to transfer containers from vessels and internal container trucks to receive containers from the crane.
3	Cargodoring (Business Process II)	The process of allocating containers by internal container trucks from berth to container yard (CY) or transfer process of container that is carried by trucks from CY and is received by Quay Crane to further loaded in the vessel.
4	Stacking (Business Process III)	A stacking process of containers using a tool called Yard Cranes (YCs) in container yard with specific location of a predetermined block; row; tier; and column of each respective container.
5	Receiving	A process when external full loaded trucks come into the terminal and transfer outbound containers to the container yard (the terminal is receiving).
6	Delivery	A process when the terminal discharges inbound containers from inside the yard to be delivered using external empty trucks (the terminal is delivering).

To be able to have ports with efficient and sustainable operations and compatibility, Indonesia needs to determine the problems in its ports by knowing first what activities are running in it. There are six common activities in loading-unloading operations in Indonesian ports that affect the efficiency. They are shipping, stevedoring, cargodoring, stacking, receiving, and delivery (Table 1).

In this paper, the authors focus on two things that are important to complete and support those six activities: terminal layout settings and characteristics of terminal equipment. Besides, this paper focuses on business process II and two variables, they are time and cost. This research identifies two Indonesian ports those are Jakarta International Container Terminal (JICT) and Port of Lamong Bay Surabaya (TTL), which have their own typical operational systems and terminal layout settings. Operational system of loading-unloading container in JICT is currently not running optimally. It causes trucks, which are the prime movers of loading-unloading container activities, operate with disorganized route that results in inefficient traffic system. In the other hand, TTL has applied zoning system in its terminal area based on allocation of each port needs. Furthermore, TTL is currently in the design of new technology for the prime movers in order to be the first green and semi automatic port in Indonesia. This research aims to review and to take the positive side from the systems that are applied in those two ports, not to mention the proposed system, wherewith to be applied in new Indonesian ports. From this paper, author wants to reach the objectives, which are to identify existing business process of container loading-unloading activities, to compare implemented system in JICT; TTL; and the proposed system, and to analyze the effect of proposed system if implemented in JICT and TTL in terms of time and cost.

Table 1 shows that there are three kinds of business processes those are Business Process I that is called Stevedoring, Business Process II that is called Cargodoring, and Business Process II or Stacking. Business process itself is a process when the containers move from vessel to container yard, and vice versa (Vis and Harika, 2004). There are many studies in the literature on different aspects of container terminal operational systems. The handling system is classified into two groups according to the different types of yard-side equipment, i.e "*direct transfer system*" and "*indirect transfer system*".

The remainder of this paper is organized as follows. Second section, which is the body text, presents the basic theories, research results of JICT and TTL, the proposed system, and comparison outputs of three different systems in this research. Finally, the third section is result analysis and conclusion, which gives analysis results both in quantitative and qualitative way as well as suggestions for some parties.

THEORETICAL BASIS

In recent years, the growth of shipping in terms of container movements, increasing rapidly that led to the importance of port role in global shipping network (Vacca et al., 2010). A good water transportation system design should be accompanied by comprehensive considerations of every aspects that could affect the system, which are ship services, port infrastructure (e.g., container yard), the potential of area where the port is located, and land transport network that connects ports, industrial park areas, and others (Notteboom, 2009). Port facilities are divided into two kinds of categories; they are basic facilities or infrastructure and supporting facilities or superstructure (Gurning et al., 2007). In Steenken et al., (2004) research, they stated that container terminal could be described as a system of materials/goods movement that happens between two different sides those are waterside and landside. The container itself has two types, which are empty containers and full containers.

With the presence of two primary sides, which connect the container terminal, it shows that activities occurring inside the terminal are complex and involve number of aspects include transportation modes, technical equipment, and parties outside the terminal in non-technical terms that collaborate into a proper system design. One of the main equipment in container terminal serves as prime movers. This equipment/vehicle moves between container yard and berth. In Indonesian ports, commonly the prime movers operated by a head truck with a smart chassis in its back. In the case of vehicles, chassis is a body to complete the head truck that loads containers. Moreover, internal container trucks also use fuel to operate so it can be concluded that terminal container needs operational cost, fuel cost, and maintenance cost in using internal container trucks. In their research, Kim and Kim (1998) and Huynh and Walton (2005) stated that by optimizing truck's turn-round time, container terminal would gain advantages in the industries. Land transportation traffic system is a system that manages all the land transport modes to transfer the goods from one area to another with the most proper way by doing zoning and routing. Zoning needs to be done in container terminal by dividing its area efficiently and in appropriate into some zones with specific functions so that it can improve the ability and security of the ports. Routing also needs to be applied in container terminal to ensure how each transport modes that work inside the terminal have the best route adjusted to the zones (Vis and Harika, 2004). Zoning and routing are two keys that are influence each other and very important to enhance the loading-unloading container operational system in the container terminal.

Automated Lifting Vehicles (ALVs) are a further development of the previous advanced vehicles Automated Guided Vehicles (AGVs) technology. Both types of vehicles transfer containers over fixed paths and are controlled by navigation and management software that centralized in the control room. ALVs use tape for the guide path and the tape can be one of two styles: magnetic or colored. In this paper, author presents the magnetic tape for the guide path. The advantage of magnetic tape is it has dual polarity. Magnetic tape is laid on the surface of the floor and serves to provide the path for the ALV to follow, change lane, speed up, slow down, and stop. An AGV receives a container from a container crane (CC) or yard crane (YC) and those cranes are required to take the container off to the vehicle. Otherwise, the ALV is capable to lift a container from the ground by itself so that it does not need to wait for other equipment to pick up or delivery containers. If the container terminal uses lifting vehicles as its prime movers, the loading-unloading container activities at the cranes (CC or YC) and the transportation process can be decoupled so that it will minimize loading and unloading times of the containers. Furthermore, when using ALVs, the containers are placed in a buffer area and can be transferred in a random order. Buffer area is needed to prevent queues when the transportation and loading sequences different. Nevertheless, to make sure the operations run continuously, the right container should be available at the moment the crane needs it. Yang et al., in 2004 studied about simulation-based performance evaluation of transport vehicles at automated container terminals. They demonstrated that the ALV is more advanced than the AGV in both productivity and efficiency because the ALV minimize the waiting time in the buffer area. Here is the characteristic of ALVs (Table 2).

Table 2 The Characteristic of ALV

Characteristic	ALV
Speed of Full Vehicle	6 m/s
Speed of Empty Vehicle	7 m/s
Acceleration	0.5 m/s2
Deceleration	0.5 m/s2
Capacity of vehicle	2 TEUs
Time to lift a container	22 s
Time to put a container down	22 s
Max number of vehicles in queue	unlimited

EXISTING CONDITIONS OF JICT AND TTL

In this section, author defines the current conditions of JICT and TTL in terms of operational system design both in terminal layout settings and characteristics of terminal equipment. These explanations will be followed by the observation results, both in time and cost, of loading-unloading container activities in JICT and TTL.

Jakarta International Container Terminal (JICT)

JICT is part of PT Pelabuhan Indonesia (Pelindo) II operational zones that does import-export activities globally and is located in North Jakarta. JICT is a 100-hectares area that has two terminals, which are Terminal I and Terminal II. Terminal I or JICT I has two berths that are North Berth, which has 720 meters in length, and West Berth that has 900 meters in length. Container yard in JICT consists of 106 blocks with 2334 slots and planned to accommodate up to 44365 TEUs. Containers that are stacked in JICT's container yard have a direction parallel to the arrangement of West Berth, which requires the use of Rubber Tyre Gantry Crane (RTGC). In JICT, IHT can do its trips to any block in the container yard, even if that block is located in the furthest point of the terminal.

Port of Lamong Bay Surabaya (TTL)

TTL is part of PT Pelindo III operational zones that serves loading-unloading container activities and is located in Surabaya. The area of TTL is divided into two main sides, which are Water Side Transfer Area (WSTA) and Land Side Transfer Area (LSTA). Currently, TTL is in its first phase of development and it has two types of berths those are International Wharf, which has 500 meters in length, and Domestic Wharf, which has 350 meters in length. Not to mention that the land area of this terminal is 38.86 hectares. Moreover, TTL also has a 1-meter jetty that serves to connect berths and container yard. In contrast to JICT, containers in TTL are stacked perpendicularly to both berths so that the container yard uses Automated Stacking Cranes (ASCs). This system simplifies stacking activities in the yard as it has transfer point in WSTA that facing the berth. Moreover, TTL has a specific route for each of equipment in the terminal to prevent congestions (Putri, 2015). Table 3 compares both of JICT and TTL equipment.

Table 3 JICT and TTL Terminal Equipment

No.	JICT		TTL	
	Equipment	Explanation	Equipment	Explanation
1	Quay Container Crane (QCC)	An equipment that is used in Business Process I. Its average productivity is 35 box/hr. In 1 shift, it needs 8 manpowers.	Ship To Shore (STS)	An equipment that is used in Business Process I. Its average productivity is 25 box/hr (twin-lift). In 1 shift, it needs 8 manpowers. Uses electrical energy
2	Rubber Tyre Gantry Crane (RTGC)	An equipment that is used in Business Process III. Its average productivity is 13 box/hr. In 1 shift, it needs 2 operators.	Automated Stacking Crane (ASC)	An equipment that is used in Business Process III. Its average productivity is 25 box/hr. In 1 shift, it needs 3 operators for every 10 units. It operates automatically.
3	Internal Head Truck (IHT)	An equipment that is used in Business Process II (prime movers). Its average productivity is 12 box/hr. In 1 shift, it needs 1 operator.	Straddle Carrier (SC)	An equipment that is used in Business Process II. It is used to transfer containers from CTT's chassis to buffer area in CY. Its average speed is 25-30 km/hr. In 1 shift it needs 1 operator.
4	Supporting Equipment	Consist of several types: Side Loader, Top Loader, and Fork Lift. These are used to transfer containers from one place to another, which is not included in three business processes.	Combine Terminal Trailer (CTT)	An equipment that is used in Business Process II (prime movers). In 1 shift, it needs 1 operator. It uses solar deck for its fuel.

Figure 1 and Figure 2 illustrate the business process and terminal layout setting of JICT and TTL.

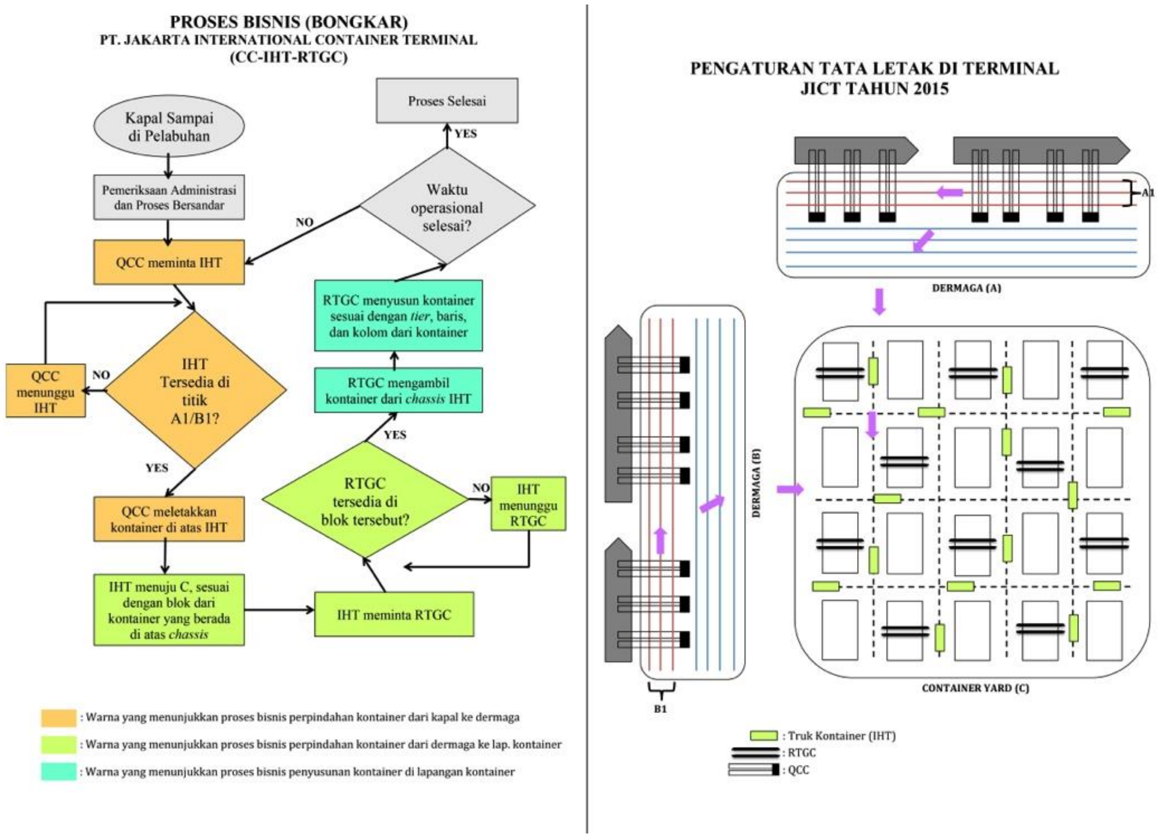

Figure 1 Business Process and Terminal Layout Setting of JICT

The difference between business process in JICT and TTL is in their Business Process II. In TTL, there are two types of equipment, which are Straddle Carrier (SC) and Combine Terminal Trailer (CTT) those are used in its Business Process II. Furthermore, TTL has buffer areas in its Water Side Transfer Area (WSTA), which is located near the parking line. This causes CTT works depends on the available of SC.

PROPOSED OPERATIONAL SYSTEM DESIGN

Terminal Equipment Strategies

Proposed system in this research focuses on Business Process II that happens between berth and container yard and uses internal head truck as the prime movers. In this paper, author proposes Automated Lifting Vehicle (ALV) to replace the function of IHT in JICT and CTT in TTL as a prime mover. ALVs work automatically and independently however require buffer areas to help them support the containers. Magnetic technology in ALV system is called Grid Navigation System (GNS), which has several magnetic points that are embedded in the road surface and form into a grid pattern as it uses as ALV’s routes.

This proposed system refers to the system that is being used in TTL, which uses automatic yard cranes, has buffer areas, and stacks the containers perpendicularly to the berths. To complete the system, author proposes Automated Stacking Crane (ASC), as used in TTL, to be the equipment for Business Process III and Container Crane (CC) that has twin-lift capability. To determine the number of equipment and the required time for this system, simulation method of every business processes is used (Vis and Harika, 2004). This simulation has business processes that are similar to the ones in this research. It is assumed that there were 2000 containers, 4 CCs, 16 ASCs, 21 ALVs, and 5 lines of buffer area. As the result, the first business process needs 16 s/TEU, the second one needs 17 s/TEU, and the third needs 37.86 s/TEU. Table 4 shows the comparison of equipment and number of operators in JICT, TTL, and proposed system.

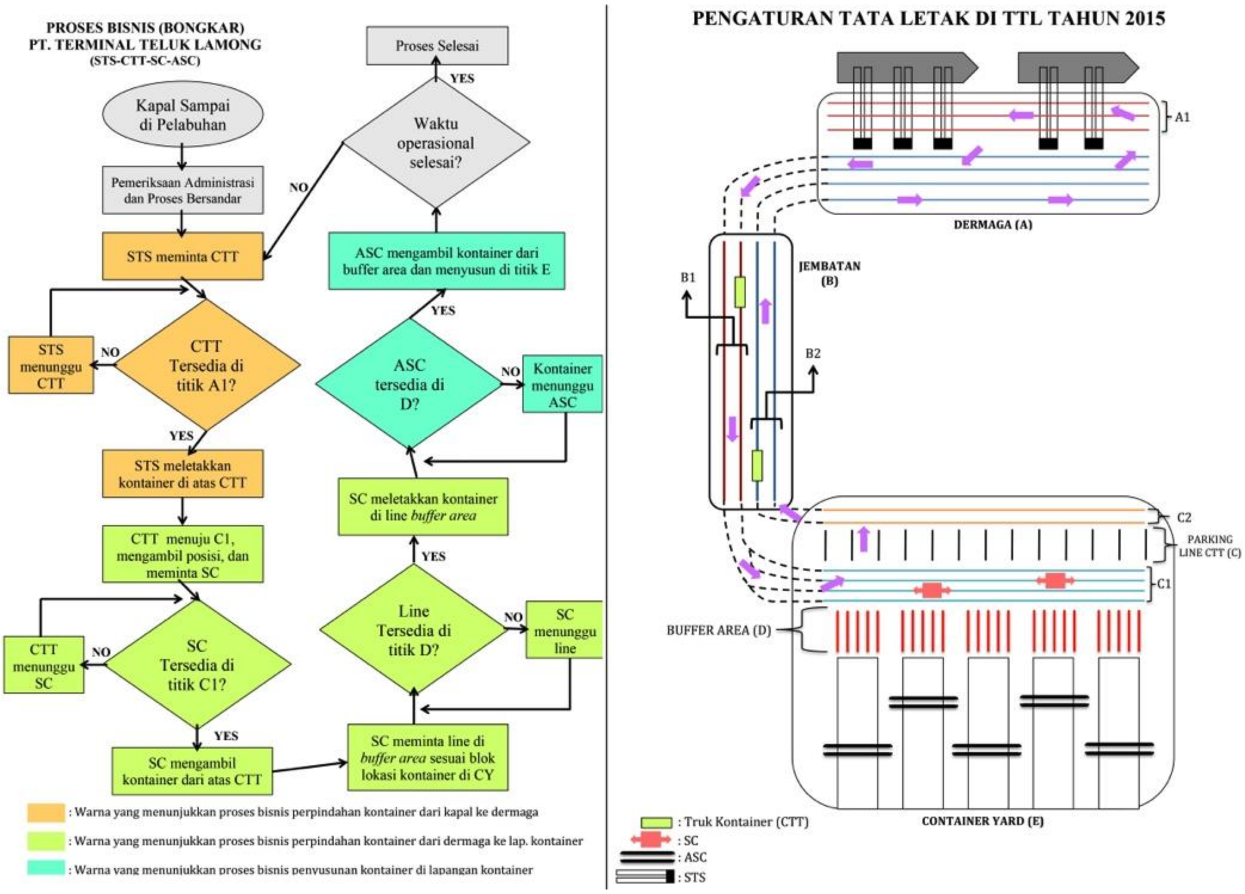

Figure 2 Business Process and Terminal Layout Setting of TTL

To enhance the equipment strategies, author also proposes new terminal layout setting since it is related to the equipment performance. This paper determines three zones in terminal area those are Quay Side Container Transfer Zone (QSZ), Container Yard (CY), and Yard-Land Container Transfer Zone (YLZ). This zoning system brings all the business processes occur systematically and all the activities are well-organized. Figure 3 illustrates the business process and terminal layout setting of proposed system.

Table 4 The Comparison of Equipment and Number of Operators in JICT, TTL, and Proposed System

Comparison	JICT	TTL	Proposed	Explanation
Berth Equipment	QCC	STS	CC	CC is twin-lift and works electrically
Internal Container Truck	IHT	CTT	ALV	ALV works automatically
Yard Equipment	RTG	ASC + SC	ASC	ASC is an automatic crane
Number of Truck/CC (unit)	8	6	21	
Number of SC/block (unit)	-	1	-	
Number of CC's Operators	38	5	8	Proposed system uses 4 CCs/shift
Number of YC's Operators	73	3	5	Proposed system uses 16 ASCs/shift
Number of SC's Operators	-	5	-	
Number of Truck's Operators	139	30	6	

Terminal Layout Setting Strategies

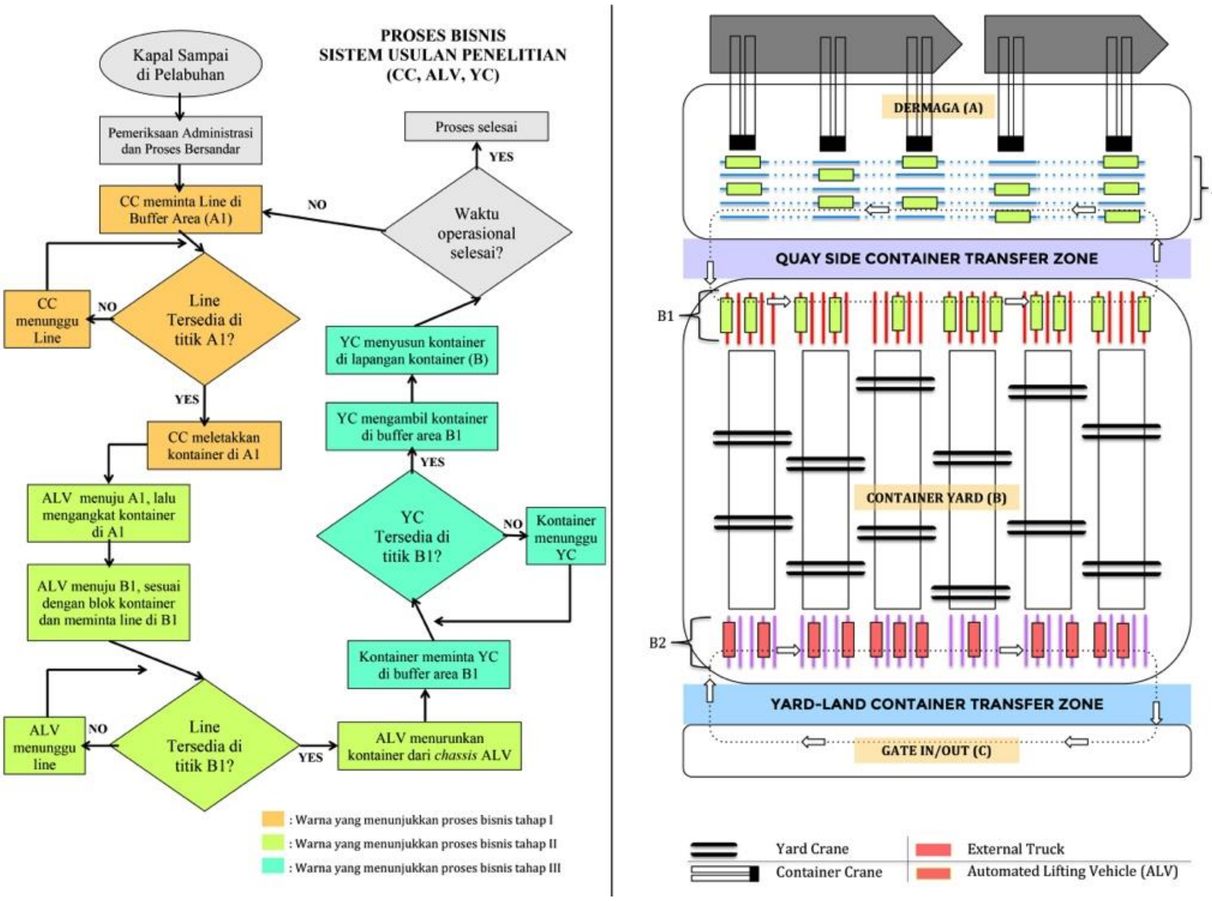

Figure 3 Business Process and Terminal Layout Setting of Proposed System

ANALYSIS RESULTS

As explained before, this research compares those three systems based on time and cost. Here are the explanations about symbols that are stated in the table.

t_1 : Time spent in Business Process I

t_2 : Time spent in Business Process II

t_3 : Time spent in Business Process III
OPEX Cost : Cost used for operational purposes (worker; fuel; maintenance)
CAPEX Cost : Cost used for investment purposes

The result analysis of this paper is shown in Table 5 and Table 6, which Table 5 points out the time and Table 6 elucidates the cost.

Table 5 The Comparison of Container Loading-Unloading Time in JICT, TTL, and Proposed System

Parameter	Average Time per TEU (T)			Proposed compares to JICT and TTL (%)
	JICT	TTL	Proposed	
t_1 (sec)	41.3267 (10.36% *T*)	24.4113 (10.39% *T*)	16.931 (23.60% *T*)	t_1 of Proposed System is 59.03% faster than JICT and 30.64% faster than TTL
t_2 (sec)	293.9066 (73.67% *T*)	172.7318 (73.50% *T*)	16.956 (23.63% *T*)	t_2 of Proposed System is 94.23% faster than JICT and 90.18% faster than TTL
t_3 (sec)	63.7135 (15.97% *T*)	37.8644 (16.11% *T*)	37.8644 (52.77% *T*)	t_3 of Proposed System is 40.59% faster than JICT and as same as TTL
Total Time (*T*) (s/TEU)	398.95	235.01	71.75	Total Time of Proposed System is 82.01% cheaper than JICT and 69.47% cheaper than TTL
Total Time (*T*) (min/TEU)	6.649	3.917	1.1959	

Table 6 The Comparison of Container Loading-Unloading Cost in JICT, TTL, and Proposed System

No	Parameter	JICT	TTL	Proposed	Proposed compares to JICT and TTL (%)
1	Worker Cost per TEU	IDR40,596	IDR24,676	IDR7,767	Worker Cost of Proposed System is 80.87% cheaper than JICT and 68.52% cheaper than TTL
2	Fuel Cost per TEU	IDR46,920	IDR27,600	IDR25,585	Fuel Cost of Proposed System is 45.47% cheaper than JICT and 7.3% cheaper than TTL
3	Maintenance Cost per TEU	IDR30,912	IDR42,375	IDR38,080	Maintenance Cost of Proposed System is 23.19% more than JICT and 10.14% cheaper than TTL
4	Total OPEX Cost per TEU	IDR118,428	IDR94,651	IDR71,431	Total OPEX Cost of Proposed System is 39.68% cheaper than JICT and 24.53% cheaper than TTL
5	Total CAPEX Cost	IDR150,026 x 10^6	IDR218,070 x 10^6	IDR209,000 x 10^6	Total CAPEX Cost of Proposed System is 39.31% more than JICT and 4.16% cheaper than TTL

CONCLUSION

Overall, the objectives of this research are to analyze and to derive both positive and negative points of those three systems that will be considered for use in new Indonesian ports. In conclusion, there are several things pertaining to terminal layout settings and characteristics of terminal equipment that should be considered for ports development. Firstly, the distance between the berth and container yard must be designed appropriately when determining terminal layout. Secondly, to control mileage of trucks, zoning and routing should be planned in port systems. Thirdly, the main purpose of logistics is to work in the most efficient and effective time, as it will directly affect the cost. From the result, it is proven that Total OPEX Cost of proposed system is the cheapest between the other two systems, yet its Total CAPEX Cost is more expensive than JICT given that its equipment are more automatic and modern. Last, it is believed that the faster time of business processes, the greater the terminal productivity. Not to mention, the greater the profit.

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REFERENCES

Gurning R. O. S. and Budiyanto E. H. 2007. *Manajemen Bisnis Pelabuhan*. Surabaya: PT Andhika Prasetya Ekawahana.

Huynh, N. and Walton, M., 2005. *Methodologies For Reducing Truck Turn Time at Marine Container Terminals*. Austin: The University of Texas.

Kim, K. and Kim, H. 1998. *The Optimal Determination of The Space Requirement and The Number of Transfer Cranes for Import Containers*. Computers and Industrial Engineering, 35: 427-430.

Notteboom, Theo. 2009. *Economic Analysis of The European Seaport System*. Report Serving as Input for The Discussion on The TEN-T Policy: ITTMA-University of Antwerp. Antwerpen.

Putri M. 2015. *Analisa Kinerja Terminal-Rencana Kerja Manajemen 2015*. Surabaya: PT Terminal Teluk Lamong.

Steenken, D., Vob, S., and Stahlbock, R. 2004. *Container Terminal Operation and Operation Research-A Classification and Literature Review*. OR Spectrum, 26: 3-49.

Vacca, I., Salani, M., and Bierlaire, M. 2010. *Optimization of Operations in Container Terminals: Hierarchical VS Integrated Approaches.* Proceeding of the Swiss Transport Research Conference. Ascona.

Vis, Iris, F. A., and Harika, Ismael. 2004. *Comparison of Vehicle Types at An Automated Container Terminal*. OR Spectrum, 26 (1): 117-143.

Yang, C. H., Choi Y. S., and Ha, T. Y. 2004. Simulation-Based *Performance Evaluation of Transport Vehicle at Automated Container Terminal*. OR Spectrum, 26 (2): 149-170.