A Study on System Dynamics Modeling to Strengthen the Competitiveness of a Container Terminal

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Abstract: A container terminal should concentrate on the efficiency of terminal operation in the long-term view and analyze the impact of the introduction of high technology, automated equipment and intelligent information system, so that it may enhance its reliability and competitive power in intense global competition. To this end, first this study has tried to find out the factors that affect competitiveness of a container terminal and the relationship among them. And then we have used a System Dynamics method to analyze an effect according to the value fluctuation of the factors in the long term.

Key-Words: Container Terminal, Reliability, System Dynamics

1 Introduction

Along with a growing world economy, cargo volume is also steadily increasing. In particular, the container handling volume of some Chinese container terminals in the Northeast Asia including Shanghai and Shenzhen is rapidly growing at an annual rate of more than 20% since 1999. Meanwhile, many shipping companies, which are seeking the economy of scale, are making their ultra large containerships call only at a hub port in certain areas, while in case of other ports using a feeder as a transit port. For this reason, many major ports of the world are making an aggressive investment in their ports to be a hub port so that they can induce ultra large containerships and secure more cargo volume. Especially, in order to effectively respond to the demand of customers (e.g. shipping companies, cargo owners, forwarding company, and trucking company), they are developing various kinds of services and are also introducing high technology, automatic equipment, and intellectual information system.

At the same time, in order to gain stable competitiveness from the long-term point of view, we have to focus on the efficient terminal operation, and also have to analyze what impact the introduction of high technologies, automated equipment and intellectual information system have on the reliability and competitiveness of a container terminal from the long-term point of view. To this end, this study has tried to find out the factors that have an impact on reliability and competitiveness of a container terminal, and define causal relationship among them. Our researches on the factors that have an impact on the competitiveness of a terminal have been made along with a literature review and help of working-level experts who have much experience of terminal operation. Also, this study used a SD (System Dynamics) method to analyze what impact by the change of these factors has on the reliability and competitiveness of a container terminal in the long run. In particular, by adopting the top-down method in SD modeling, which emphasizes feedback thinking, this study developed a model for the enhancement of competitiveness of a container terminal.

2 Factors to Enhance Competitiveness of Container Terminal

Through the literature review centering on the enhancement of competitiveness of a container terminal, this study found out the factors to enhance competitiveness and analyzed these factors from the operational point of view.

2.1 Literature Review

Due to the rapid environmental changes stirring up a fierce competition among neighboring ports, a series of researches centering on Busan port have been made to go ahead of neighboring rival ports in Korea. In order to suggest the strategy to enhance the competitiveness of a container terminal, Kwon and Ahn [1] have made researches on the future of a container terminal, level of service, and excellence of a terminal, and compared and analyzed those factors from the viewpoint of both terminal staff members and terminal users, and finally suggested the prospect and change direction of a container terminal through regression analysis. Yeo and Lee [2] have defined of ports competition, suggested the port model of each individual port, made researches on the changes in the diverse factors among many rival ports (e.g., Busan, Kobe, Yokohama, Kaoshung, Giryung), and finally suggested the results of these changes through the hybrid of SD method and HFP method. Oh and Park [3], and Park [4] have made their researches focusing on productivity and service satisfaction in order to obtain the competitiveness of a container terminal. As a way of gaining superiority in the competition with rival ports, Han [5] and Kim *et al.* [6] have analyzed the competitiveness between ports from the viewpoint of shipping companies. Besides the above-mentioned literature, more studies have been made in order to strengthen the competitiveness of a container terminal considering the competitive situation between Korea and China, and logistics and environmental changes in the Northeast Asia.

The factors for the enhancement of competitiveness, which have been defined through the literature review, can be summarized as the geographical feature of the port, location, service, hinterland, convenience, and expenses. However, these existing studies are focusing on what efforts are necessary to secure the competitiveness of port under the environmental change of each port, not paying much attention to the change of a container terminal itself. But this study tried to analyze these competitiveness factors from a microscopic point of view in relation to the operation of a container terminal.

2.2 Competitiveness Factors from the Operational Viewpoint of Container Terminal

We can find out diverse competitiveness factors (or variables) from the operational process of a container terminal, and will use these factors for causal map and also SD model. The total jobs of a container terminal can be grouped into three: inbound and outbound cargo carrying, yard work, and loading and unloading of cargo. However, the working hour and productivity of these jobs are directly affected by the degree of obsoleteness of technology, equipment, and machine.

2.2.1 Gate work

Inbound and outbound cargo carrying can be divided into two: Inbound cargo carrying is to carry containers by truck and pass through the gate into the terminal. Outbound cargo carrying is to carry containers unloaded from the ship to the yard and pass through the gate outside. The gate does recognize, check and confirm the passing trucks and containers, giving access to the trucks. Also, the gate is the place for transfer of authority [7]. In addition to this, the following work is also included in the inbound and outbound cargo carrying: moving to the TP (Transfer Point), waiting for work at the TP, loading and unloading by the yard cranes, and finally passing through the gate. Table 1 shows the classification of the jobs relating to the inbound and outbound cargo carrying, the person and technology in charge of each job.

2.2.2 Yard work

Yard work can be divided into three: inbound and outbound cargo carrying, loading and unloading of containers, and re-marshalling. The re-marshalling consists of re-marshalling within the bay, re-marshalling within the block, and re-marshalling between blocks. Here, inbound and outbound cargo carrying is related to the gate work. This work means that when incoming trucks arrive at the TP, the loading and unloading from the trucks has to be made at the yard. This is different from loading and unloading from the containerships. Yard work also includes the transfer work between yard tractors. In order to support the speedy loading and unloading, re-marshalling needs to be done by considering the destination port, weight, and size of the containers.

However, this re-marshalling can be different according to the operational type of each container terminal. Table 2 shows the classification of yard work and a worker and technology in charge of each job.

Table 1. Inbound and outbound cargo carrying and related technologies

Section	Jobs	Related workers and technology	Remarks
Inbound cargo carrying	Recognition of truck No.	Manual work, Bar-Code, OCR, RFID	Measures by job and by error type in response to errors need to be
	Recognition of container No.		
	Confirmation of container damage	ACDI	
	Storage position information	Digital Media	
	Seal Check	Manual check, e-Seal	
Outbound cargo carrying	Recognition of car No.	Manual work, Bar-Code, OCR, RFID	
	Outbound cargo carrying position information	Digital Media	
	Confirmation of outbound cargo carrying	Manual check, Bar-Code, RFID	
Common work	Moving hours to the TP	Moving to the place according to the information in the slip	
	Waiting time at the TP	Waiting for the work after arrival at the appointed place	
	Yard crane's work hours for loading and unloading	Yard crane's loading and unloading for inbound and outbound containers	

2.2.3 Loading and Unloading

Loading is to put containers on the ship and unloading is to unload containers from the ship. For loading and unloading, QC (quay crane), YT (yard tractor), AGV (automated guided vehicle), shuttle carrier, and yard crane are needed. By using these equipments, loading and unloading is performed. Generally, unloading comes first, and then loading follows. QC unloads containers from the ship, and transfer equipment transports them to the yard blocks, and yard cranes stack them. Loading is to be done in reverse order. Table 3 has classified the jobs of loading and unloading, and has also described a worker and technology in charge of each job.

The major jobs and related technologies as described above can be the key variables for measurement of the efficiency, productivity, and reliability of a container terminal. This study defines the causal relationship between these variables and develops the model for measurement from the diverse viewpoints.

Table 2. Classification of yard work and related technologies

Section	Jobs	Related workers and technology	Remarks
Landside TP Work	Confirmation of container No.	Crane worker, OCR	Comparison with work order
	Loading and unloading of containers	Crane worker (remote controller)	
Loading and unloading	Confirmation of container No.	Crane worker, OCR	
	Loading and unloading from the trucks	Crane worker (remote controller)	
Re-marshalling	Confirmation of container No.	Crane worker (autmation)	In case of work within the bay or blocks, loading and unloading can be excluded.
	Confirmation of re-marshalling position		
	Loading and unloading from the trucks		
	Storage work		

Table 3. Classification of the work of loading/unloading and related technologies

Section	Jobs	Related workers and technology	Remarks
Loading and unloading	Confirmation of container No.	Crane worker, OCR	Comparison with work order
	Loading and unloading from the trucks		
Transfer work	Confirmation of container No.	Transfer equipment worker, OCR, RFID	
	Transfer containers to the corresponding block	Crane worker (remote controller)	
Yard work	Confirmation of container No.	Crane worker or automation	Selection of optimum location is needed
	Confirmation of storage position		
	Loading and unloading from the trucks		
	Yard work		

3 Causal Relationship Analysis of Competitiveness Factors

Focusing on the operational process of a container terminal, we analyzed in the top down method the causal relationship among diverse factors that affects competitiveness of container terminal. Through the analysis of this causal relationship, this study tried to

find out which factors affect the reliability, productivity, and economy of the container terminal.

3.1 Causal Relationship among Jobs of Container Terminal

First of all, we analyzed what relationship of those jobs of a container terminal – inbound and outbound cargo carrying, yard work, and loading and unloading of containers – affects the reliability of the container terminal. The efficiency of each job has a positive effect with the reliability of the terminal, and this effect has a direct or indirect effect upon the profit of the terminal. Meanwhile, the earned profits will be reinvested for the efficiency of the container terminal in order to further enhance its reliability. Again, this investment will increase the efficiency of each job, thus bringing about a positive outcome.

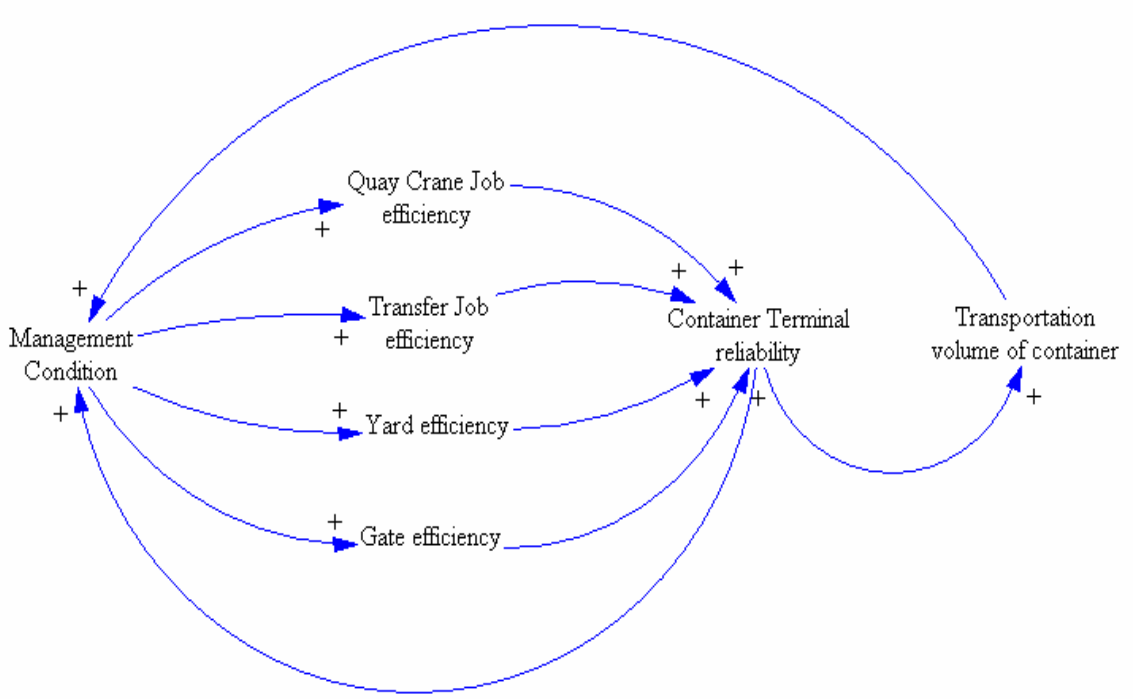

Fig. 1. Casual loop of jobs and reliability of container terminal

3.2 Causal Relationship among Detailed Jobs of Container Terminal

As there is a relationship among the detailed jobs of a container terminal, this causal relationship can be described from the viewpoint of system dynamics as Fig. 2. The working hours and handling volume have a positive effect on the reliability of a container terminal, which also encourages the introduction of state-of-the-art technologies and facilities so that it may maximize the capability of the container terminal. However, in case that it delays these efforts to introduce high technology and state-of-the-art facility, its productivity, speediness, and service quality will be lowered for a certain period of time.

When we analyzed the causal relationship as illustrated in Fig. 2, we find out that each job has a positive impact on the reliability of the container terminal. First, let's see the inbound and outbound cargo carrying. The gate-passing time depends on the number of incoming trucks, the technology applied to the gate, and the number of errors related to the recognition, confirmation and security. After this, the distance to the TP (transfer point) in the yard, waiting time for loading and unloading from the trucks, working hours of loading and unloading, and the time to pass through the gate outside, all these jobs have a impact on the turnaround time, which is a critical factor to the reliability of a container terminal.

By job analysis and measurement of working hours, the proper number of a gate lane and yard crane can be counted. Also, by using the SD model to be developed, information for decision-making on the expansion of gate lane and yard crane, and introduction of high technology can be given.

Secondly, let's see the yard work. The working hours for loading and unloading from the trucks and

the working hours required in supporting loading and unloading from the ship, these factors also affect the reliability of a container terminal. Finally, in case of loading and unloading from the ship, which is one of the most important jobs of a container terminal, the container handling volume per hour of a quay crane in relation to the number of the ships arrived at the port and the smooth connection to the transfer equipment can be a critical factor. Accordingly, the reduction of ship's waiting time at the port has a significant impact on the reliability of a container terminal.

Therefore, the improvement of reliability of a container terminal can be directly related to the profit creation of the container terminal. After a certain period of time, these profits will be reinvented in the state-of-the-art technologies and facilities for the enhancement of productivity, consequently improving the reliability of the container terminal.

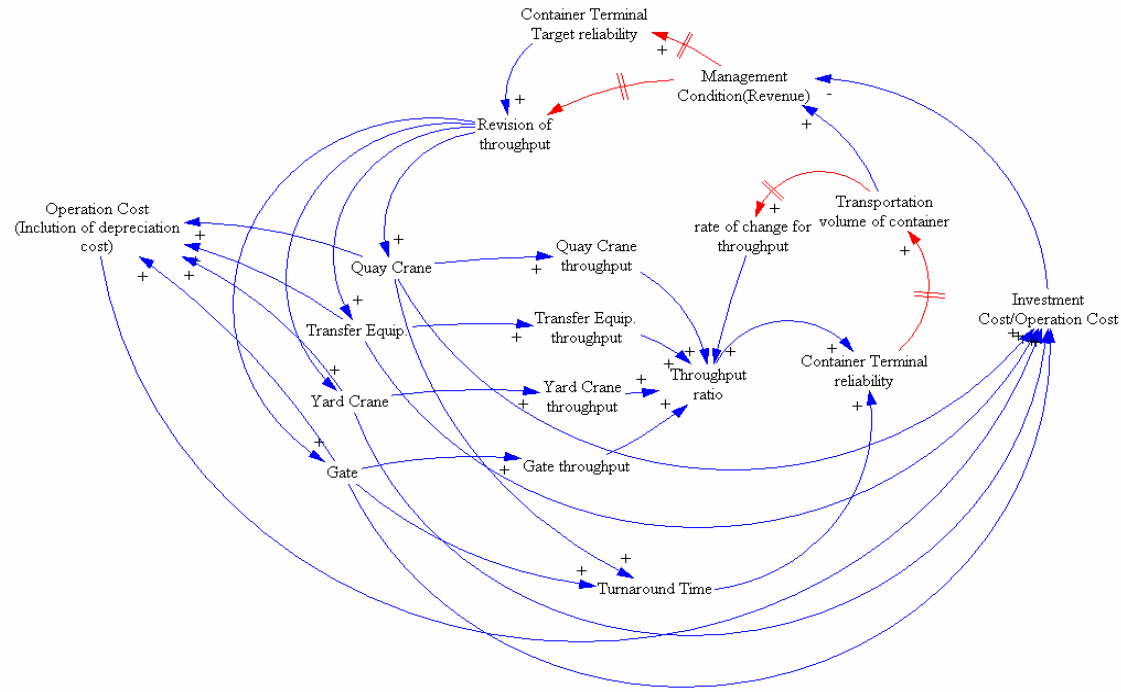

Fig. 2. Casual loop of the reliability and equipment and facility of container terminal

4 Measurement for the Reliability of a Container Terminal using System Dynamics Method

Based on the causal map as shown in Fig. 2, this study has analyzed what impact for the efficiency of each factor (e.g. equipment, facility and technology) has on the reliability of a container terminal, and how the measured reliability affects the management environment of the terminal, eventually pushing ahead with modernization of the equipment and facility.

The model developed in this study has been made focusing on the handling volume of major equipment and facilities and the turnaround time, which also has a significant impact on the reliability of a container terminal. The SD model analyzed what impact of the major jobs – the handling volume of the quay crane, transfer equipment, yard crane, and gate – have on the reliability of a container terminal, and also analyzed what impact of the turnaround time, which is critical to the customers (e.g. shipping companies and trucking company), has on the reliability.

The simulation has been made for 50 years, i.e. from opening of a container terminal to its closing. Measurement has been made for the satisfaction degree of the TT (turnaround time) of the quay and gate, and for the reliability of the container terminal in relation to the total container-handling rate. The change of reliability according to the satisfaction of TT is shown in Fig. 3.

The TT satisfaction degree and reliability are below 40% and 70% in the beginning stage as shown in Fig. 3. This is because the container terminal in the beginning stage lacks equipment and facilities and its efficiency is also low. But this situation is improving with the passage of time, thus enhancing the TT satisfaction degree and reliability, enabling the

container terminal to induce more shipping companies and transporters, and consequently increasing container cargo volume. Fig. 4 shows that the reason for the reduction of container cargo volume is similar to that of low TT satisfaction degree and low reliability. The container cargo volume increases with the passage to time. But because of the limit of area expansion of a container terminal as well as the difficulty in the unlimited introduction of equipment and facilities, the container cargo volume will remain in the same level after a certain period of time.

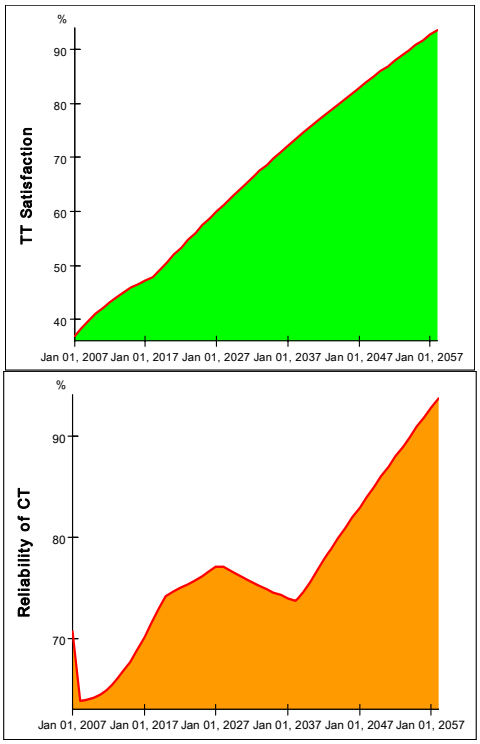

Fig. 3. Change of reliability and TT in a container terminal

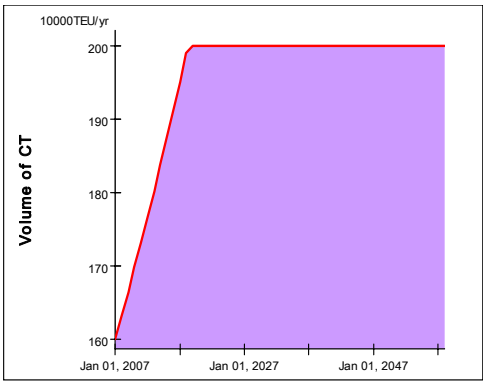

Fig. 4. Change of container cargo volume in relation to TT satisfaction degree and reliability

5 Conclusion

This study tried to find out the factors, which have an impact on the reliability of a container terminal, from the operational point of view, and then has analyzed the relationship between them. According to the container terminal, the type of equipment and operational method are quite different. Therefore, many researches have been made on the productivity. But the relationship analysis among factors that have a positive effect on the reliability of a container terminal has not been made much.

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