

A Study on the Type of Automatic Yard Operation for a Container Terminal*

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Key Words : Yard Operation, Automated Container Terminal, Economic Analysis

Abstract

In order to cope with improvement of labor cost and cargo volume, Korean ports, especially Busan port, are in need of many new facilities. Of course, current facilities should be fully used, and at the same time it needs to make every effort to maximize its productivity as well as cost saving. To this end, this study has decided to focus on automatic yard operation suitable to the domestic container terminal environments, making a survey of many advanced container terminals, trying to find out their common factors, and finally suggesting several alternatives based on the combination of these factors. Also, this study has suggested the present value of initial investment and operating cost by alternative, and at the same time presented the relationship between cargo handling volume and cost/revenue of the optimal alternative, so that it may be of help in decision making.

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I. Introduction

Domestic container terminals are, on an ongoing basis, making every effort to keep up with the rapidly changing environment and to go ahead of competitors at home and abroad. In particular, Busan port is the fifth largest all over the world in handling container cargoes, and because of this, most container terminals in Busan are in urgent need of taking measures to cope with increasing cargo volume. Therefore, current facilities of the terminals should be fully and optimally used. Also in the construction of a new terminal or in the expansion of berths, new facilities and new operation method should be effectively connected to the existing container terminals(Park et al., 2004; Choi et al., 2004).

In an effort to be of help to the development of a new container terminal and to the introduction of automatic yard operation, this study has tried to suggest diverse types of automatic yard operation, analyzing the features of these types as well as its economic factors.

As our research method, we have made researches on preceding literatures, making a visit to many advanced ports for a survey, and conducting a scrupulous analysis, and finally finding out the factors defining automatic yard operation. In order to test these factors, we have gathered, by means of questionnaire, the opinions of the experts specializing in the container terminal, so that this study may be more practical in the real case. We believe this research will be a useful guide in selecting an optimal type for automatic yard operation of the domestic container terminals.

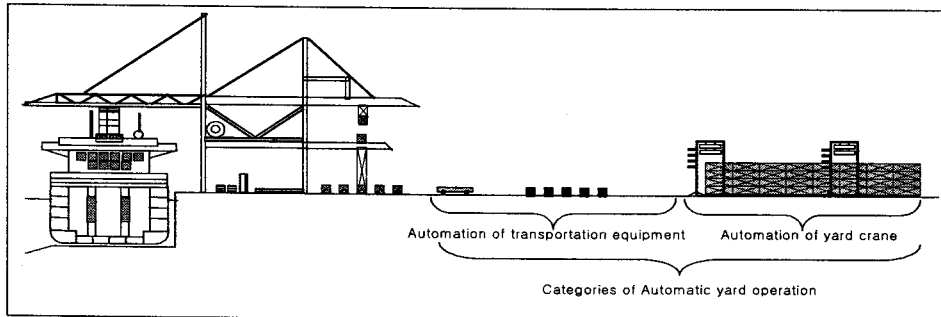
II. Yard Operation Method of Overseas Container Terminal

This chapter analyzes the yard operation method of many overseas container terminals in order to find out the factors suitable to the automatic yard operation.

1. Concept of Automatic Yard Operation

In case of overseas advanced container terminals, not only fully automatic yard, but also partial automation is steadily on an increasing trend(KMI, 1998). The automatic yard operation can be defined as "the container terminal that has an automatic transportation function, and fully or partially automated storage function." Also the

automatic yard operation can be divided into the automation of transportation equipment and automation of the yard cranes as shown in the <Figure 1> (Vob et al., 2004).



<Figure 1> Concept and Category of Automatic yard operation

In this respect, the following section 2.2 analyzes the current situation of the automatic yard operation of overseas advanced container terminals, so that it may be used as a guideline in determining the type of automatic yard operation of domestic container terminals.

2. Analysis of the Types of Automatic Yard Operation

The terminals for our analysis include CTA(Container Terminal Altenwerden) in Germany, ECT(Europe Container Terminal) in Netherlands, TMP(Thamesport) in United Kingdom, PPT(Pasir Panjang Terminal) in Singapore, HIT(Hongkong International Terminal) of Hong Kong, and OI of Japan. The CTA of Germany and ECT of the Netherlands belong to a fully automated container terminal, but their aspect of yard operation is closely related to this study, and it is believed that these two can be a model when transforming the current partial automation of domestic terminals into full automation in the future.

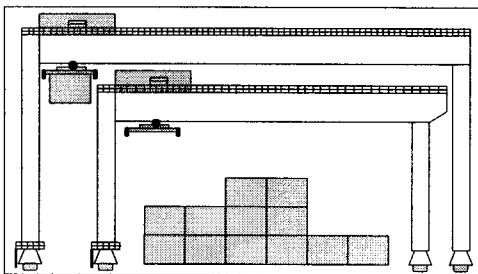
Also, in case of TMP of the United Kingdom and PPT of Singapore, the cranes in the storage yard are operated on an unmanned basis, but in case of HIT of Hong Kong and OI of Japan the cranes are operated on a manual basis. As this distinction is only part of the features of automatic yard operation, more survey has to be made with regard to the yard cranes, transportation equipment, interface area between these facilities, and effective yard layout. First, the yard equipment situation of overseas container terminals is as in the <Table 1>.

<Table 1> Yard Equipment Status of overseas Container Terminals

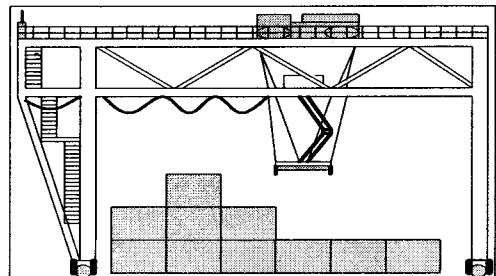
terminal	yard crane	trans-porter	Loading & Unloading
CTA	DRMGC (unmanned)	AGV	Remote control
ECT	ASC(unmanned)	AGV	Remote control Straddle Carrier
TMP	RMGC(unmanned)	Y/T	Joy-stick by field worker
PPT	OHBC(unmanned) RMGC(manned)	Y/T	Remote control
HIT	RMGC(manned) RTGC(manned)	Y/T	Worker's operation of cranes within 14 feet
OI	RMGC(manned)	Y/T	Worker's operation of cranes within 14 feet

CTA of Germany is based on DRMGCs (Double Rail Mounted Gantry Cranes) system, i.e. having two units of crane, small and large, in one block, as shown in the <Figure 2>.

The two units of crane are performing alternately, thus reducing interference with the other crane, maximizing the productivity of yard operation, and if one crane is in failure, the other can support its yard operation. And loading and unloading between DRMGC and AGV is performed automatically, and the work of outside trucks is conducted by a remote controller in the remote control office(Koch, 2003).



<Figure 2> DRMGC of CTA



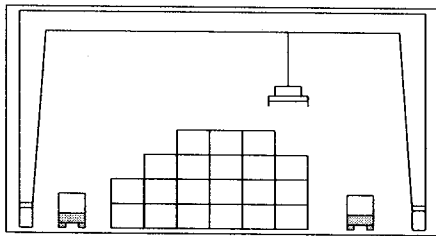
<Figure 3> DRMGC of ECT

In case of ECT of the Netherlands, the yard operation is conducted by ASC (Automated Stacking Crane) as shown in the <Figure 3>. But due to the short length of each block, each block has one unit of crane. Therefore, if one unit is in failure, the rescue crane helps. The operation of AGV and ASC is conducted automatically. For

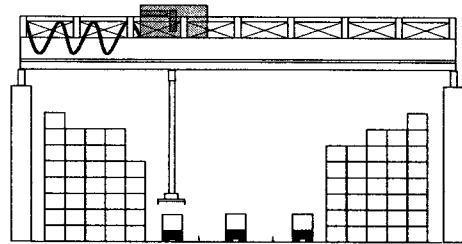
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the work of outside trucks, the straddle carrier performs the role of intermediation between ASC and an outside truck(LEGANA, 2002).

As shown in the <Figure 4>, the TMP of United Kingdom is using RMGC (Rail Mounted Gantry Crane), each block having two units of crane. RMGC has a Rahmen type. If one crane fails, the other helps. Loading and unloading between inside trucks and outside trucks is conducted by workers of the terminal by means of joystick, so immediate response can be made in time of troubles(Choi, 2004).



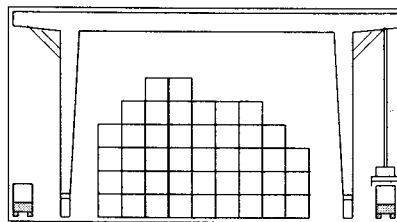
<Figure 4> RMGC of TMP



<Figure 5> OHBC of PPT

PPT of Singapore is using an OHBC (Over Head Bridge Crane) as shown in the <Figure 5>, which is one of the most expensive yard cranes, but highly productive (35 per hour) and useful. The OHBC of PPT has a structure in the right and left of each block that is made for crane movement, so that the traveling road for inside trucks may run between blocks. Loading and unloading of containers by truck is conducted by the remote controller in the control office just like CTA of German

As in the <Figure 6>, HIT of Hong Kong uses a RMGC-typed crane. Each block has 4 units, and unlike TMP of United Kingdom, Hong Kong is using a cantilever-typed RMGC. Most work is conducted automatically, but there is a worker always riding in the RMGC, who is directly handling containers for loading and unloading.



<Figure 6> RMGC of HIT

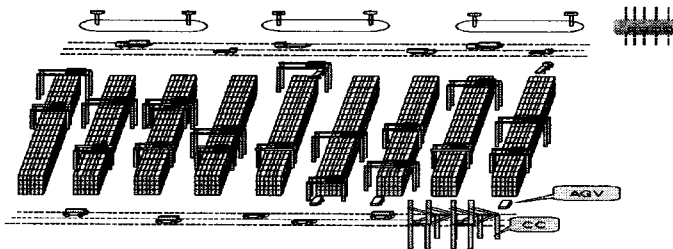
OI of Japan is using the same kind of equipment as Hong Kong, and owing to labor problem, workers are performing jobs. In case of Hong Kong and Japan, as workers are riding on the cranes, the job accuracy and trouble-shooting ability is much better than unmanned cranes. This problem is an important factor to be considered for automatic yard operation in the future because the weight of labor cost is very high in the operation of domestic container terminals(CIIPMS, 2004).

Next, the yard layout situation of overseas container terminals is shown in the <Table 2>. With regard to a yard layout, major categories cover yard arrangement, truck parting area, buffer zone, and division of import and export yard.

<Table 2> Yard Layout Situation of Overseas Container Terminals

Terminal	Yard layout type	Transfer point area	Buffer zone	Separation of import and export yard
CTA	Vertical layout	At the end	Nonexistence	No separation
ECT	Vertical layout	At the end	Nonexistence	No separation
TMP	Horizontal layout	At the end	Existence	No separation
PPT	Horizontal layout	inside the area	Nonexistence	Separation of transshipment area
HIT	Mixed layout	inside the area	Nonexistence	No separation
OI	Horizontal layout	inside the area	Nonexistence	No separation

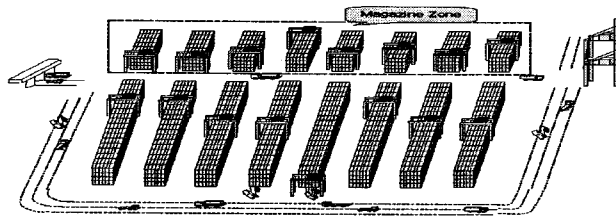
From the berth standpoint, table. 2 shows that fully automated container terminals have a vertical layout, but partially automated terminals usually have a horizontal layout or a mixed type. <Figure 7> is the typical type of a fully automated container terminal where AGV and TP for outside trucks are separately divided to help the yard cranes work smoothly.



<Figure 7> Yard Layout of a Fully Automated Container Terminal

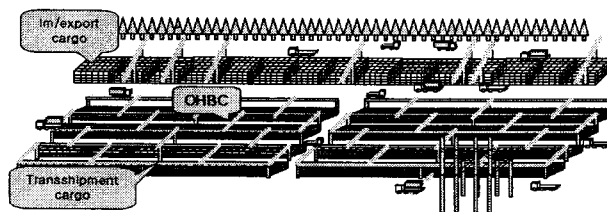
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As shown in the <Figure 8>, TMP of United Kingdom has a horizontal layout, but as the TP is separately operated, it seems to be similar to a vertical layout. Differently from other overseas container terminals, TMP has a Magazine Zone, and all containers for import and export should go through a Magazine Zone, in which rearrangement is being made for a smooth work process.



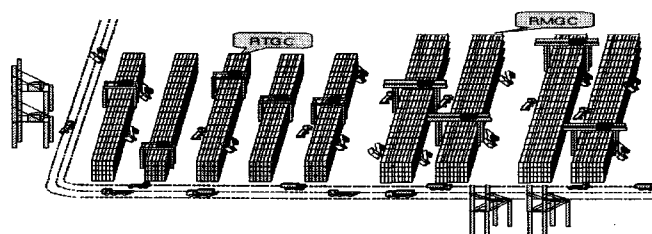
<Figure 8> Yard Layout of TMP

As shown in the <Figure 9>, PPT of Singapore and OI of Japan have a horizontal layout, and outside trucks are allowed to work inside the blocks. However, in case of OI, the way for trucks to enter the blocks and its equipment are different from PPT. In case of PPT, more than 80% of its cargo volume is transshipment cargo. Because of this, transshipment area is separated from import and export area.



<Figure 9> Yard Layout of PPT

Finally, HIT of Hong Kong is shown in the <Figure 10>. According to the location of berth, its layout has a mixed type, vertical and horizontal. But its operation is performed horizontally just like domestic conventional container terminals



<Figure 10> Yard Layout of HIT

As mentioned above, each advanced container terminal has a different type of automatic yard operation of its own, trying to improve its productivity and save operating costs. Likewise, in deciding the type of automatic yard operation for domestic container terminals, the environmental aspect related to the terminals should be considered. Now, from the above-mentioned case study, we can find out several important factors for the selection of the type of automatic yard operation as shown in the table. 3.

<Table 3> Factors for selecting the type of automatic yard operation

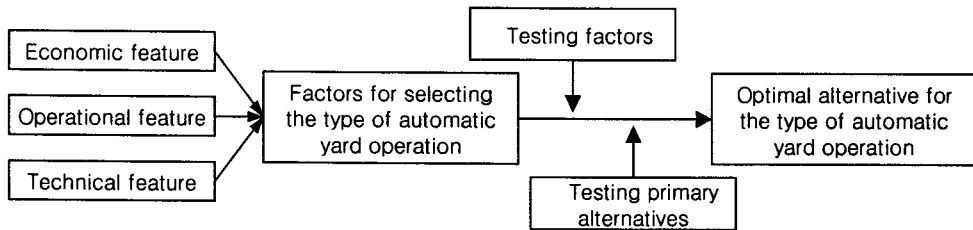
Factors for type selection	Attributes
Yard layout	Horizontal type, vertical type
Buffer zone	Existence, nonexistence
External Truck transfer point	Enter inside, at the end
Division of yard use	For transshipment, for import and export
Loading and unloading	Manned local control, unmanned remote control
yard crane	Difference of performance

III. Factor for Selecting the Type of Automatic Yard Operation

1. Research Model

For this research, the diverse situational features of domestic container terminals should, first of all, be taken into consideration. And these considerations can be divided into three aspects economic, operational, and technical. This study has prepared the primary alternatives based on the factors derived from the case study of overseas advanced container terminals, and then the primary alternatives have been tested by expert group in this field. Again, the modified alternatives have been analyzed from the aspect of investment cost and operating cost in order to suggest an optimal alternative.

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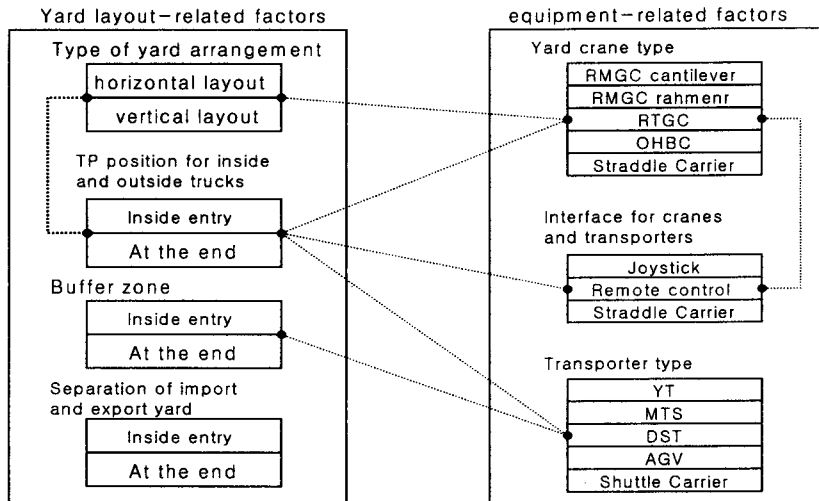


<Figure 11> Research Model

2. Factor Classification and Relationship between Factors

As mentioned in the chapter 2, the method of automatic yard operation of the overseas container terminal can be divided into two aspects: equipment and yard layout. Also equipment-related factors can be divided into the type of yard crane, interface between crane and transporter, and the type of transporter. Yard layout can be classified: the type of yard arrangement, TP location for inside and outside trucks, existence of buffer zone, and division of import and export yard.

Meanwhile, some factors related to the equipment and yard layout are affecting other factors. Because of this, it should be taken into consideration that what kind of equipment would be suitable for the work between outside-trucks and yard equipment. Yard layout and TP have also a close relationship. If a terminal has a vertical layout, it means that insides trucks and outside trucks have a separate workplace, and therefore TP is supposed to be at the end of the blocks. Let's take another example of relationship between factors. In case of a vertical layout, it is wasteful from the viewpoint of both economy and space to adopt an RMGC cantilever type, and if TP is located within the blocks, it brings difficulty on the AGV. Therefore, these relationships between factors become critical considerations in selecting the type of automatic yard operation.



<Figure 12> Relationship of Factor for Automatic Yard Operation

3. Features by Factor

Among the equipment-related factors, characteristics of yard crane and particulars to be considered during automation, were investigated through interview based on questionnaire held for fifteen days from April 10th, 2005 to April 25th, 2005, targeting 38 professional experts who are employed in actual container terminals and related institutions.

In this section the detailed features of the factors in each division will be described as well as important considerations. But some factors not suitable to the domestic container terminal environment will be eliminated. And based on selected factors, the initial alternatives will be made and go through testing process.

1) Features of Yard Equipment

First, the features of a yard crane and factors to be considered are as follows. Concerning cantilever-typed RMGC, It is easy for outside trucks and yard trailer (YT) to enter into and work inside the blocks, and safe work and full use of its yard space is possible. Also, as this equipment has a high productivity, it is preferred in the new investment. But its weak point is too expensive initial investment compared with Rahmen type. In order to make use of this equipment effectively, trucks and yard trailers has to enter inside the blocks, but in this case, loading and unloading of the trucks in the TP area are expected to meet with many difficulties.

In case of Rahmen-typed RMGC, the parking position of the transporters is possible either inside the block or at the end of the block. But in case that TP is inside the block, a measure for safety improvement has to be taken, and in case that TP is at the end of the block, a measure for productivity enhancement is required.

In case of OHBC, the productivity is higher than other equipment, but excessive costs are required (about twice as much as RMGC), and also it needs an additional structure for crane operation within the yard as well as an additional space. Because of this, this is not suitable to the domestic environment.

In case of Straddle Carrier, it is cheap and speedy in comparison with other equipment, but as it is impossible to stack up high (3-4 stacks), it causes a problem of productivity. In case of a low stacking, it requires a large space. Therefore, this equipment also is not fit for domestic environment.

In an effort to hear the opinions of experts specializing in this field, this study has made a survey of what kinds of yard crane are desirable for the automatic yard operation of domestic container terminals in the near future. As a result, among a total of 38 respondents, 22 persons have preferred a cantilever-typed RMGC, 14 have preferred Rahmen-typed RMGC, and 2 has preferred OHBC. This means RMGC can be an influential alternative.

2) Features of Transporters

Now take a look at the features of transporters of a container terminal such as YT (Yard Trailer), AGV, and other equipment, as well as considerations related to the automatic yard operation. In case of YT, as most domestic terminals are using YT, it is preferred in the economic standpoint and conventionality.

AGV is mainly used in the full automatic container terminal whose layout is closely related to the location of TP. When introducing AGV, TP is required to be placed at the end of the blocks, so that the productivity of AGV can be fully obtained without interference of outside trucks. But in case of domestic terminals that basically have a horizontal layout, introduction of AGV is likely to cause many problems in the operation of transporters. Owing to this kind of problems, PPT of Singapore and TMP of United Kingdom has abandoned introduction of AGV.

In case of PPT that uses OHBC, as AGV and inside trucks (manned) have to enter into the block simultaneously, interference has been taking place. Because of this, AGV introduction has failed. In case of TMP, the productivity coming from AGV introduction and initial investment amount have been compared and analyzed, but its profitability has not turned out satisfactory. In conclusion, AGV plan has been

postponed. These examples show that however excellent the new equipments, the current situation of a container terminal plays a critical role in its introduction.

Other equipments such as MTS (Multi-Trailer System), DST (Double Stacking Trailer), and Shuttle Carrier, have usually been introduced in accordance with the features of each container terminal. And when taking into consideration the domestic container's area size and the height of YT, the above-mentioned equipments have not been suitable to the domestic container terminals. Therefore these equipments also have been dropped from our research.

In the survey, as shown in the yard crane, 32 among a total of 38 respondents have preferred the use of YT, and only 6 have preferred early introduction of AGV in preparation for full automatic yard operation. Accordingly, the use of YT is supposed to be practical.

3) Loading and Unloading Control Method of Yard Crane

With regard to the work relationship between yard cranes and transporters, let's take a look at the features of these equipments as well as considerations related to the automation. As a way of yard operation, there are two ways: manned control of a yard crane and unmanned remote control of a yard crane.

In case of manned control, due to the labor union's claim and for the sake of safety, a worker rides on the yard crane at the time of loading and unloading. HIT of Hong Kong and OI of Japan belong to this manned control type. This type is different from automatic yard operation, but is important in reality. In case of manned control, it is not easy to save operating cost, but in case that trucks and containers are working together in a near place, manual work is quite effective.

In comparison with this, CTA and PPT is adopting an unmanned remote control type. Only part of loading and unloading job are performed by a worker in the remote control office. Accordingly, one worker can take care of 3-4 units of crane. Therefore, this type can much save labor costs, but as the control is being done in the distant place, an immediate action is not easy in time of trouble. So many additional devices including a variety of cameras and indicators are required for smooth work.

In case of Straddle Carrier, when the crane has unloaded containers in the yard, the straddle carrier loads containers on the trucks, and also unloads containers from the trucks for transportation. But this equipment needs not only manual operation, but also additional equipment purchase and additional space for operation. Because of this, the survey has shown that the straddle carrier is not suitable to the domestic container terminals.

According to the preference survey, 20 persons among 38 respondents have said that manned control on or near the crane is preferable, and 16 have said that remote control is desirable, and there are two who have not answered. As shown in the survey results, it means that many factors including labor union's opinion and labor cost should be taken into consideration.

4) Features by Factor of Yard Layout

Now let's see the features of each factor of the yard layout. In the previous chapter, the factors of the yard layout have been categorized by division, but they have close relationship between them. First of all, the most basic factor in the yard layout is whether it is a vertical type or horizontal type. According to this type, an operation method and diverse equipments will be determined. However, in addition to the yard layout, the TP for inside and outside trucks and yard crane have to be dealt with together.

In case of a horizontal layout, a yard runs parallel with a berth, and in this case a TP and a yard crane have a close relationship. If the TP is at the end of a block, it is easy for the yard crane to recognize the trucks, and safe. But as the yard crane's moving distance becomes longer, its productivity lowers. If trucks enter into the blocks, additional devices for recognizing them are needed, and also traffic jam caused by trucks and safety problem should be taken into consideration. In case of domestic container terminals, because of the relationship with existing container terminals and accumulated know-how on the horizontal layout, the survey shows that the horizontal layout is preferred.

The vertical layout is mainly applied to full automatic container terminal. So the traffic roads of AGV and outside trucks are separated to avoid the interference with each other. As the TP for outside trucks is located at the end of the blocks, it is easy for a yard crane to recognize the trucks and safe. However, as the TP is at the end of the blocks, the moving distance of the yard crane is too long, thus lowering its work productivity. As a result, it is not suitable in case of only yard automation.

In case of a buffer zone, TMP of the United Kingdom is using the buffer zone, and all the containers for import or unloading are to go through the buffer zone. The imported containers are usually placed on the blocks, and then they are transferred to the buffer zone and rearranged for smooth loading. In case of domestic container terminals, because of narrow space and too much investment, it cannot be a good alternative.

With regard to the yard layout, owing to accumulated know-how of most existing

container terminals, the horizontal layout has been preferred than the vertical layout. Also, due to the difference of working environment between domestic terminal and overseas terminal, the respondents' opinion on the separation of import yard and export yard and buffer zone has been in the negative.

Finally, the separation of import yard and export yard is being applied to the PPT of Singapore. PPT has a transshipment yard used by only inside trucks, and the import and export yard is used by outside trucks, using the cranes of manned control. In case of PPT of Singapore, the transshipment cargo accounts for about 85% of total cargo handling. Therefore, the yard separation is not suitable to the domestic container terminals whose transshipment cargo is about 40% of total cargo handling. To sum up, the factors to be considered in the initial alternative suggestion are shown in the <Table 4>.

<Table 4> Major Factors of Automatic Yard Operation

Yard layout type	TP position for inside and outside trucks	Interface for cranes and transporters	Yard crane type	Transporter type
Horizontal layout	Inside entry	Joystick	RMGC cantilever	YT
	At the end	Remote control	RMGC Rahmen	

IV. Alternatives for Automatic Yard Operation of Container Terminals

Based on the factors studied in the chapter 3, this chapter has produced initial alternatives, presenting the present value of total expenses per alternative, providing a guideline for a decision maker, and suggesting the relationship between cargo handling and cost/revenue analysis of the optimal alternative in an effort to support the validity of automatic yard operation.

1. Alternatives for Automatic Yard Operation of Container Terminals

<Table 5> is the research surroundings that can define the merits and demerits of the initial alternatives.

<Table 5> Research Surroundings

Section	Contents
Area	8.9 ha.
Block width	28.5 m 28.6 m (about 19 m in case of RTGC)
Block length	219.9 m
Bay length	12 m
Number of block in use of RMGC	Cantilever type: 5 units
	Rahmen type: 7-8 units
Number of RMGC in use	Cantilever type: 10 units
	Rahmen type: 15 units
Number of block in use of RTGC	7 ~ 8 units
Number of RTGC in use	15 units

For comparison of each alternative, we have supposed that one berth is newly built in the same size of area, and tried to choose an optimal alternative in consideration of cost aspect. In particular, we have to point out that the difference in the number of units in case of RMGC in our study comes from the research surroundings as showing the above <Table 5>. Based on these environments, this study has suggested 8 alternatives as shown in the <Table 6>. These alternatives have been composed of factors that have more than two alternatives. In case of a yard layout and transporters that have no alternative, a vertical layout and YT are supposed to be used.

Now let's see the merits and demerits of 8 alternatives as well as their cost analyses.

In case of alternative one, inside and outside trucks can enter into the blocks, and there should be a worker in the storage area for the operation of cantilever-typed RMGC, recognizing the arrival of trucks, and confirming their parking position for the sake of safety. Because of this, the purchase of additional equipment is required. When in use of cantilever-typed RMGC, work should be done at both sides of the block, so the roads for traveling and working need to be separated. Accordingly, initial investment and maintenance costs should be added. However, as trucks enter inside the blocks, the moving distance of RMGC is shortened, greatly improving the equipment productivity per hour.

Alternative two uses Rahmen-typed RMGC, which is a main difference with alternative one. Rahmen-typed RMGC has a storage capacity of 4 stacks and 6 rows, but cantilever-typed RMGC has a capacity of 6 stacks and 9 rows. Therefore,

Rahmen-type RMGC needs more equipments than cantilever-typed RMGC. Also in case of Rahmen-typed RMGC, trucks have to enter under the cranes for loading and unloading, and because of this, the safety problem is raised.

<Table 6> Initial Alternatives for deciding the type of automatic yard operation

Section	TP position for inside and outside trucks	Interface for cranes and transporters	Yard crane ty
Alternative 1	Inside entry	Manned local control	Cantilever-typed RMGC
Alternative 2	Inside entry	Manned local control	Rahmen-typed RMGC
Alternative 3	Inside entry	Remote control	Cantilever-typed RMGC
Alternative 4	Inside entry	Remote control	Rahmen-typed RMGC
Alternative 5	At the end of the block	Manned local control	Cantilever-typed RMGC
Alternative 6	At the end of the block	Manned local control	Rahmen-typed RMGC
Alternative 7	At the end of the block	Remote control	Cantilever-typed RMGC
Alternative 8	At the end of the block	Remote control	Rahmen-typed RMGC

However, compared with a cantilever type, it is cheap and provides enough space between the blocks, consequently causing less cost for truck traveling. Also, when in use of AGV at the time of full automation in the future, as the TP for trucks is put at the end of the blocks, this type is useful.

The main difference of alternative 3 from alternative 1 and 2 is that a worker in the control office performs loading and unloading of the truck cargo by remote control. A more important thing from the aspect of operation is that one person can operate many units of cranes, consequently reducing labor costs to a greater extent.

Alternative 4 is based on remote control and Rahmen type. So, it is convenient and has a merit in the operation standpoint, but because of increasing number of cranes, it has a drawback from the cost standpoint. Meanwhile, the main difference of alternative 5 to 8 in comparison with alternative 1 to 4 is that they have the TP for trucks at the end of the blocks. If the TP is located at the end of the blocks, the inside and outside trucks can be put at the fixed parking place. Therefore, it can greatly reduce a labor cost, but owing to the longer moving distance of cranes, the crane's productivity is to be lowered. In particular, in case of cantilever type, a space problem will be raised as mentioned previously.

2. Economic analysis for Automated Yard Operation by Alternatives

In this chapter, Net Present Value (NPV) method was applied to seize Break-even Point

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(BEP), targeting various alternatives presented previously for yard operation automation.

Yard operation automation method presented in this research uses NPV method, which differs from Internal Rate of Return (IRR), which executes evaluation after actual application, or Return on Investment (ROI), which analyses actual yield on investment. Also, a concrete forecasted scope can be seized and it is judged that in the future if methods like IRR are used complementarily, it enables more accurate feasibility analysis.

The costs related to the type of yard operation can be divided into two: initial investment and operating cost. Initial investment includes public works cost, electric work cost, and equipment purchase cost. Operating costs cover labor cost, energy cost, maintenance cost, and depreciation.

Public works cost includes ground improvement work cost, road construction and pavement cost, and accessory construction costs. Equipment purchase cost includes RTGC and YT purchase cost in case of a conventional terminal, and for automatic yard operation additionally includes RMGC (Rahmen and cantilever), YT, facilities and equipments related to the inside and outside trucks.

Labor cost includes the wages for truck handling, and control work in the remote control office. In case of energy cost, it is supposed that RTGC is ₩21,000 per hour, RMGC is ₩29,400 per hour, and YT is ₩15,120 per hour.¹⁾ Maintenance cost (meaning pavement cost) is supposed to be 1% of road construction and pavement cost. Equipment maintenance cost is 5% of equipment purchase cost. Accessory facility maintenance cost is 1% of accessory facility construction cost, and electric communication cost is 6.5% of electric communication construction cost. The depreciation period is supposed to be 30 years.

1) Average operation cost at A terminal in 2005

<Table 7> The costs related to the type of yard operation

		item	Cost(thousand Won)
Initial investment cost	Public works cost		32,985,000
	electric work cost		7,645,000
	Equipment purchase cost(EA)	RTGC	1,400,000
		RMGC(cantilever)	2,600,000
		RMGC(Rahmen)	2,300,000
YT		80,000	
Operating cost	Labor cost(per person)		4,000
	Energy cost	RTGC(per hour)	21
		RMGC (per hour)	29.4
		YT (per hour)	15.12
	Maintenance cost ²⁾	Pavement	1%
		Equipment	5%
		Accessory facility	1%
Electric communication		6.5%	

source : Data of Hyundai-Samho Heavy Ind., A terminal and BPA

Based on the same size of area (9.8 ha.), the cumulative cost (refer to the below formula) of the present value of each alternative has been compared with a conventional terminal as shown in the Fig. 13. In case of cantilever-typed RMGC (4 stacks and 9 rows), 10 units of RMGC in the 5 blocks and 20 units of YT are required. But in case of RTGC (4 stacks and 6 rows) and Rahmen-typed RMGC, 15 units of TC and 20 units of YT are required. As for labor cost, we suppose that it is 3-shift work system, monthly wages is ₩4,000,000 per person, and wage increase rate is 7% annually.

$$NPV = \sum_{i=0}^n \frac{C_i}{(1+d)^i} \quad i = 1, 2, 3, \dots, n$$

C_i : cost of i year

d : discount rate applied (on the supposition of 10%³⁾)

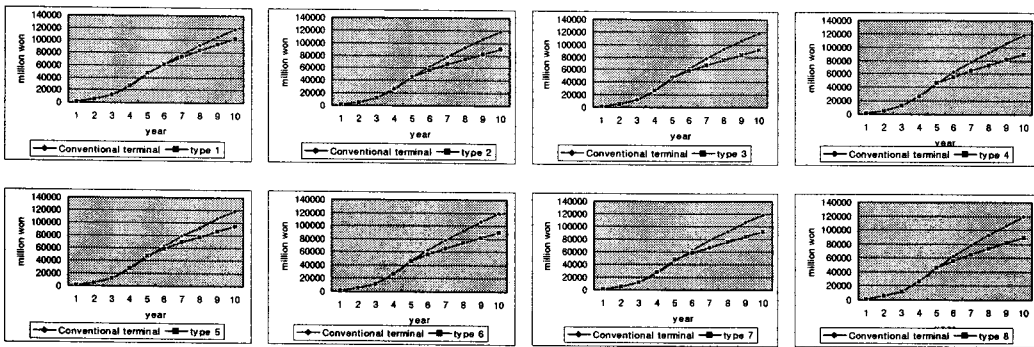
If the unreclaimed land has been used for the development of a berth, the land price could be increased by the reclamation cost in the initial investment. In the below <Figure 13>, the alternative 1, 3, 5, and 7 among the 8 alternatives is based on the

2) UNCTAD & KMI

3) The discount rate is generally applied 8% to case of port development in public work, but conservatively 10% to this study, for conventional terminal is more investment cost than automated terminal

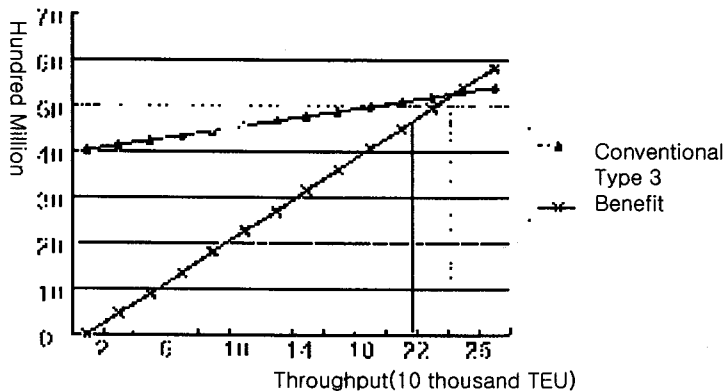
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cantilever-typed RMGC and the alternative 2, 4, 6, and 8 is based on the Rahmen-typed RMGC. Rahmen-typed RMGC costs much more than the conventional container terminal, because in case of 4 stacks and 6 rows, more units of equipment and more blocks are required, thus increasing costs. So, this cannot be an appropriate alternative.



<Figure 13> Comparison between Conventional Container Terminal and Alternatives

In case of cantilever-typed RMGC, if these alternatives move on from I to 7, the cost is reducing more quickly, compared with the conventional container terminal. However, in case of alternative 5 and 7, the TP for trucks is at the end of the blocks, and so it is not proper to use the cantilever type. As a result, the alternative 3 has become the best alternative.



<Figure 14> Break-even Point of Best Alternative

Fig. 14 shows the break-even points of both the best alternative and conventional

container terminal in consideration of cargo handling volume and initial investment and operating cost. The break-even point of a conventional type is about 240,000 TEUs, and that of the best optimal alternative 3 is about 200,000 TEUs. Accordingly, if a container terminal has 3-4 berths, the difference in the cargo handling volume become about 120,000 - 160,000 TEUs annually. If a new container terminal's period of return on investment is 5 years, the difference of more than 500,000 TEUs will happen during the five years.

In the cost analysis, fixed costs include maintenance cost and depreciation, and variable costs cover labor cost and energy cost. The maintenance costs are as follows: equipment maintenance cost (5% of equipment purchase cost), road pavement maintenance cost (1% of road pavement cost), accessory facility maintenance cost (1% of accessory construction cost), and electricity and communication cost (6.5% of electricity and communication construction cost). The depreciation of RMGC and TC is based on 30-year period.

$$\text{Fixed cost} = \text{maintenance cost} + \text{depreciation cost}$$

Variable costs include labor cost and energy cost. Labor cost includes the wages for CC engineers, remote controller, and TC engineers. In case of energy cost, it is supposed that the energy cost per hour for CC, RMGC, and RTGC is 60,000WON, 29,400WON, and 21,000WON respectively.

$$\text{Variable cost} = \text{labor cost} + \text{energy cost}$$

$$\text{Energy cost} = \text{equipment usage hour} \times \text{units of equipment}^{4)} \times \text{energy cost per hour}^{5)}$$

4) Number of TC per a block : 2

① Partially automated: cantilever-typed RMGC(10)

② Conventional: RTGC(15)

5) KMI, 1998

V. Conclusion

To be a hub port in the Northeast Asia and to secure a comparative advantage in the competition, each nation in this area is making every effort. The purpose of this study is to enhance the competitiveness of our container terminals. From now on, domestic container terminals will continue to try to expand their berths or construct new terminals. To this end, the primary tasks to be done are to take into consideration the budget scale and surroundings of domestic container terminals, and to decide the type of automatic yard operation. This study has tried to analyze the key factors to be considered in deciding the type of automatic yard operation as well as the analysis of economic factors.

However, not only various models related to container terminal yard operation automation must be considered, but also problems about various economical analysis for determining yard operation automation can be raised, or apart from economic aspect, technical and operational validity need to be considered from various points of view, in detail. Therefore it is suggested that when it is time for actual decision making, results that can provide more accurate information must be deducted.

Besides the above-mentioned studies, there are a couple of things to be considered for automatic yard operation. First, with regard to the yard allocation plan, many jobs that workers do manually in the conventional container terminal will be done by new systems. Therefore, measures for the new systems have to be taken. Secondly, outside trucks arrive at the gate, move to the TP, and recognizing the trucks' movement, an automatic crane performs its operation. Therefore, how to enhance the efficiency of these processes ought to be studied further, and also more investment in facilities will be required. In addition, more studies on the proper number of the crane according to each kind of job and the efficient way of block usage need to be made to improve the practicality of this study.

For this purpose, this study will include further analyses from different standpoints, consequently suggesting an optimal alternative, which is able to reflect the weight requested by a decision maker.

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