EVALUATION OF HANDLING SYSTEMS FOR CONTAINER TERMINALS

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ABSTRACT: The issue of adopting automated handling systems is critical for both newly developing container terminals and existing ones because related technologies are rapidly progressing. However, this always increases capital burdens on terminal operators and does not always guarantee increased productivity. This general aspect of automated systems is somewhat dependent on terminal characteristics such as labor costs. This paper, therefore, discusses the determination of handling systems, particularly with respect to Korea.

INTRODUCTION

The changes surrounding terminal operation such as developments in the fields of communication technology and information control as well as developments in handling equipment technologies are rapidly progressing. Several leading terminals in the world have introduced considerably high levels of such technologies.

The most critical aspect for terminal operators is the adoption of advanced technologies in terminal operation such as intelligent planning systems, operation systems, and automated handling systems. Planning and operation systems that are based on information technology (IT) and artificial intelligence (AI) are generally proven in many terminals and do not require much capital. Unmanned handling systems such as an Automated Stacking Crane (ASC) or an Automated Guided Vehicle (AGV) are, however, still uncertain in some respects and require much capital. Such consideration is a very complicated matter, and decision making is highly dependent on the characteristics of the terminal operation such as availability of land, local labor costs, a single or a multiuser, and land price or lease. Therefore, the evaluation of alternative handling systems is worthy of attention.

There have been a few studies on the evaluation of handling systems for container terminals. Recently Ballis et al. (1997) did a comparison between conventional and unmanned handling systems based on simulation methods. D'Hondt (1996) has also examined the feasibility of introducing unmanned handling systems to the Port of Antwerp. A similar study has recently been conducted in Korea by two overseas consultants: Jordan Woodman Dobson (JWD) from the United States and Korean Port Consultants (KPC) from The Netherlands. The study observed Pusan New Port which is currently under construction. This study examines both unmanned and conventional handling systems. Unlike the two former studies, this project is concerned with a huge terminal with an estimated yearly throughout of 2.55 million, twenty-foot equipment units (TEUs) targeting over 100,000 TEU vessels.

This paper will first provide a conceptual model for evaluating alternative handling systems, particularly for unmanned and conventional systems, and apply it to Korean terminals.

ADVANCED SYSTEMS FOR CONTAINER TERMINALS

Advanced systems for container terminal operation are focussed on the reduction and eventual elimination of labor through automation. The field of automation can be divided into planning and operation. The former mainly includes berth allocation, ship planning and yard planning, and the latter is subdivided into software and hardware; the software is the operating system (equipment control), and the hardware is the ASC and the AGV as seen in Table 1. In addition there are several elementary technologies related to terminal automation such as wireless communication, monitoring systems, networks, and databases.

For both the planning and operation systems, information technologies, artificial intelligence, and optimization models are so advanced that many container terminals have been adopting intelligent planning and operation systems. It is generally agreed that the intelligent systems reduce planning time, increase resource utilization, and significantly reduce labor. Therefore, there is no reason for terminal operators not to adopt the most advanced planning and operation systems, resulting in almost unmanned monitoring and resource allocation.

When regarding the hardware aspects, particularly container handling systems, most terminal operators may still have difficulty in choosing between the most advanced handling systems such as ASC-AGV or Thamsport systems, which were developed by Thamsport in England, and conventional handling systems also known as semiauto systems, comprised of partly automated equipment.

CONCEPTUAL MODELS FOR EVALUATING HANDLING SYSTEMS

Determinants for Handling Systems Selection

The main points for determining handling systems may be viewed in terms of cost and productivity. Of course any system with lower costs and higher productivity would be preferred. In addition, a number of other aspects surrounding a particular terminal operation might affect the appropriateness of automated handling systems. Broadly, these may include the main goals of terminal operation, terminal characteristics, and social/economic/cultural aspects (Table 2). The system characteristics may consist of cost, productivity, flexibility, and reliability. Due to inherent system characteristics, some aspects are more favorable for automated handling systems, whereas others favor conventional systems.

The main objective for terminal operation may vary for different terminals. For instance, most terminals will try to improve productivity, but some terminals, which have high labor costs or high-cost leases, will focus on reducing costs. For terminals having very high labor costs, automated handling systems are most appropriate. For terminals with high-cost leases, however, automated handling systems are inappropriate because they are usually capital intensive and labor saving.

Terminal characteristics are also influencing factors in determining automated handling systems. Small, single terminals or dedicated terminals are more adaptable to automated handling systems than larger, multiuser terminals because the more simple the terminal operation the more adaptable to automation. Land price or lease, cost also has effects because

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TABLE 1. Main Advanced Technology Systems for Container Terminals

Systems	Sub modules	Element technologies	Main effect
Intelligent planning systems	Berth assignment Ship planning Yard planning	Artificial intelligence Optimization models	Time reduction Maximizing space and equipment usage
Intelligent operating systems	Gate control Yard control Equipment control	Identification technologies Artificial intelligence Optimization models	Maximizing space and equipment usage Increasing productivity
Unmanned handling systems	Quay Crane (Q/C) ASC AGV	Identification technologies Control technologies	Labor saving

TABLE 2. Influencing Factors on Determining Automated Handling Systems

Aspects	Factors
System characteristics	Costs Productivity Flexibility Reliability
Main goal for terminal operation	Improving productivity Saving cost Improving level of services Saving labor Gaining automated technologies
Terminal characteristics	Single or multiuser terminal Small or large terminal Level of land price or lease Usable land space
Social/Economic/Cultural aspects	Labor cost and usable labor Skill of labor and contract of labor Diligence

there is more room for investment on handling systems if the lease price is low. Usable land space is usually a scare resource, and terminal operation emphasizes efficient use of storage space, resulting in higher stacks that may be a barrier for automated handling systems. The workable stack height for an existing automated handling system is about 2.5 units high, which is half the height of conventional systems.

Social, economic, and cultural aspects effect labor in areas such as labor cost, usable labor, skill of labor, and labor contracts. Labor costs are a significant part of any terminal operation and must be considered in any analysis of a marine terminal. Higher labor costs result in less room for investment on superstructure. A lack of skilled labor and inefficient union labor also encourage automated handling systems.

Consequently, choosing between automated handling systems and conventional systems is highly dependent on the environment and characteristics of terminals rather than the inherent merit and demerit of each system.

Evaluation Models

On the basis of the previous discussion, conceptual models for evaluating handling systems can be derived. Fig. 1 shows the comparison of the unmanned systems and conventional systems, with respect to system characteristics. Fig. 2 shows the result with respect to the main target of terminal operation and Fig. 3 with respect to characteristics of terminal operation.

Assumed the state-of-the-art of unmanned handling systems, the conventional system seems to be better than the unmanned system in all aspects. The lack of flexibility and reliability are some of the most prominent inherent defects of unmanned systems so far. Usually, automated handling systems claim to reduce labor costs, but it is often proven that these systems do not do this. This cost aspect might be relative, because there is a trade-off between high capital costs and low labor costs, according to the characteristics of terminals. Productivity seems to be a defect as well, mainly due to such things as the slower moving speed of equipment and lower stacking height.

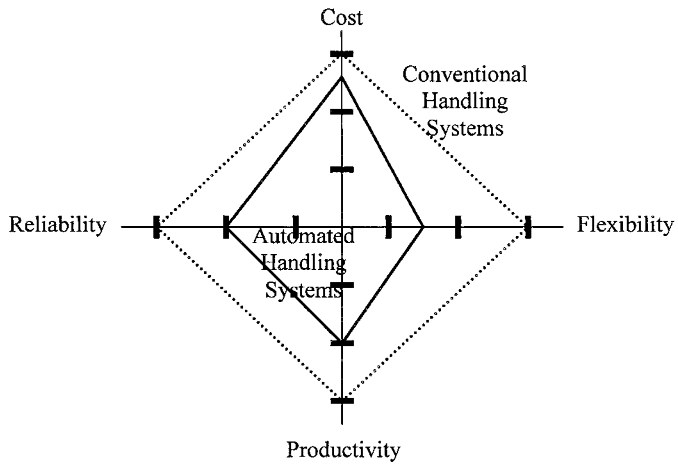

FIG. 1. Evaluating Handling Systems with Respect to System Characteristics

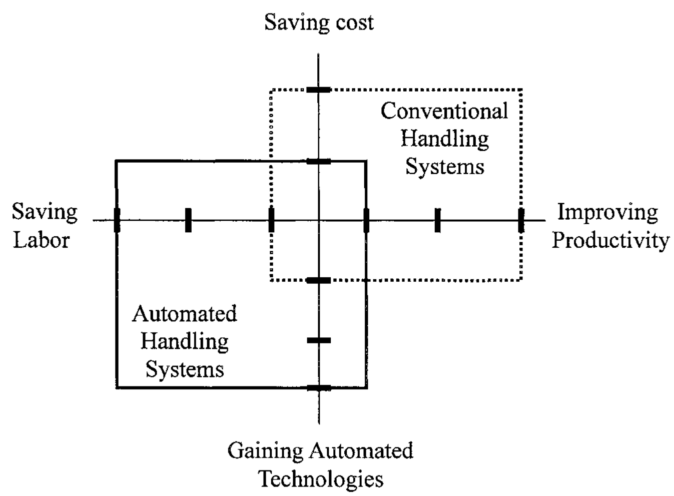

FIG. 2. Evaluating Handling Systems with Respect to Goal of Operation

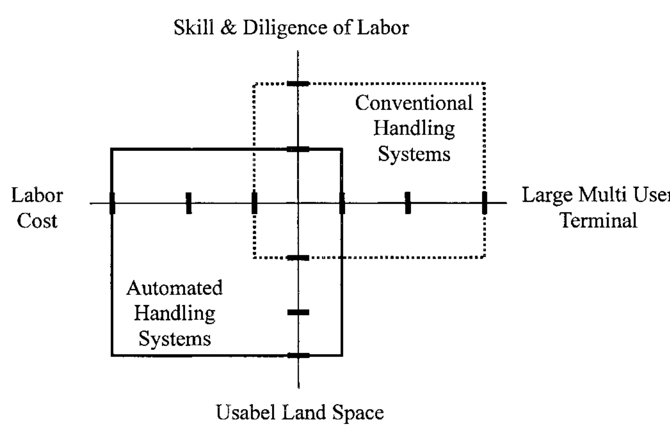

FIG. 3. Evaluating Handling Systems with Respect to Characteristics of Terminal

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The goal of terminal operation could be evaluated in conjunction with system characteristics. If the main goal of terminal operation is to save cost and to improve productivity, conventional handling systems are more favorable; whereas, in order to save labor and to gain advanced technologies, unmanned handling systems are more feasible.

Terminal characteristics could also be evaluated in conjunction with system characteristics. Conventional handling systems are more favorable for terminals having good labor available and offering service to multiusers, whereas unmanned handling systems are more feasible for terminals having high labor costs and sufficient land space.

EVALUATION WITH RESPECT TO KOREA

This section attempts to evaluate unmanned systems and the conventional system on the basis of the above evaluation criteria, especially with reference to Korean cases, specifically the Pusan New Port project and private terminals in Pusan and overseas that are operated by ''H'' Shipping Line. First, evaluation is carried out with respect to both cost and productivity, second with respect to the goal of operation, and finally with respect to the characteristics of terminals.

For the Pusan New Port project, both JWD and KPC have conducted comprehensive computer simulation analyses by using their own models: JWD's General Marine Terminal Simulation systems (GMTS) and Container Terminal Simulation Release 5 (CTS5), respectively. The models produced numeric data on terminal and equipment performance, service delays, resource utilization, and operating costs. Detailed information on GMTS can be found from the documentation provided by JWD (JWD, 2000), but for CTS5, partial information can be referenced with published material (Ballis et al., 1997).

TABLE 3. Basic Assumption of Simulation for Pusan New Port

Items	Unit	Unmanned system	Conventional system
Annual throughput	TEU	2,550,000	2,550,000
Lifts per ship	Lift	698	1,333
Quay crane productivity	Lift/H	27	25
Maximum number of guay cranes assigned per ship	Equipment	5	4
Seasonal peak	percent	120	120
Ship arrival pattern		40% of calls occur on the first two days of the week, and 60% is divided among the other five days	
Time taken for mooring and unmooring	h	3	3
Distance between ships moored	m	20	$20 + \alpha^a$
Dwell time	Day	7	7

[a]An additional length equal to 1.645 × the standard deviation of ship length modeled. Source: Derived from PNC (1999).

TABLE 4. Resources Required for Alternative Handling Systems

Resources	Unmanned system	Conventional system
Quay length	2,600 m	2,100 m
Number of quay crane	19	19
Total area	150 ha	117 ha
Stack height	3	5
Equipment type	ASC	RMGC
Equipment number	90	65
Equipment type	AGV	Y/T and chassis
Equipment number	120	140
Equipment type	S/C	Y/T and chassis
Equipment number	16	140

Note: ASC: Automated stacking crane; AGV: Automated guided vehicle; RMGC: Rail mounted gantry crane; S/C: Straddle carrier; Y/T: Yard tractor. Source: Derived from PNC (1999).

COST AND PRODUCTIVITY COMPARISON

Resource Comparison

The basic assumption for the simulation studies of Pusan New Port done by both JWD and KPC is shown in Table 3. As different entities have conducted simulation analyses for both unmanned and conventional systems, some assumptions are different between the two systems, such as lifts per ship, quay crane productivity, and maximum number of quay cranes assigned per ship.

The results reveal significant differences between the two systems, particularly with respect to quay length and stacking area. As shown in Table 4, the required quay length for the

TABLE 5. Number of Employees Required

Field	Unmanned system (A)	Conventional system (B)	Difference (B-A)
Equipment operators	536	994	−458
Maintenance	67	67	0
Information/Communication	50	50	0
Supporting/Marketing	100	100	0
Engineering	30	10	+20
Total	783	1,202	−419

Note: Source: Derived from PNC (1999).

TABLE 6. Capital Costs (Unit: One-Hundred Million Korean Won)

Items	Unmanned system (A)	Conventional system (B)	Difference (A-B)
Civil engineering costs	10,742	9,578	+1,164
Building	551	685	−134
Electricity/Communication	1,047	699	+384
Operating equipment	3,725	3,232	+493
Total ('98 constant worth)	16,065	14,194	+1,871

Note: About 1,300 Korean Won is equivalent to 1 United States dollar. Source: Derived from PNC (1999).

TABLE 7. Annual Operation Costs (Unit: One-Hundred Million Korean Won)

Items	Unmanned system (A)	Conventional system (B)	Difference (A-B)
Labor cost	278	438	−160
Fuel cost	172	133	+39
Maintenance costs	382	318	+64
Depreciation	358	263	+95
Total ('98 constant worth)	1,190	1,152	+38

Note: Source: Derived from PNC (1999).

TABLE 8. Productivity Comparison

Items	Unmanned system	Conventional system
Apron length (m)	2,600	2,100
Apron productivity (TEU/m)	980	1,214
Stacking yard area (m^2)	2,500 × 600	1,950 × 600
Stacking yard productivity (TEU/m^2)	1.7	2.2

Note: Source: Derived from PNC (1999).

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TABLE 9. Characteristics of Terminals (Unit: Percent)

Items	Korean Terminals				Overseas Terminals			
	Pusan A	Pusan B	Kwangyang D	Average	Tokyo	Osaka	Long Beach Calif.	Average
Lease	49	46.2	62.6	52.6	30.7	26.6	25.7	27.7
Labor	38	22	21.2	27.1	65	68	63.4	65.5
Fuel	4.9	5.3	6	5.4	3.4	5.1	2.4	3.6
Other	8.1	26.5	10.2	14.9	0.9	0.3	8.5	3.2
Total	100	100	100	100	100	100	100	100

Note: Source: Jung (1999).

unmanned system is 2,600 m, whereas that of the semiauto system is 2,100 m. The total area of terminal required is 150 ha for the former and 117 ha for the latter. These differences may have come from the maximum stack height of three for the former and five for the latter. The handling equipment, except the quay crane, shows a significant difference between the two systems, but it is not suitable to compare quantitatively due to the different types of handling equipment.

The number of employees also shows a significant difference in favor of unmanned systems. The unmanned operation of yard equipment requires 458 less operators than the conventional system, which is the most significant merit of that system (Table 5).

Economic Comparison

An economic comparison could be done in terms of capital cost and operating costs, including labor cost, fuel cost, maintenance cost, and depreciation. The unmanned system is known to require high levels of initial investment, which is compensated for mainly by lower labor costs. As shown in Tables 6 and 7, the capital cost and the operation costs are in favor of the conventional systems, resulting in 1,871 hundred-million Korean Won and 38 hundred-million Korean Won less than the unmanned system, respectively. The higher operation costs of the unmanned systems seem to result from relatively lower labor costs in Korea.

Productivity Comparison

Productivity is another critical factor besides costs for evaluating any type of handling system. Productivity could be measured in many forms, such as number of boxes per quay crane per hour. For a comparison of basic infrastructure of container terminals such as quay and stacking areas, the number of boxes per unit quay length (TEUs/m) and per unit stack area (TEUs/m^2) could be used.

As shown in Table 8, based on the target throughput of 2.55 million TEUs, both the TEU per unit quay length and the TEU per unit stacking area are in favor of conventional handling systems, showing 24% and 29% higher productivity, respectively.

Goal of Terminal Operation

Pusan New Port aims at achieving the position of being the hub port in Northeast Asia. This will require the most efficient operation utilizing the most advanced technologies and modernized facilities. At the same time, this new port needs to pay much attention to cost reduction. Unlike other ports in Korea, a huge amount of private capital needs to be invested there.

The main characteristics of Pusan New Port can be described as follows:

1. Huge private capital investment
2. Lack of usable land
3. Skilled labor
4. Reasonable level of labor cost

Huge private capital investment might push terminal operators to pay more attention to cost reduction. The lack of usable land space together with higher land prices require higher stacks of boxes. Skilled labor and reasonable labor costs are unfavorable for labor saving. Therefore, conventional handling systems could help Pusan New Port lower its costs and improve productivity.

Terminal Characteristics

Particular features of container terminals in Korea can be derived in comparison with those overseas that are operated by the same Korean shipping line on lease. As shown in Table 9, the average percentage of lease to total cost is 52.6 and 27.7 for the Korean terminal and the overseas terminal, respectively, whereas that of labor cost is 27.1 and 65.5, respectively. These are the most significant features of container terminals in Korea. The high level of lease for Korean terminals narrows the room for investment for superstructure such as more sophisticated information systems and unmanned handling systems. The relatively low level of labor cost makes the unmanned handling system less attractive.

CONCLUSIONS

This paper sets the criteria for the evaluation of handling systems, and applies them to cases in Korea. It was proposed that evaluating alternative handling systems be carried out based on system characteristics, the goal of operation, and terminal characteristics. With reference to the simulation studies done for Pusan New Port, it was proved that the conventional system is better than the unmanned system with respect to both cost and productivity. With respect to the goal of operation, the new port, with heavy pressure of capital investment, is more likely to seek ways that lead to cost savings. Pusan New Port therefore seems to be in favor of the conventional system. With respect to terminal characteristics, Korean terminals are featured as having relatively low labor costs and a high lease, which act in favor of the conventional system.

For the unmanned handling system considered here, it was revealed that the system needs to be cost effective and needs to overcome the present image of low productivity, resulting mainly from lower stacks and slower moving equipment.

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