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Comparison of Various Indicators for Measuring Operational Performance of Container Terminals
(Illustrative Case: Busan Port)
컨테이너 터미널의 운영성과 측정을 위한 제 지수의 비교 고찰
(부산항 현장자료를 중심으로)

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Abstract : Recently, the harbor function is being reconsidered with the viewpoint of logistics, and various efforts are given to enhance the harbor performance agglomerating all procedures of stevedoring, treatment and background transportation of freight. The harbor performance largely depends on the efficient combination of the engineering part of harbor construction and the forthcoming logistics part. It may thus be anticipated in the future that the design concept of harbor construction will be transferred to a comprehensive consideration integrating both engineering and logistics parts to maximize the ultimate harbor operational performance. In the present study, various indicators for assessing a modern container terminal performance are presented for the purpose of helping harbor engineers understand the fundamental logistics through container handling operations. The indicators are compared, analyzed and compiled, by referring to the practical cases of Busan and Gwangyang ports as an illustration.

Keywords : logistics, container handling operation, Busan port, Gwangyang port

요 지 : 최근 각국에서 대형항만 건설이 가속화되는 추세에서 화물수송의 국제적 우위를 점하기 위한 경쟁이 날로 치열해지고 있다. 따라서, 물류유통의 측면에서 항만기능이 재조명되고 있으며 화물의 하역, 처리 및 수송과정을 포함하는 일련의 항만기능의 생산성 제고를 위한 노력들이 경주되고 있다. 항만을 통한 물류유통의 효율 및 생산성은 항만시설과 운영체계의 효율적 결합을 통하여 가능하다. 과거에는 항만건설이 주로 공학적 측면에서 수행되었으나 향후에는 건설 이후에 발생하는 물류유통의 효율을 보다 정확히 고려하여 종국적으로 항만의 생산성을 극대화하는 방향으로의 전환이 시도될 것으로 전망된다. 본 연구에서는 항만기술자들의 이해를 돕기 위하여 항만을 통한 화물처리과정의 생산성을 평가하기 위한 제반 지표를 소개하였다. 아울러, 부산항과 광양항 컨테이너 터미널의 현장 데이터를 이용하여 각 지표들을 비교 평가하였으며 이들의 개선방향을 제시하였다.

핵심용어 : 물류유통, 화물처리과정, 부산항, 광양항

1. Introduction

In the past twenty years, the annual growth rate of the container ports throughput has been nearly 10% in average (Hamburg port statistics, 2003), and the forecasts for the next decade show comparable figures. In the meantime, the share of the twenty main ports has continuously increased, representing 53.6% of the global traffic in 2002

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(United Nations, 2003). Considering this concentration trend, these are expected to place their logistical practices within a process of continuous improvement.

In this view, the port communities and related organizations are currently trying to standardize their performance indicators, in order to reach a better level of transparency. However, the large variety of stakeholders involved in the port activities, each one with his own standards and interests, makes this standardization process long and uneasy.

This article will mainly focus on the role, interests, and measurement methods of the three main stakeholders involved in the container traffic as shown in Fig. 1. Shipping Lines, Port Authorities, and Terminal Operators. Then, a synthesized tool of performance measures is proposed, that takes into account each of these three stakeholders' aim and that could help in the standardization process.

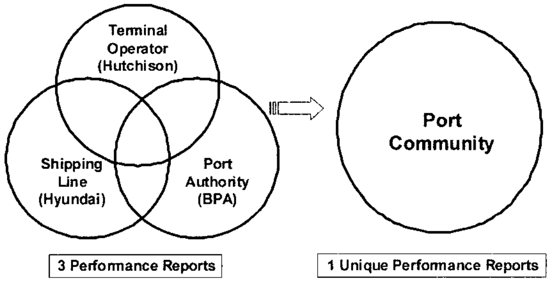

Fig. 1. Three main stakeholders involved in the container traffic.

2. The Stakeholders and Their Concerns

2.1 Shipping Lines

The daily operational concern of a shipping line is to manage its container and vessel fleet in the most profitable manner. Vessels are dedicated to regular maritime routes calling in a certain number of ports, according to a given schedule. Permanent changes and adjustments are brought in order to match a demand which constantly varies in this business.

The key issue, both for vessels and containers fleet management, is that these assets represent a considerable amount of fixed capital which must be constantly circulating in order to be profitable. Thus, shipping lines show the deepest concern for detention times. How long is my vessel about to spend in port before departure? As a consequence, port performance is above all a matter of productivity.

2.2 Port Authorities

Port Authorities are regulating the port organization. In most cases, they are not directly involved in daily operations. As they are responsible for the port planning and development policies, port authorities traditionally tend to focus on port traffic (container volume) and delay rates at the port entrance in priority. However, they are likely to adopt an enlarged number of performance indicators, depending on whether the port management structure refers to a "service port", a "tool port", or a "landlord port" (Gouvernal, 2003).

2.3 Terminal Operators

Private terminal operators have gained considerable growth and importance in the sea shipping industry, particularly in the last 15 years, as a result of the privatization processes launched on major world ports. As they are private companies, the stevedores' main purpose is to make business and money. The daily concern of a stevedore company is to reduce its costs and maximize its profits, that is, to make sure that manpower and facilities utilization constantly matches the volume of containers handled.

3. Origin of Statistics

3.1 PORT-MIS

There is one centralized information system and statistics provider for Korean ports called "PORT-MIS" (for PORT Management Information System). Basically, PORT-MIS copes with vessel and cargo movement activities in and out of ports. It is used to link ports with paperless administration, and it provides users with real time information about vessel departure/arrival, port facilities management and planning. However, PORT-MIS does not control the terminal and inland multimodal operations. Each stakeholder involved in port activity is connected to PORT-MIS, in particular port authority, customs, and shipping lines.

3.2 Stevedores computer systems

This unique and centralized computer system is in total contrast with the multiple and various measure tools used by the terminal operators to manage their operations (berth, yard, gate processes, equipment and labor allocation). Both at Busan and Gwangyang ports, it is an astonishing fact that no terminal is using the same tool, some provided by specialized software companies, others being developed and upgraded by stevedores themselves, even though they are performing exactly the same job. For example, the Korea Hutchison Company which operates both in Busan (Jaseongdae and Gamman Container Terminals) and Gwangyang, uses a "home-made" computer tool in Busan, while the Gwangyang terminal is managed by a tool (CATOS) designed by a private company.

An expectable consequence is that there is a small gap between the traffic statistics provided by PORT-MIS and those provided by the various operators' tool. The gap is varying from ±0.5% to ±1%, according to a Korea Hutchison representative. As little as it may seem, this 1% "error", is a striking concern, as there is no clear explanation for the cause.

4. Performance Indicators

Now, let's consider in detail the performance indicators used by the quoted stakeholders, and examine how to unify them and what improvements can be performed.

4.1 Traffic

4.1.1 Berth Traffic

An endless debate dividing the specialists is whether the terminal's container traffic should be registered in boxes or TEUs. Jaseongdae Terminal is a representative example, as the quay throughput is expressed in TEUs while the gate traffic is expressed in boxes. Both "TEUs" and "boxes" have their own advantages. "TEUs" reflects the real cargo volume, while "boxes" reflects the true number of moves, whether quay crane moves or any other container handling moves. As a result, "TEUs" are usually used for traffic (production) statistics, while "boxes" are preferred for productivity statistics, usually expressed as a number of moves per unit of time.

Moreover, while the port authorities closely control the status of each container (import/export/transhipment/coastal), operators and shipping lines just consider the loaded/unloaded TEUs. By doing so, the port authorities can get the feedback of any specifically oriented incentive policy, for example the incentive system to attract transhipment traffic.

4.1.2 Gate Traffic

Today's gate operation systems detect and register each truck move and container move according to proper electronic administrative documents. A truck entering the terminal is detected at the gate whether loaded (for container identification) or unloaded (in order to launch the process of container yard picking). In the same way, a truck leaving the terminal is registered whether loaded (for container identification) or unloaded (because of the limited number of trucks allowed to enter within the terminal area). Thus, the number of trucks, boxes and TEUs processing through the gates is duly registered. But what figure does best reflect the gate activity? Is it the number of trucks, the number of boxes, or the number of TEUs passing through the gate?

The truck throughput is not interesting because it only depends on the activity within the terminal, which is reflected by more relevant indicators. The Port Authorities usually choose the number of TEUs for statistics reasons, as it is more convenient to establish the relative shares of all modes for the inland transportation to and from the terminal. On the contrary, terminal operators prefer the number of boxes, for the previously quoted reason that each box reflects one handling operation.

4.1.3 Diverted Traffic

In a classical operational scheme, the planning of operations is completed many hours before the ship's arrival, with differences between the discharging plan and the loading plan. The discharging plan is easier to perform, as it only requests a sufficient area within the container yard. It is usually completed 4 or 3 hours before the ship's arrival. The loading plan is more complex to prepare, as containers have to be picked up in different places, with potential reshufflings. That is why the loading plan is usually completed 11 or 10 hours before operations in average.

However, it often happens that a vessel is diverted to another terminal due to berth congestion. This diverted traffic accounts for about 10% of the Jaseongdae terminal's throughput, which means that a substantial portion of handling operations are "improvised", according to available facilities when vessels arrive in port. This diverted traffic is controlled by the terminal operators, as it can explain a temporary drop of productivity due to lack of planning.

4.1.4 Vessel Size

The vessel size is controlled by both operators and port authorities, but for different reasons. Terminal Operators register the vessel size because the berth productivity depends on the number of box per call, which depends itself on the vessel size. They differentiate "large vessel" (more than 800 container movements) from "small vessels" (less than 800 container movements).

Port Authorities control the size of vessel in order to get a picture of mid/long-term evolution of the port as a feeder/hub port or a hinterland port. This time, vessel size is expressed in "Gross Registered Tons". The link between Gross Ton and TEU Capacity is not easy to establish, as it can vary from one vessel type to another. But one can give an approximate range: Feeders (<1,500 TEU) correspond most often to <20,000 GT. Larger vessels (1,500~4,000 TEU) correspond to 20,000~40,000 GT, and largest vessels (>5,000 TEU) correspond to >40,000 GT.

4.2 Productivity

On a container terminal, the productivity is expressed in moves per unit time alongside the berth. For a Shipping Line, this is a crucial indicator as productivity will determine how long the vessel will stay alongside the berth. For the Operator, this is a strong commercial argument.

Two indicators are expressed here as shown in Fig. 2: the vessel operating rate (VOR), defined as the total daily quay crane moves divided by the total vessel operating time, for all vessels (unit: moves per hour). And the gross crane productivity (GCR), defined as the total daily container moves divided by the total quay cranes operating time for all vessels (unit: moves per hour). In none of the cases is there any concern for the proportion of unproductive lifts.

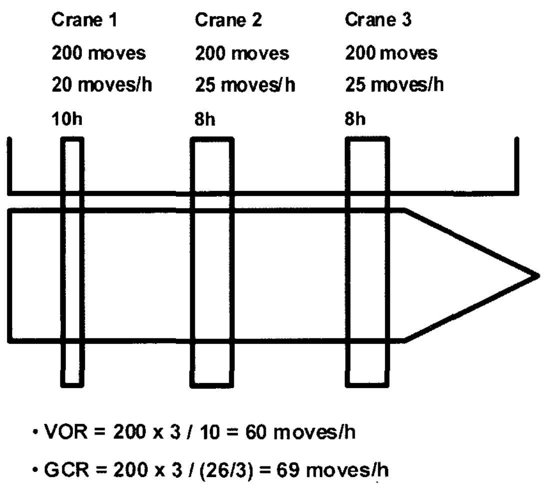

Fig. 2. Illustration of the difference between GCR and VOR.

Let's underline the difference between the GCR and the VOR with an example. Let's say that a vessel is operated by three quay cranes, including two new cranes and one "old" crane. As they are more productive, the two new cranes will complete work before the old one. But the vessel will have to stay alongside the berth until the job is fully completed. Here is the point: while the GCR gives an average productivity depending on the performance of each single crane new or old the VOR, on the contrary, only depends on the less productive crane. In other words, the GCR allows the Operator to promote its average productivity by taking into account each of its individual crane assets, while the VOR allows the Shipping Line to keep focused on the berth time.

Here are two additional remarks about terminal productivity. First, the shipping lines remain focused in priority on the average number of dedicated quay cranes servicing a vessel during the berth time, as it governs strongly the berth time. Four dedicated cranes and more must be assigned for the biggest vessels. Second, the shipping lines calling at one port don't make any distinction between the terminals situated within a same port, even though they are operated by different companies (This is true for Hyundai Merchant Marine, calling at three different terminals in Busan).

Finally, let us add that a vessel staying alongside the berth is not necessarily ready for loading/ unloading operations. Thus, the indicators of productivity should distinguish a "gross berth time" from a "net berth time" to issue more precise measures. The former would include the time for first and last operations like lashing/unlashing, placing/removing cones, opening/closing hatch covers between ship and dock, while the latter would only measure the time while the ship is ready for container operations.

4.3 Resource Utilization

4.3.1 Equipment Utilization

Equipment utilization is defined by Hutchison Company as the operation hours divided by the available equipment hours, supposing that the number of available equipment units is subject to prevailing maximum possible manning.

The various handling equipments are not equivalent, so their utilization is measured separately. By doing so, operators can rationalize the equipment needs respectively, and their utilization. For example, if the "Yard tractors" utilization rate is too high, this might be the cause of a bottleneck under the quay cranes. Operators can then invest in extra equipment, or try to find a new organization, by setting a pooling system instead of affecting each truck to one precise crane. Such changes are currently being considered favoured by technologies now allowing real time monitoring. Another example regarding the use of rubber tyred gantry cranes (RTGC): instead of booking one big exclusive area for one vessel's unloading, the planner is now booking many smaller exclusive areas situated in different yard lanes, which improves both yard productivity via a better RTGC utilization in parallel, and reshuffling rate.

4.3.2 Manpower Utilization

Here again, the manpower utilization is calculated with regard to the different types of equipment, because labour agreements and work hours are different from one type of operator to another. It is calculated as the actual working hours divided by the net attendance hours. Other aspects are also taken into account in calculations, like meal break times.

4.3.3 Yard Density

The yard density ratio provides both operator and its customers a valuable indicator of current operations level of difficulty, because the higher the density, the more the needs for reshufflings. The yard density ratio is situated between 45% and 60% in average on Jaseongdae terminal. The container stacking total capacity (100%) depends on the number of ground slots and the number of stacking levels. Yard density is measured in TEU/. The considered surface must not be the total terminal surface but only the yard surface.

4.3.4 Annual Handling Capacity

While it is designed, a container terminal is given an "annual container handling capacity". However, when comparing the handling capacity and the actual throughputs in the Busan terminals' case, it appears that they handle more than they are supposed to be able to (Jaseongdae capacity: 1,200,000 TEUs per year; Jaseongdae throughput in 2003: 1,584,429 TEUs. The same observation can be made on other terminals). This is first due to the "off-dock" facilities out of the terminals, which increase the actual traffic capacity. A second reason is related to the definition and designing of this "annual handling capacity", as we may see now.

The annual handling capacity is defined as follows: Yard Stacking Capacity/(Peak Factor x Segregation Factor) × (365/Free Storage Days). The peak factor (usually: 1.30) reflects the seasonal effects and discontinuities in demand. The segregation factor (usually: 1.30, and between 1.20 and 1.70) reflects the fact that slots are dedicated to specific categories of containers (reefers, dangerous, import, export...) and, as such, cannot be used in total freedom. And free storage days are usually seven days. One understands here that these values partially depend on the terminal manager's will. In order to increase the capacity of his terminal, the operator can reduce the free storage days, or reduce the segregation factor. Thus, the "annual handling capacity" is not necessary a "maximum capacity".

4.3.5 Berth Occupancy

The berth occupancy ratio is defined as follows: total berthing time/(berth number × hours (24) × day). Port Authorities prefer to have a high ratio, while shipping lines prefer a low ratio, for the obvious reason that high ratio means optimized port infrastructure utilization, whereas low ratio means no waiting time for berth. However, port authorities are more interested in those indicators in the long term, as they impact the decision to build new terminals.

4.4 Punctuality

4.4.1 Delayed Vessels

Port Authorities distinguish "delayed" vessels (more than 2 waiting hours for a berth) and "congested" vessels (more than 12 waiting hours). Terminal operators also distinguish the waiting times for "small" and "large" vessels. Priority rules are in favor of biggest vessels.

The shipping lines pay particular attention to punctuality, as any late in planning has immediate repercussions on the next port of call. A late at one port can even lead the vessel to skip the next step in order to keep the sched-

Table 1. Busan Schedule Punctuality (source: 2004, HMM simplified monthly report)

		0-6 Hrs (=on time)	6-12 Hrs	12-18 Hrs	18-24 Hrs	24-36 Hrs	36-48 Hrs	> 48 Hrs	Skip	Total
		Arrival at Busan / Berth operations / Departure from Busan								
% of Punctuality		47/46/47	5/5/4	5/6/5	6/6/5	9/9/9	3/3/7	19/19/17	6%	100%
Route 1	East	90/90/90		10/10/10						100
Route 1	West	20/20/20	40/40/20		0/0/20			40/40/40		100
Route 2	East	80/80/80	20/20/0	0/0/20		50/50/25	25/25/50		29	100
Route 3	East	0/0/25	25/25/0							100
Route 4	South	100/100/100							33	100
Route 5	West	60/60/60		40/40/40					25	100
Route 5	east	75/75/75	0/0/25	25/25/0						100

ule. Delays are also difficult to manage for terminal operators, as the berth plans have to be remodeled.

Table 1 gives a simplified example of a monthly punctuality report.

4.4.2 Truck Time

The truck turnaround time reflect the time spent by the truck in the terminal. Recent improvements have made it possible to measure it in real time. However, it does not take into account the outside waiting time in queue before entrance admittance. Moreover, trucks passing through the gate can handle either one single container (20 foot or 40 foot length) or two containers (20 foot length), and either for one way or a round trip. Of course, the turnaround time depends on these particular aspects, which are ignored here.

4.4.3 Reliability

Shipping lines defines reliability in terms of punctuality according to an established plan (Hamilton, 1999). This includes the operator's ability to predict how long the operations are going to take until completion. Improvements have been made recently, thanks to real time information technologies. Operators now offer real time information on their website, like "expected time of arrival/berth/ departure", "expected time of completion", "starting/ closing time" and even the loading/unloading rates per crane.

4.5 Efficiency

Efficiency can be defined as the proportion of "valuable" container moves within the terminal area, compared to the total number of moves, including re-handlings and reshufflings. Little work has been published about that subject, because it needs a precise and differentiated analysis of container moves within the yard, while the operators' like to keep this kind of statistics confidential. However, some indicators have been built previously to reflect the efficiency of quay/yard operations in a proper manner (Robinson, 1999). Two of them are listed in the final synthesis below.

4.6 Synthesis

After describing the features and operations of a container terminal by considering the example of port of Busan, we examined and classified a range of performance indicators with accordance to respective port stakeholders' interests. By describing all those differences, we have been able to complete our measures tool further and further. Table 2 provides a synthesis of the indicators that have been discussed and criticized in this study, with units and definitions. Some of these are currently in use; others are not, as quoted above. One can rank them into five main families:

- Production (traffic)
- Productivity (traffic per unit of time)
- Resource Utilization (equipment and manpower)
- Punctuality (according to a time schedule)
- Efficiency (proportion of valuable container moves)

Operational performance can be defined as a combination of these five main components.

6. Conclusion

This tool has been suggested to reflect the operational

Table 2. Synthesis of performance indicators

PERFORMANCE INDICATORS	Definition	Unit	Data Provider
PRODUCTIVITY			
Gross Quay Crane Rate	total daily quay crane moves divided by total quay crane operating time for all vessels (Large / Small vessel)	moves/hour	Stevedore
Net Vessel Operating Rate	total daily quay crane moves divided by total vessel operating time for all vessels (Large / Small vessel)	moves/hour	Stevedore
Gross Vessel Operating Rate	total daily quay crane moves divided by berthing vessel operating time for all vessels (Large / Small vessel)	moves/hour	Shipping Line
TRAFFIC			
Loading / Unloading		TEU	Steved / Ship Line
Import / Export / Transshipment / Coastal		TEU	Port Authority
Diverted to / from other terminals		TEU	Stevedore
Full / Empty		TEU	Port Authority
Number of Vessels (Large / Small)	Large = > 10,000 Ton and > 800 moves	Vessel	Port Authority
Gate Movement	number of containers passing through the gate (enter / exit)	Box	Stevedore
RESOURCE UTILIZATION			
Yard Density	100×number of TEU in the yard / yard capacity (Full / Empty containers)	%	Stevedore
Berth Occupancy	100×total berth time for all vessels / total considered period	%	Steved / Port Authority
Equipment (QC / RTGC / YT / Reachstackers / Forklifts)	100×operation hours / available equipment hours	%	Stevedore
Manpower Utilization (QC / RTGC / YT / FL Operator)	100×actual working hours / attendance hours	%	Stevedore
Crane Split	average number of cranes per vessel (Large / Small vessel)		Shipping Line
PUNCTUALITY			
Average Vessel Waiting Time	total berthing delay time of vessels / total number of vessles departed in the considered period (Large / Small)	moves/hour	Ship Line / Port Authority
External Truck Turnaround Time	total time spent within the terminal area	Minute	Stevedore
% of > 1Hr			
Stevedoring Reliability	Stevedore's ability to perdict time of completion		Steved / Ship Line
EFFICIENCY			
Vessel planning efficiency	100×number of containers (import+export+TS+coastal) / total number of QC moves	%	Stevedore
Yard storage efficiency	100×number of containers entering or leaving the yard / tatal numer of container lifts within the yard	%	Stevedore

performance of a container terminal, in the most complete manner. Comparisons can be made between terminals possible, even though the terms of definitions may have to be adapted to specific cases.

However, if the global competitiveness of a port is at stake, the operational performance is just an aspect among others that will impact the choice of one port of call. There are a full range of factors that have to be examined (geographical, economical, financial and commercial, institutional) which don't deal with operations but deserve consideration.

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