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## **Performance Measurements of Container Terminal Operations**

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### **Abstract**

*In the world, all ports are unique, and the task of measuring and analyzing performance is not simple and is made more difficult by the failure to establish industry standards on what to measure, how to measure it and how to express the measure in an informative and consistent manner. This difficulty is compounded by the fact that there is no single measure that can sum up all the important aspects of port or terminal performance. This study aims to analyze the existing literature about performance measures of container terminal operations.*

**Key Words:** Performance, Port, Terminal, Container, Measurement

### **INTRODUCTION**

Maritime transportation plays a major role in the national and international trade and economic growth. The seaborne trade represents more than 90 percent of the international trade in the world. A seaport is defined as a terminal and an area within which ships are loaded and/or unloaded with cargo and includes the usual places where ships wait for their turn or are ordered or obliged to wait for their turn no matter the distance from that area. It has

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interface with other forms of transport and in so doing provides connecting services. In general seaports have five principal roles (Branch, 1986):

- a) Cargoes and passengers handling.
- b) Providing services for ships such as bunkering and repair.
- c) Shelter for ships in case of heavy sea and storm conditions.
- d) Bases for industrial development.
- e) Terminals forming part of a transport chain.

Port efficiency is an important requirement in order to survive in the competitive world of shipping industry. Different facilities in the port are

expensive to run and purchase. Hence, under-utilizations will result in capital loss and higher cost for running the port. However, inadequate facilities result in delays which in turn lead to capital and customer loss (Tahar and Hussain, 2000). And also ports form a vital link in the overall trading chain and, consequently, port efficiency is an important contributor to a nation's international competitiveness (Tongzon, 1989; Chin and Tongzon, 1998).

Seaports are complex dynamic systems consisting of numerous interacting elements, influenced by random factors. Hence, full utilization of the available resources and efficient management of operations are two major goals. Under these two goals many objectives will be achieved such as increasing the port throughput and utilization of resources (berths, cranes, quay, yards, etc.), reducing handling time, minimizing port congestion, minimizing disruptions, demurrage and operating costs (Tu-Chang, 1992).

The rate of growth in world trade has been strong and since the mid-1980s, it has consistently exceeded that of world output. Rising trade is linked to the increasing integration of national economies across the globe, the deepening of the international division of labour, and the concomitant emergence of increasingly internationalized production patterns. These developments have greatly increased the difficulties of monitoring a port's performance (Park and De, 2004).

The effects of poor port performance on a country's trade have become too obvious. According to Thomas and Monie (2000), ports and terminals must measure their performance. The measurement of port or terminal efficiency is of particular importance because they are vital to the economy of the country and to the success and welfare of its industries and citizens. There are many reasons why a port or terminal needs to measure its performance:

- First, it needs to know how effectively it is operating. How much cargo it handles every day? How many customers does it serve in a week?
- Next, it must know how efficiently it is operating. What resources (in terms of people, machines, surface area etc) does it take to carry out its activities? How much cargo does it handle per employee? How much does it cost to handle each tones of cargo?
- It needs to know how its present performance compares with past performance. Is it handling more cargo per employee or machine than last year? Is there any improvement in efficiency?
- Any business needs targets, and must compare its performance with those targets. Has the port or terminal achieved the production targets set at the beginning of the year? Has it beaten its traffic targets?
- It is important for a port or terminal to compare its performance with that of its competitors, particularly relevant with the use of benchmarking. Where is it in the league table of best in class of similar businesses? Is it climbing that table or falling behind.
- In the light of its present performance, it needs to adjust its targets for future periods. How much better in terms of effectiveness and efficiency should the company be by the end of the next trading year.
- Finally, there is the need to promote its business and to attract new customers, so it must constantly monitor how satisfied its customers are with its services and facilities.

For all these reasons, it is vital that port/terminal managers measure its performance, set performance targets, and then regularly assess its performance against those targets.

## **1. MEASURING PORT PERFORMANCE**

Understanding performance is a concept fundamental to any business, whether it is the measuring of achievements against set goals and objectives or, against the competition. Ports are no exception and it is only by comparison that performance can be evaluated. Ports are, however, a complex business with many different sources of inputs and outputs which make direct comparison among apparently homogeneous ports seem difficult (Valentine and Gray, 2002).

The port industry like any other industry measures its performance. Such measurement has been focused on productivity indicators. Performance appraisal is a requirement for the development of any economic activity and the literature offers different definitions of performance (Marlow and Casaca, 2003). Mentzer and Konrad (1991) define performance as an investigation of effectiveness and efficiency in the accomplishment of a given activity and where the assessment is carried out in relation to how well the objectives have been met.

UNCTAD (1999) suggests two categories of port performance indicators: macro performance indicators quantifying aggregate port impacts on economic activity, and micro performance indicators evaluating input/output ratio measurements of port operations (Bichou and Gray, 2004).

Traditionally, the performance of ports has been variously evaluated by calculating cargo-handling productivity at berth (Bendall and Stent, 1987; Tabernacle, 1995; Ashar, 1997), by measuring a single factor productivity (De Monie, 1987) or by comparing actual with optimum throughput over a specific time period (Talley, 1998). In recent years, significant progress has been made concerning the measurement of efficiency in relation to productive activities. In this vein, two more complex, yet more

appropriately holistic approaches, named Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA), have been increasingly utilized to analyze port production and performance (Culliane at all, 2004, Sanches at all, 2002).

Complexity of the different seaport operations often results in difficulties in using analytical tools as a method of investigation. In such a situation, computer simulation provides a powerful tool to analyze the port performance (Tahar and Hussain, 2000). Simulation has been widely used and applied for the planning and management of the port system (Borovits and Ein-Dor, 1990; Hassan, 1993; Collier, 1980; Merkuryev et al., 1998; Geert and Janssens, 1998; Gambardella et al., 1998). Tongzon (1995) suggested that attention should be paid to this information when developing a port reform aimed at improving port performance methods as this provides a clear distinction between port efficiency and effectiveness. Consequently, port performance indicators have been classified into two broad categories, financial and operational.

**Table 1: Summary of performance indicators suggested by UNCTAD**

Financial indicators	Operational indicators
Tonnage worked	Arrival date
Berth occupancy revenue per ton of cargo	Waiting time
Cargo handling revenue per ton of cargo	Service time
Labor expenditure	Turn-around time
Capital equipment expenditure per ton of cargo	Tonnage per ship
Contribution per ton of cargo	Fraction of time berthed ships worked
Total contribution	Number of gangs employed per ship per shift
	Tons per ship-hour in port
	Tons per ship hour at berth
	Tons per gang hours
	Fraction of time gangs idle

**Source:** UNCTAD (1976).

**Table 1** presents the traditional port performance indicators that underlie productivity and effectiveness measures as suggested by UNCTAD (1976) and have been used as a reference point (Marlow and Casaca, 2003).

Some approaches look at ports as business organizations with performance measurement based on profits. For instance, Leonard (1990) analyses port performance and comparison from a value-added perspective. ‘Value-added’ in this context is defined as the difference between port revenues and port costs, and varies according to ship and cargo types. Conceptual and organizational differences explain the variety of measures, but also underline the difficulty and complexity of port performance measurement and comparison. As long as there is no unanimously accepted approach to the roles and functions of ports, the subject of what and how to measure will remain debatable (Bichou and Gray, 2004).

## **2. PERFORMANCE MEASUREMENT OF CONTAINER TERMINAL OPERATIONS**

Container terminals are facilities for transferring containers between different modes of transport and provide a package of activities/services to handle and control container flows from vessel to railroad, or road, and vice versa.

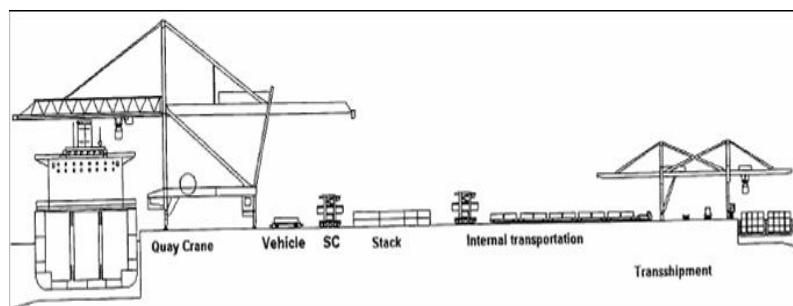
Fourgeaud (2000) implies that container terminals performance depends on:

- Ratio loaded vs. unloaded containers: empty boxes are not always included in the port statistics (they may be considered as other tare weights) but have to be handled;
- Unproductive moves, i.e., the handling of all the containers that do not have to be unloaded but have to be moved: mostly empty and light containers and those containing hazardous materials, loaded on top or on the deck;
- The level of automation of the gantry-cranes; one of the limiting phases of the handling cycle is the time spent positioning accurately the spreader on a container (loading), or the container on a trailer, a MAFI trailer

(specialized equipment used to shift containers within port limits) or a chassis maneuvering on the apron (unloading). Most modern gantries are automated and equipped with anti-sway devices, and now, the problem is more the capacity to deliver or remove containers without delaying ship-to-shore operations.

- The average weight of containers and the proportion of containers requiring special attention: flats, liquid bulks, reefers etc.; and the mix of containers of various sizes: 20'/40'/45' which will require to maneuver or change spreaders;
- Commercial constraints; most of the lines calling at a port may have similar commercial constraints, leading to unevenly distributed calls.

**Figure 1: Process of unloading and loading a ship.**



**Source:** Vis and Coster, 2003.

The main activities shown in **Figure 1** that make up the whole container port operation can be broken up into the following (Koh and Ng, 1994):

**Berth operation:** The berth operation concerns the schedules of arriving vessels and the allocation of wharf space and quay crane resources to service the vessels. The port is fully equipped to handle almost all types of vessels. The key concern of the berthing operation is the turn-around time of vessels.

**Ship operation:** The ship operation involves the discharging and loading of containers onboard the vessel. This is handled by quay cranes working in synchronization so as to maintain safe separation from each other. To achieve high crane rates (number of containers moved per hour), the planner has to optimize the crane working sequence (a detailed list of crane moves), so that there would not be any clash involving neighboring cranes and at the same time ensure a smooth feed rate of prime movers to cart away (discharge) and send (load) containers to the quay cranes.

**Yard operation:** The yard operation is perhaps the busiest of all the activities in the terminal. The operation involves discharging of containers from the vessels, loading of containers onto vessels, shuffling of containers that are out of sequence, in the yard block, redistribution of containers to other blocks (yard shifting) for more efficient loading onto the second vessels and inter-terminal haulage where containers are moved to other yards in another terminal.

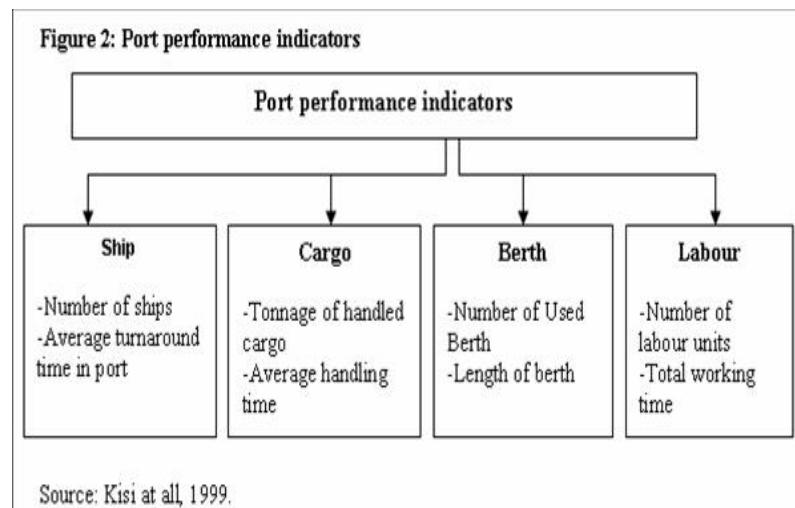
**Gate operation:** The gate operation deals with external freight forwarders. Two activities are involved, namely export delivery where the freight forwarders bring in export containers to the yard or wharf to be loaded onto the vessels, and import receiving, where the freight forwarders receive containers from the yard or wharf to bring into the country.

**Scheduling:** This is the function that ensures the various resource pools, such as the prime mover, yard crane and other container handling equipment pools, are utilized efficiently given the constraints and other conflicting demands on them.

### 3. CLASSIFICATION OF CONTAINER PORT PERFORMANCE MEASURES

The container terminal is the physical link between ocean and land modes of transport and a major component of the Containerization System. Container terminal productivity deals with the efficient use of labor, equipment, and land. Terminal productivity measurement is a means to quantify the efficiency of the use of these three resources (Dowd and Leschine).

There are many classifications of measuring performance of a container terminal. Kisi at all (1999) classify the port performance indicators in to four levels, these are shown in Figure 2.



Hassan and et al (1993) and Hassan (1993) suggested that complicated interconnected port operations are divided into four categories:

1. Ship operations,
2. Cargo handling,
3. Warehousing,
4. Inland transportation.

This model can be used to evaluate different performance indicators to perform port improvement analysis, to study port expansion possibilities, to estimate future view of the port and economic impact evaluation.

On the other hand, there are many ways of measuring port efficiency or productivity, although reducible to three broad categories: physical indicators, factor productivity indicators, and economic and financial indicators (Trujillo and Nombela, 1999).

Physical indicators generally refer to time measures and are mainly concerned with the ship (e.g. ship turnaround time, ship waiting time, berth occupancy rate, working time at berth). Sometimes, co-ordination with land modes of transport is measured, e.g. cargo dwell time or the time elapsed between cargos being unloaded from a ship until it leaves the port. Factor productivity indicators also tend to focus on the maritime side of the port, for example to measure both labour and capital required to load or unload goods from a ship. Similarly, economic and financial indicators are usually related to the sea access; for example, operating surplus or total income and expenditure related to gross registered tonnes (GRT) or net registered tonnes (NRT), or charge per twenty foot equivalent unit (TEU) (Bichou and Gray, 2004).

Thomas and Monie (2000) suggested that the measures can be divided into four categories also. These are production, productivity, utilization and service measures.

### **3.1. Production Measures**

These are the level of activity of the business. In the ports industry a number of different terms are used to represent this category such as 'trade', 'traffic', 'throughput' and 'output'. Traffic measures, which indicate in various ways the quantity of cargo passing through a port or terminal in unit time, and throughput measures, which indicate the effort involved in moving that cargo, in terms of tonnes handled or containers movements per unit of time.

Throughput measures include:

- **Ship throughput:** Measures the entire activity involved in loading and discharging vessels in a given time period (a shift, day, month or year).
- **Quay transfer throughput:** Measure of the number of tonnes or containers moved between the quay and the storage areas.
- **Container yard throughput:** This is the sum of the movements that take place in the storage areas.
- **Receipt/delivery throughput:** Measure of the activity relating to the delivery of outbound cargo or containers the port or terminal and collection of inbound cargo.

Each of them is expressed as container moves/unit of time. The value of this measure is very important when estimating resource needs and the actual costs of handling the cargo.

### 3.2. Productivity Measures

Productivity Measures calculate the ratio of output to input. Productivity measures are particularly important to the terminal operator as they are directly related to the cost of operating the terminal. There are seven different productivity measures which terminal operators need to compute, although they may wish to include others for monitoring their productivity. These core productivity measures are:

- **Ship productivity:** The broadest measures of ship productivity relate container handling rates for a ship's call to the time taken to service the vessel.
- **Crane productivity:** Crane productivity is calculated per crane and can be expressed in gross and net values.
- **Quay productivity:** Defines the relation between production and quay resources. The latter can be measured by defining, for a given unit time, the length of a typical berth (which will then produce a 'berth productivity' figure) or by working on the basis of a particular length of quay or per meter of quay.

- **Terminal area productivity:** Similar to the quay productivity indicator is the measure of ‘terminal area productivity’ which applies to the entire terminal and expresses the ratio between terminal production and total terminal area for a given unit time.
- **Equipment productivity:** The value that is of interest is the number of container moves made per working hour, either for an individual machine or for the stock of a particular type of machine. The number of moves can be deduced from data collected per
- **Labour productivity:** Even with a high level of mechanization, labour costs still form a large part of total terminal costs and it is important to monitor labour well and know what the productivity per man-hour is over a measured period.
- **Cost effectiveness:** This brings the all- important element of cost into the equation. Perhaps the simplest and most revealing measure of a terminal’s efficiency is the cost of handling its container traffic or throughput over a specified period (typically a month or a year).

### 3.3. Utilization Measures

Utilization Measures allow management to determine how intensively the production resources are used. The most common and most relevant utilization measures are:

- **Quay utilization:** This measure reflects the amount of time that the berth was occupied out of the total time available.
- **Storage utilization:** It is calculated by comparing the number of storage slots occupied with the total number of available slots according to the yard’s design capacity.
- **Gate utilization:** The smooth and rapid processing of incoming and outgoing road vehicles at the gate is a very important factor in efficient terminal

operations. Thus, gate utilization is a valuable measure for container terminal operators.

- **Equipment utilization:** Because the terminal's investment in cargo-handling equipment is very costly, equipment utilization is an extremely important performance measure. The utilization of any item or type of equipment is defined as the proportion of time that it was effectively deployed over a specified period.

### 3.4. Services Measures

These measures indicate the satisfaction of the customers with the services offered to them in terms of reliability, regularity and rapidity.

The principal external service measures include:

- **Ship turnaround time:** One of the most significant indicators of service to ship operators is ship turnaround time. This is the total time, spent by the vessel in port, during a given call. It is the sum of waiting time, plus berthing time, plus service time (i.e. ship's time at berth), plus sailing delay. Ideally, ship turnaround should be only marginally longer than ship's time at berth and thus waiting time in particular should be as near to zero as possible.
- **Road vehicle turnaround time:** For shippers/receivers (and trucking companies) the most important measure of a terminal's service quality is the time required to collect a container from the terminal or deliver one.
- **Rail service measures:** Train turnaround time would not be a useful measure for the service performance of a container terminal to the rail.

## **CONCLUSION**

This study has covered a wide range of performance measures using the container terminals that reviewed in existing literature. There is little agreement between ports, international organizations concerned with ports, and experts in the field over what these performance measures (often referred to as performance indicators) should be. In literature, many alternative measures have been reviewed and described for different purposes, but there is little consistency over how the terms should be defined and calculated. The measures can be divided into four categories. These are production, productivity, utilization and service measures which are discussed in the study.

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