

# Optimum Port Productivity

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**The port industry has historically restricted optimum port throughput to that throughput for which ports are technically efficient (i.e., maximum throughput in the use of resources) for evaluating their performance.**

**However, there are alternative optimum throughputs, e.g., cost efficient and effectiveness optimum throughputs, that may be used in evaluating a port's performance.**

**From an engineering perspective, a port's technically efficient optimum throughput is the maximum throughput that it can physically handle under certain conditions.**

**This optimum throughput is often referred to as the port's capacity.**

**The theoretical engineering optimum throughput of a port has been classified as: (1) design capacity, (2) preferred capacity and (3) practical capacity.**

**A port's design capacity is its maximum utilization rate.**

**For example, the design capacity of the storage area of a container port is the maximum number of containers that can physically be stored in the storage area.**

**A port's preferred capacity is the utilization rate beyond which certain utilization characteristics or requirements cannot be obtained, e.g., the utilization rate beyond which port congestion occurs.**

**Port congestion at the gate of a container port occurs when the waiting times for trucks to enter the gate increase beyond normal waiting times due to the increase in the number of trucks seeking entrance.**

**A port's practical capacity is its maximum utilization rate under normal or realistic conditions.**

**For example, the practical capacity for a container port's ship-side crane is the maximum number of containers that the crane is expected to load and unload from a ship per hour under normal working conditions.**

**A port's economic optimum throughput is that throughput that satisfies an economic objective of the port.**

**It may be either an economic: 1) technically efficient optimum throughput (based upon the port's economic production function), 2) cost efficient optimum throughput (based upon the port's economic cost function) or 3) effectiveness optimum throughput (based upon a port's effectiveness operating objective such as maximizing profits).**

**Thus, in addition to evaluating the performance of a port from the perspective of technical efficiency, a port may also be evaluated from the perspective of cost efficiency and effectiveness, i.e., by comparing its actual throughput with its cost efficient and effectiveness optimum throughputs.**

**A port's economic production function represents the relationship between the port's maximum throughput and levels of resources used in the provision of throughput, i.e.,**

$$\text{Maximum Port Throughput} = f(\text{Port Resources}) \quad (1)$$

**where, port resources include labor, mobile capital (e.g., cranes and vehicles), immobile capital (e.g., berths and buildings), fuel and ways (e.g., port roadways and railways).**

**If the port achieves the maximum throughput in the use of a given levels of resources, then it is technically efficient; otherwise it is technically inefficient.**

**A port's economic cost function represents the relationship between the port's minimum costs to be incurred in handling a given level of throughput, i.e.,**

**Minimum Port Costs =  $g(\text{Port Throughput})$   
(2)**

**If the port provides throughput at a minimum cost (given the prices or unit costs of resources), then it is cost efficient; otherwise it is cost inefficient.**

**When a port faces price competition from other ports, it should not only be concerned with whether it is technical efficient but also with whether it is cost efficient.**

**If it is cost inefficient, it can lower throughput costs and prices by coming cost efficient.**

**The given combination of resources used to provide a given level of port throughput may be a technically efficient combination but not a cost efficient combination.**

**Alternatively, there may be another combination of resources used to provide the given level of port throughput that is also technically efficient as well as cost efficient.**

**Effectiveness relates to how well the port provides throughput services to its users, shippers and carriers (ocean and inland).**

**Port effectiveness operating objectives will differ between privately-owned and government-owned ports.**

**If the port is privately owned, its effectiveness economic operating objective might be to maximize profits or to maximize throughput subject to a minimum profit constraint.**

**If the port is owned by government, its effectiveness economic operating objective might be to maximize throughput subject to a zero operating deficit (where port revenue equals cost) or subject to a maximum operating deficit (where port revenue is less than cost) that is to be subsidized by government.**

**In order for a port to be effective, it must be efficient -- i.e., it must be cost efficient which in turn requires that it must be technically efficient.**

**Alternatively, cost efficiency is a necessary condition for a port to be effective.**

**For example, if a port has the effectiveness operating objective of maximizing profits and is cost inefficient, it can obtain greater profits for the same level of throughput by lowering its costs in becoming cost efficient.**

**As in the case of a port being technically efficient but cost inefficient, a port can also be cost efficient without being effective.**

**A port's effectiveness operating objective function includes the demand function for throughput.**

**A port's throughput demand function represents the relationship between the port throughput demanded by its users and the generalized port price (per unit of throughput) incurred by these users, i.e.,**

$$\text{Port Throughput} = h(\text{Generalized Port Price}) \quad (3)$$

where,

**Generalized Port Price = Port Price Charged + Ocean  
Carrier Port Time Price + Inland**

**Carrier Port Time Price + Shipper Port Time Price (4)**

**The Port Price Charged per unit of throughput represents prices charged by the port for various port services, e.g., wharfage, berthing, cargo handling and wharfage charges.**

**The Ocean Carrier Port Time Price per unit of throughput represents the time-related costs incurred by ocean carriers while their ships are in port, e.g., ship fuel, labor and depreciation costs.**

**The Inland Carrier Port Time Price per unit of throughput represents the time-related costs incurred by inland (rail and truck) carriers while their vehicles are in port, e.g., vehicle fuel, labor and depreciation costs.**

**The Shipper Port Time Price per unit of throughput represents the time-related costs incurred by shippers while their shipments are in port, e.g., inventory costs such as insurance, depreciation and obsolescence costs.**

**If a port seeks to maximize profits, its profit (or effectiveness operating objective) function may be written as,**

$$\text{Profit} = \text{Port Price Charged} * \text{Port Throughput} - \text{Minimum Costs} \quad (5)$$

**Substituting the port's throughput demand function (3) and economic cost function (2) into profit function (5) and rewriting, it follows that:**

$$\text{Profit} = \text{Port Price Charged} * h(\text{Generalized Port Price}) - g(\text{Port Throughput}) \quad (6)$$

**Finally, substituting the economic production function (1) into profit function (6) and rewriting, it follows that:**

$$\text{Profit} = \text{Port Price} \cdot \text{Charged} \cdot h(\text{Generalized Port Price}) - g[f(\text{Port Resources})] \quad (7)$$

**The resources in profit function (7) in turn may be expressed as functions of the port's operating options and the amounts of given types of cargo (provided by carriers and shippers) to be handled by the port.**

**A port's operating options are the means by which it can vary the quality of its throughput service.**

**The relationship between the minimum amount of a given resource employed by a port and its levels of operating options and amounts of given types of cargo to be handled is referred to in the literature as a resource function:**

**Minimum Port Resources = j(Port Operating Options; Amounts of Given Types of Cargo Provided by Carriers and Shippers) (8)**

**Substituting the resource function (8) into profit function (7) and rewriting, it follows that:**

**Profit = Port Price**

**Charged\* $h$ (Generalized Port Price) -  
 $g\{f[j$ (Port Operating Options;**

**Amounts of Given Types of Cargo**

**Provided by Carriers and Shippers)]} (9)**

**A port can differentiate the quality of its service with respect to such operating options as: (1) ship loading and unloading service rates, i.e., ship loading and unloading times incurred per port call, (2) ship berthing and un-berthing service rates, i.e., ship berthing and un-berthing times incurred per port call, (3) inland-carrier vehicle loading and unloading service rates, i.e., vehicle loading and unloading times incurred per port call, and (4) inland-carrier vehicle entrance and departure service rates, i.e., vehicle entrance and departure queuing times per port call.**

**Entrance (departure) time for an inland-carrier vehicle is the queuing time incurred to be cleared for entrance into (departure from) the port once arriving at the port's entrance (departure) gate.**

**What are the means by which port management can optimize its effectiveness operating objective and thus determine its effectiveness optimum throughput?**

**That is to say, what are the choice variables to be utilized by port management in the optimization?**

**For a variable to qualify as a choice variable, its value must be under the control of port management.**

**Suppose the port's effectiveness operating objective is to maximize profits, where profits are expressed as in profit function (9).**

**In this function, Port Price Charged is a choice variable, unless constrained by port competition.**

**The other choice variables are the port's operating options.**

**Changes in the values of operating options not only affect the level of resources used by the port and thus port costs, but also the times incurred in port by ocean carriers' ships, inland carriers' vehicles and shippers' cargo.**

**These times in turn affect the port time costs incurred by these port users B consequently, affecting the port's profits.**