DOI: 10.2507/35th.daaam.proceedings.xxx

METHODS FOR ESTIMATING THE ECONOMIC IMPACT MODEL OF PORTS

Astrida Rijkure

This Publication has to be referred as: Rijkure Astrida (2024). Methods for estimating the economic impact model of ports, Proceedings of the 35th DAAAM International Symposium, pp.xxxx-xxxx, A.Rijkure (Ed.), Published by DAAAM International, ISBN 978-3-902734-xx-x, ISSN 1726-9679, Vienna, Austria
DOI: 10.2507/35th.daaam.proceedings.xxx, ORCID: 0000-0001-5449-4796

Abstract

Port performance evaluation is becoming increasingly topical in modern port management, especially for comparing a port with competing ports. Port performance can be achieved by comparing the port to predefined standards of accuracy, completeness, cost, and speed. Some ports monitor their activities solely on the basis of functional characteristics, while others cover wider aspects such as administrative and financial performance. But the overall goal of any port is to maximise profits, develop and increase the volume of transhipment. The efficiency of ports varies considerably: not all ports function equally well, and in recent years, the gap between ports adapted to new logistical and economic requirements and those that have failed has widened. Differences in performance result in a significant diversion of traffic, with a negative impact on business opportunities in well-functioning ports. This threatens the efficiency and sustainability of the transport network and the competitiveness of the economy in general. This study will rank and group the criteria for port performance and when exiting these criteria, the methods for calculating these performance criteria will be derived.

Keywords: ports economic; port efficiency; blue economy; port performance indicators

Introduction

Port performance evaluation has become an increasingly important topic in contemporary port management, particularly in the context of comparing the efficiency and competitiveness of ports. As ports play a critical role in global trade and supply chains, their ability to meet evolving logistical, economic, and environmental requirements is paramount. Measuring port performance involves assessing key parameters such as accuracy, completeness, cost, and speed against predefined standards, which serve as benchmarks for efficiency and operational excellence. These parameters help identify performance gaps and areas for improvement, enabling ports to stay competitive in a rapidly changing global market.

Traditionally, many ports have focused on monitoring functional characteristics, such as cargo handling capacity, ship turnaround time, and berth occupancy rates. However, in recent years, port management has expanded to include broader aspects like administrative efficiency, financial performance, and environmental sustainability. The primary goal of any port remains maximizing profits, increasing transshipment volumes, and enhancing overall operational effectiveness. The increasing complexity of global trade and the rising demand for seamless logistics networks have made these broader measures essential to evaluating port performance comprehensively.

The efficiency of ports varies significantly, with some ports successfully adapting to new logistical and economic demands, while others have lagged behind. This divergence has led to increasing disparities in performance, which in turn impacts the global transport network and the competitiveness of various economies. Efficient ports that have embraced technological advancements and optimized their operations are capturing more business, while underperforming ports risk losing traffic, market share, and business opportunities. This dynamic has far-reaching implications, as the efficiency of ports is critical not only for the ports themselves but also for the sustainability and competitiveness of the entire transport network and the broader economy.

This study aims to systematically rank and group the key criteria for port performance evaluation. By doing so, it will provide a comprehensive framework for assessing and comparing ports, taking into account functional, administrative, and financial aspects. Additionally, the study will derive methods for calculating these performance criteria, ensuring that the evaluation process is both rigorous and relevant to the modern context of port operations. The research will provide insights that can guide port authorities and stakeholders in making informed decisions about resource allocation, operational improvements, and strategic planning. By aligning the evaluation criteria with current industry standards and expectations, the study will contribute to enhancing port efficiency and competitiveness on a global scale.

The primary research question guiding this study is: *What are the most critical performance criteria for evaluating port efficiency, and how can these criteria be effectively measured and ranked to support decision-making in port management?* In answering this question, the study will offer a structured methodology for port performance evaluation, preparing the reader for the subsequent methods and results sections where the ranking, grouping, and calculation processes will be detailed.

The aim of the study is to compare port performance assessment models (Stochastic Frontier Analysis, Data Envelopment Analysis, Key Performance Indicators), identifying new aspects in port economic performance assessment and model development. The purpose of this study is to identify possible performance indicators (port equipment, cargo handling, capital equipment costs, staff costs, berth facility etc.) that would measure the impact of ports on the port economy.

Materials and methods

The principal materials used for the studies are as follows: various sources of literature, e.g. scholars' articles, research papers and the reports of institutions (European Commission, Ministry of Transport, World bank etc.). The following suitable qualitative research methods have been used: monographic; analysis and synthesis; grouping, logical and abstractive constructional (literature review). Due to the importance of maritime transport in countries' economies, in the literature, many studies for evaluating port efficiency have been carried out [7], [11], [14], [16].

Results and discussion

The result of the study is to assess the importance of the port industry and the need for specific performance indicators. This study has developed a system of port performance indicators that allows us to identify opportunities that generate the highest returns compared to other international standards in ports. It will also allow the impact of improvements made in ports to be assessed.

Under conditions of competition, ports are not merely facing the issue of cost efficiency, but also the technical efficiency of services. Port efficiency is related to the efficiency of using available resources and the ability to provide high transshipment capacity services to their customers. Technical and cost efficiency must be in balance. Traditionally, port performance is evaluated in terms of actual and optimal throughput, measured in tonnes or number of containers processed and transshipped. A port can also use other performance indicators to evaluate the efficiency thereof.

To determine port capacity indicators, it is important to be aware of what the input data are. Usually, the principal port performance indicator is cargo turnover over a certain period of time. It is also the main parameter that is accessible for statistical analysis. However, the actual efficiency of a port is characterised by a range of other indicators, since, depending on the port administration model, the port administration itself is not involved in the reloading of cargo, which is performed by terminals that rent land from the port for the performance of cargo operations, while the responsibility of port administration is to ensure high-quality infrastructure to enable reloading of the particular cargo at the terminal of the port. Therefore, in the context of a port, cargo turnover at the port is an insufficient indicator. Due to the effectiveness of the programme, automated inspection has already found applications. The user merely needs to provide inputs to the software. [4]

In a global supply chain, customers expect services of intermediaries to be flexible and less expensive. In the context of maritime transportation, cargo owners expect delivery to be reliable, and non-costly. On this basis, Logistics services providers' focus on designing an efficient method in which ports advantageous to minimization of costs overall transport costs are preferred. [1]

Various empirical studies have been conducted in recent years to examine the impact of economic efficiency on economic growth. In general, these studies reveal that measuring economic efficiency, especially overall economic performance, has a statistically significant, positive effect on economic growth rates [2], [3], [5], [9], [13].

The author offers to group port performance indicators into 3 large packages: general indicators, financial indicators and operational indicators. According to the author, this grouping of indicators enables one to realise how important the selection of the criteria that need to be assessed and calculated is.

Averages	Finance	Actions
waiting time	berth throughput	ship expenditure by GT
berthing time	berth handling volume per 1m	handling per ton operation profit
cost berthing time	cargo port time per tonn	gross profit margin
ship capacity per day	berth occupancy ratio %	
shipping turnover	berth usage ratio	

Table 1. Port performance indicators

Definitely, all aforementioned indicators must be financed, including the balancing of required administrative costs with financial indicators that are required to monitor transport infrastructure and the provision of transport services irrespective of the model that is used. The administration of the port must make decisions regarding how the volume of public or private resources will be divided among different tasks, as well as transport infrastructure and the provision of transport services.

These indicators are directed towards the increase in port profits. These indicators can be mutually attributed to each other or by using additional values or criteria. World Bank (1993) defined the study of the Port productivity index that was divided into three types: by operational productivity, assets (equipment) productivity and financial productivity indicators. Each of these indicators can be calculated. Scientists have offered different combinations and formulae for measuring and calculating these criteria. One of the methods for indirectly determining unknown parameters is the use of computer models that can replace costly experimental tests. [6] The author has developed her own simplified table for the calculation of these criteria, which provides a formula and a concise explanation of the expected result for each criterion and the use thereof.

	Criteria	Formula	Description
Averages	waiting time	$\frac{total\ ship\ waiting\ time}{number\ of\ ships}$	Usually, the average indicator value is calculated for a period of 1 year, but it can also be evaluated every month. This indicator demonstrates the speed of the performance of loading operations, and enables one to evaluate how efficient the technical equipment of the berths is. This indicator is critical for the customer, since time is money.
	berthing time	$\frac{total\ berthing\ time}{number\ of\ piers}$	The equipment of berths differs and this criterion allows one to evaluate which berths are efficient and which ones require upgrade.
	cost berthing time	$\frac{income\ from\ the\ docking\ charge}{total\ call\ number}$	The average indicator that not only points to the intensity, but also the adequacy of the determined docking charge.
	ship capacity per day	$\frac{total\ cargo\ volume}{number\ of\ ships\ x\ port\ time}$	This indicator enables the port to determine how high the load or intensity of the port is. The criterion is very important for the evaluation of the use of port capacity.
	shipping turnover	$\frac{port\ time}{number\ of\ ships}$	The indicator that characterises the load or intensity of the port. The indicator that shows how much time ships stay in this port on average.
	berth throughput	$\frac{total\ cargo\ volume}{number\ of\ piers}$	The average cargo turnover at the berth points to the load of berth, which is important when assessing capacity criteria.
Finance	berth handling volume per 1m	$\frac{total\ cargo\ volume}{Bert\ lenght\ (m)}$	The indicator points to the volume of cargo per 1 m of berth area. This criterion can also be used to determine the capacity of warehouse use, except that the unit of measure used is m², instead of m.
	cargo port time per tonn	$\frac{total\ cargo\ volume}{port\ time}$	The indicator determines how much time is required to process a particular cargo volume within a selected time period.
	berth occupancy ratio %	$\frac{ship\ berth\ time}{number\ of\ ships\ x\ 365\ day} X100$	The indicator demonstrates the percentage (%) of time the specific berth has been in use during a year, as well as the intensity of its use.
	berth usage ratio %	$\frac{handling\ berth\ time}{ship\ berthing\ time}$ x 100	This indicator demonstrates the share of loading operations within the total amount of time spent by the ship in the port. Respectively, the time that the ship spends in the port.

Actions	ship expenditure by GT	$\frac{total\ port\ income}{total\ GT}$	Gross tonnage is the criterion that determines the capacity of the port to accept ships of a particular size. The higher the GT, the more specific the requirements for certain port infrastructure.
	handling per ton operation profit	$\frac{port\ operation\ profit}{total\ handling\ tonn}$	The indicator determines the profit generated as a result of reloading one tonne of cargo.
	gross profit margin	$\frac{port\ operation\ profit}{operation\ income}$	Gross profit margin is a financial indicator used to evaluate the financial health and business model of the company that demonstrates the amount of money left over from product sales after subtracting the cost of goods sold. It can be calculated by dividing the gross profit by total income.
	capacity used by the port	$\frac{total\ port\ handling\ capacity}{total\ cargo\ volume}\ x\ 100$	It is very important to determine this criterion, since at every port the maximum cargo loading capacity must be calculated depending on its area, number of berths and equipment in order to evaluate the proportion of port capacities that are used every year, which enables decision making on whether an additional increase in port capacity is required.

Table 2. Methods for calculating port performance indicators

This table graphically demonstrates how simple, but important methods, by attributing respective criteria relative to other criteria, can be used to assess how efficient the particular port is, whether it is customer focused or profit orientated only, how cost efficient services provided by the port are, and how well equipped and efficient the overall operation of the port itself is. It is important to evaluate the throughput capacity of each berth within a certain time period – usually it is one year. The speed of loading and unloading of a ship characterises technical provisions, which are also important characteristics of port performance. This service provision indicator characterises the quality of service provision at the port; loading and unloading speed of the ship is a very important element in determining the costs of transport services. Usually, this indicator is evaluated in hours per unloaded tonnes. It is important to evaluate how large a team is attracted to unload one ship, which allows one to evaluate the productivity of work, as well as the automation of loading procedures and whether the time of return on investment may be evaluated, if the human factor is replaced with automation. How many accidents occur at the port during loading operations, whether these accidents can be prevented, if the processes were automated. But the present study addresses measurable and evaluable criteria. It is important to evaluate how intensively the berths of the port are loaded, what the business hours of the berth are and the number of personnel employed. The load of a berth actually points to the level of demand for the services of the port. This can be measured in time periods (a year, a month, a week) and is usually expressed in %.

Productivity indicators that point to cost efficiency are important; they involve the evaluation of costs or the reloading of one tonne of cargo. This indicator is very difficult to measure, since it involves sensitive company data. In the competition between port terminals, data on the costs of reloading one tonne of cargo are difficult to obtain, since they depend on the amount of cargo, intensity of deliveries and form of co-operation with the customer; therefore, reloading costs of the same type of cargo or reloading tariffs may differ for each of the customers.

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.

A port's economic production function represents the relationship between the port's maximum throughput and given levels of its productive resources, i.e.

Maximum Port Throughput = f (Port Productive Resources)

,where throughput may be the number of containers (measured in 20-foot equivalent units or TEUs) or tons of cargo handled and port productive resources include labor, immobile capital (e.g. berths and buildings), mobile capital (e.g. cranes and vehicles), fuel and ways (e.g. port roadways and railways). If the port achieves the maximum throughput for given levels of its 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 (Port Throughput)

,where the costs are those incurred in the use of the port's resources, e.g. wages paid to labor and vehicle fuel expenses. If the port provides throughput at a minimum cost (given the unit costs or resource prices to be paid), then it is cost efficient; otherwise it is cost inefficient.
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 service by lowering costs in becoming cost efficient. However, note that a port can be cost efficient without being effective. [15]
Port users seek information that has a direct impact on their business and the commercial choices they make. They are interested in the performance of the port in terms of operational time factors such as vessel waiting or cargo dwell times, or indeed labour productivity. Both factors will affect cargo transit costs. [10]
These are formulas for the reaching of the objectives of every port development programme, which enable evaluation of the development direction and targets to be strived for, ways of optimising port procedures and achieving maximum profit at minimum investment. However, there must be an awareness that the optimisation of resources is not always sufficient for the economy of ports, competitiveness must be ensured, market trends must be followed, since it is possible that, in the absence of investment in port development, your cargo shall move to a neighbouring port because you are no longer capable of serving ships of new fleets with larger displacement or ships that require more modern technologies to unload cargo or to fill up the ship with new generation fuel or other new technologies that are developing rapidly, and changes that occur particularly in the transport sector. This is a rapidly changing sector, it is syncing with time, developing new technologies and attempting to minimise the environmental impact.
Port operation focuses on improving port sustainability in order to add value to the high profile of international ports and reduce environmental and social impacts. Together with this port operation supports maritime transport and the overall economic system. [8]
At the same time, upgrading of processes can also have a negative effect on the development of the sector. Like energy efficiency measures delay the growth of the global oil industry and the development of the steel industry is delayed by the reduction of dimensions and mass of various products, the transport sector must take the fact that everything is becoming "more compact" into consideration. The process called dematerialisation of economy can also have a long-term negative effect. The upgrade of technologies reduces the mass of durable goods; the increase in energy efficiency reduces the mass of energy resources, and the fuels will be replaced by electricity in the future.
Nowadays port development is a rapid process. A couple of decades ago, ports were relatively isolated territories, where reloading of cargo took place, but nowadays ports represent a complex ecosystem that is closely integrated into the economy of the city or country, which unites several stakeholders and areas of operation. Contemporary ports are transferring from the simple reloading of cargo to "smart logistics". Therefore, cargo turnover at the port is not the only criterion to be analysed nowadays. Currently, the range of port services is very wide and everything needs to be analysed in conjunction, instead of evaluating through cargo turnover alone.
The choice on what port to use are made based on the criteria deemed relevant by the users which could vary between them. To an extent, the volume of cargo throughput in a port is dependent on the choice of the users on the port that offers the criteria. The frequency at which the ports are used by the users could as well be linked with the quality of services rendered at the port. It is therefore important for port authorities to know these factors so it can serve as a guide in policy formulation geared towards improving services at port and the market share. Policies formulated on these improves the quality of services rendered by the ports and increase the level of satisfaction derived by clients. [1], [12]

The process of industrialisation in the countries of the Asian region is expected to have an equally important effect on the development of the sector. Along with common economic and global factors, future scenarios of the port and shipping sector are increasingly affected by the development of modern technologies – the sector of transport and logistics will be significantly affected by the regions, where robotics and 3D printing sectors are developed, since these will affect the volume of product and raw material flows, as well as the geography thereof.
The scenarios of port and shipping industry development will be affected by how the manufacturers of goods change, for instance, how their production volumes and capacity to respond flexibly to market trends change, how potential consolidation and mutual integration of manufacturing sector participants occur. The capacity to maintain high productivity, as well as predictable and stable chains of supply will definitely be important factors, as well as ecological aspects, which are becoming increasingly important in practically all sectors of the modern global economy. The sector of e-commerce is an important factor for the development scenarios of the future. It has seen a significant increase of volumes on a global level, thus considerably affecting the area of cargo transportation and logistics, as well as ports and maritime transport.

Conclusion

This study set out to evaluate the performance of ports by developing a comprehensive system of port performance indicators. The primary issue addressed was the need for accurate, standardized methods to assess port efficiency, especially in light of intense competition and evolving global logistical demands. Traditional metrics, such as cargo turnover, were found to be insufficient on their own, necessitating the inclusion of a wider range of indicators, including financial and operational metrics, to provide a more complete picture of port performance. The solution proposed by the study involved grouping port performance indicators into three major categories: general, financial, and operational. This approach enabled a more holistic evaluation of port efficiency by addressing both cost and technical efficiency, thereby

balancing resource use with service provision. The study also introduced practical methods for calculating these indicators, which allow for easy benchmarking against international standards and the identification of areas for improvement. By using these indicators, ports can more accurately measure factors like berth throughput, handling capacity, and profitability, which are critical for maximizing returns and enhancing competitiveness. The results demonstrate that effective port performance evaluation requires a multifaceted approach that includes not only operational efficiency but also financial viability and customer satisfaction. The study successfully developed a framework of indicators that can be applied across different ports to assess their relative performance, identify opportunities for growth, and optimize resource allocation. This system allows for the assessment of both immediate operational improvements and long-term strategic planning, making it a valuable tool for port authorities aiming to enhance their competitive edge. One key outcome of this study is the recognition that port efficiency cannot be solely measured by traditional cargo handling statistics. A broader view of efficiency, which includes the effectiveness of port infrastructure, financial health, and service quality, is essential for the modern port industry. By applying this comprehensive system of performance indicators, ports can better align themselves with global logistical demands, improve their technical and cost efficiency, and attract more business. Looking ahead, future research should focus on the development of automated systems and advanced technologies, such as AI and robotics, to further enhance the accuracy and efficiency of port operations. Additionally, as environmental sustainability becomes a more pressing concern, the integration of green technologies and practices into the performance evaluation framework will be critical. This will allow ports to not only remain competitive but also contribute to broader environmental and social objectives, ensuring their long-term sustainability in a rapidly evolving global economy.

ACKNOWLEDGMENT
ERDF project No. 1.1.1.2/VIAA/1/16/061 “Long-term impact of blue economy on the increase of the competitiveness of ports in the Baltic Sea region”

References

[1] Blessing A.S., (2019) Port selection criteria from logistics service providers' perspective: a case study of West Africa. World Maritime University Dissertations. 1221.
[2] Cebula R., Mixon J F., (2012) The Impact of Fiscal and Other Economic Freedoms on Economic Growth: An Empirical Analysis, International Advances in Economic Research, volume 18, pages 139–149
[3] Galindo M., Sotos F.E. Méndez M.T. (2007) Value at Risk and Economic Growth, International Advances in Economic Research, volume 13, pages 214–221
[4] Gheorghiță V., Geantă F.A. (2023) Design of an Experimental Model of a System for Product Sorting Through Image Processing, Proceedings of the 34th DAAAM International Symposium, pp.0203-0208, B. Katalinic (Ed.), Published by DAAAM International, ISBN 978-3-902734-41-9, ISSN 1726-9679, Vienna, Austria DOI: 10.2507/34th.daaam.proceedings.026
[5] Haralambides H.E., (2015) Competition, Excess Capacity and the Pricing of Port Infrastructure, Port Management pp 221-252
[6] Kozar I., Sulovsky T. (2023) Numerical Model for Identification of Fiber-Reinforced Concrete Parameters from the Crack-Mouth Opening Displacement, Proceedings of the 34th DAAAM International Symposium, pp.0544-0550, B. Katalinic (Ed.), Published by DAAAM International, ISBN 978-3-902734-41-9, ISSN 1726-9679, Vienna, Austria DOI: 10.2507/34th.daaam.proceedings.072
[7] Magdiel A. Agüero-Tobar, Marcela C. González-Araya, Rosa G. González-Ramírez, (2023) Assessment of maritime operations efficiency and its economic impact based on data envelopment analysis: A case study of Chilean ports, Research in Transportation Business & Management, Volume 46, 100821
[8] Muangpan T., Suthiwartnarueput K.(2019) Key performance indicators of sustainable port: Case study of the eastern economic corridor in Thailand
[9] Park N., Yoon G. (2014) Port Capacity Evaluation Formula for General Cargo, The Asian Journal of Shipping and Logistics Volume 30, Issue 2, August 2014, pages 175-192
[10] Pazienza P, (2015) The Environmental Impact of the FDI Inflow in the Transport Sector of OECD Countries and Policy Implications, International Advances in Economic Research volume 21, pages 105–116
[11] Pérez I., González M.M, Trujillo L., (2020) Do specialisation and port size affect port efficiency? Evidence from cargo handling service in Spanish ports, Transportation Research Part A: Policy and Practice, Volume 138, Pages 234-249, ISSN 0965-8564
[12] Philipp R., (2020), Digital readiness index assessment towards smart port development, Sustainability Management Forum | NachhaltigkeitsManagementForum volume 28, pages 49–60
[13] Poufinas T., Galanos G., (2021) The Impact of Competitiveness on the Shadow Economy, International Advances in Economic Research, volume 27, pages 29–46
[14] Tongzon J., (2001) Efficiency measurement of selected Australian and other international ports using data envelopment analysis., Volume 35, Issue 2, 2001, Pages 107-122, ISSN 0965-8564
[15] Wayne K. Talley,(2006) Port Economics, PORT PERFORMANCE: AN ECONOMICS PERSPECTIVE, Research in Transportation Economics Volume 17, 2006, Pages 499-516

[16] Wilmsmeier G.,Tovar B., Sanchez R.J., (2013) The evolution of container terminal productivity and efficiency under changing economic environments, Research in Transportation Business & Management, Volume 8, Pages 50-66, ISSN 2210-5395