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Evaluating the Impact of Private Sector Participation on Operational Efficiency in Container Terminals: A Case Study of Colombo Port

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Abstract

Sri Lanka, strategically located in South Asia, has the potential to become a significant hub for international maritime trade. However, the current port infrastructure, particularly in Colombo, faces capacity constraints that limit its ability to accommodate larger vessels and manage increasing container traffic. This study evaluates the impact of private sector participation on the operational efficiency of Colombo's container terminals - Jaya Container Terminal (JCT), South Asia Gateway Terminal (SAGT), and Colombo International Container Terminal (CICT). Using Key Performance Indicators (KPIs) and Data Envelopment Analysis (DEA), the study found that private sector involvement significantly enhances terminal efficiency. SAGT, a privately operated terminal, exhibited the highest overall efficiency, while CICT demonstrated the highest productivity. JCT, though publicly operated, showed commendable performance but lagged behind the private terminals. The findings emphasize the value of public-private partnerships (PPPs) in optimizing port operations, offering critical insights for policymakers and stakeholders aiming to strengthen Sri Lanka's maritime economy.

Keywords: *Container terminal efficiency, Data Envelopment Analysis (DEA) model, Key Performance Indicators (KPIs), Private sector participation, Public-private partnership (PPP)*

INTRODUCTION

Port development plays a crucial role in a country's economic growth as a key component of economic infrastructure. Countries like Britain, the Netherlands, and Singapore, known as maritime powers, demonstrate the significant contribution of ports to their economic development (Tareq et al., 2021). Container port facilities important to smoothen operations for world cargo movement (Rana, 2019). Total world container volumes reached 857m TEUs in the year 2021 increased by 6.8 per cent compared with the year 2020. Asian Ports continue to play an important role in the region accounting for 6 per cent growth and 62.5 per cent of World container throughput. World's Top 10 Ports by throughput were in the Asian region led by Shanghai, Singapore and Ningbo-Zhoushan (UNCTAD, 2022). In 2022, Asia continued to be the world's top maritime freight handling location, accounting for 42% of exports and 64% of imports. In 2022, the Asia Pacific area handled 517 million (TEUs) containers, accounting for approximately 60% of global container throughput (Alphaliner,2022). It shows the importance of the development of container terminals to facilitate the growing demand of world trade and today Container ports have become an important factor in the efficiencies of global logistics and supply chain (Ng & Liu, 2014).

In recent years, many ports and container terminals have partnered with private sector entities to develop and manage their operations. Thus, because the public sector cannot bear huge capital investment in port or terminal development. Another identified problem is that shipping trends change year by year and ship sizes get bigger, therefore improvement of port and terminal facilities becomes an important factor in sustaining the shipping sector and stand the port and shipping industry. Therefore, complexities and evolving demands of the global trade landscape have necessitated the collaboration between the public and private sectors to private sector involvement brings innovative technologies, management expertise, and financial resources to drive operational

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improvements and optimize port terminal efficiency, In order to meet new developments in the port and shipping industry.

The Port of Colombo is a key maritime hub in the region (Huang et al., 2020), playing a significant role in facilitating international trade and transshipment. Historically, the port's container terminal operations were solely managed by the government. However, in recent years the private sector invested developed and maintain container terminals in Port of Colombo and also private sector participation has gained prominence by introducing new dynamics to the port's operations. This assessment delves into understanding how private sector involvement influences operational factors and the subsequent impact on the operational efficacy of container terminals in Port of Colombo.

Sri Lanka and Sri Lankan Ports must upgrade their facilities. Upgrading the port's facilities is necessary to meet the needs of shipping lines. Most of the time government sector cannot afford the huge costs for investment and the private sector should be involved in development. Therefore, private sector participation crucial factor for development of container facilities in the Port of Colombo (NPMP,2019).

The main objective of the study is to assess the operational efficiency of the container terminals operating at port of Colombo and compare the three terminals' performance with KPIs and DEA results to encourage the private sector to invest in future container terminal development. Investors can evaluate the results based on the performance of private sector terminals and public sector terminals.

Specifically, the objectives of this study include assessing and quantifying the gaps in operational factors such as turnaround times, waiting time, service time, and capacity limitations; determining the causes and underlying factors contributing to these gaps, including infrastructure issues like the number of berths, gantry cranes, and terminal tractors; evaluating the implications of adopting advanced technologies and automation to improve terminal efficiency; and analyzing the impact of human resource factors on enhancing container terminal efficiency.

The research addresses several key issues:

Assessing the effectiveness of existing private sector partnerships and their contribution to operational efficiency.

Identifying challenges or bottlenecks that impede optimal performance.

Exploring the potential role of emerging technologies, such as automation and digitization, in improving efficiency and reducing operational costs.

This study will evaluate how the PPP model can incorporate these factors to enhance operational efficiency. The Sri Lanka Ports Authority (SLPA) is responsible for determining the appropriateness of the PPP model on behalf of the Government of Sri Lanka (GOSL). It is crucial to address the viability of the PPP model in competing with international operators and shipping lines to achieve the desired objectives. In assessing the model, the GOSL must carefully consider key areas to ensure the successful implementation and sustainability of PPPs in port terminal development.

LITERATURE REVIEW

Introduction

A comprehensive review of existing literature on private sector participation in container terminal operation and how operational factors impact to efficiency of container terminal operation in other global ports will provide a solid foundation for this assessment. Previous studies on the efficiency of container terminals and private sector involvement, case studies, and best practices will be considered to draw relevant comparisons. In this study, two factors of literature are to be considered. One factor is how private sector participation in terminal development and linked with the efficiency of terminal operation in case studies. Another part considers how and what kind of operational factors impact the efficiency of container terminal operation, this will evaluate though the KPIs analysis and DEA Model Analysis.

Identifying the privatization is an important factor in this case study. Privatization can be narrowly defined as a divestiture of public enterprises to private owners and more generally as a placing of a larger share of the economy into the private sector. This worldwide trend which started in the early 1980s is only part of the overall trend towards greater involvement and participation of the private sector in the operation and management of state-owned enterprises.

The empirical studies that have investigated the association between port ownership structure and port operation efficiency seem to provide more evidence, some research evidence that there is no clear-cut relationship, between the type of ownership and port efficiency. For example, Liu (1995) used the stochastic production function to calculate technical efficiency, and compared the impact of public ownership and private ownership on differences in port efficiency. The study concluded that the British model of mixed port ownership, involving both public and private entities, provides evidence that challenges the notion of the inherent superiority of private enterprise control systems. In this study, based on observations of output and inputs for 28 ports in the UK, Liu (1995) did not find significant evidence that port ownership has a substantial effect on port performance. Notteboom et al. (2000) used the Bayesian Stochastic Frontier Model, developed by van den Broeck et al. (1994), where comparison of efficiency levels across a series of 36 European container terminals and four Asian container ports were done. The study revealed when comparing the efficiency levels of the terminals studied, no relationship could be found between ownership type, terminal operations and efficiency levels. Coto-Millán et al. (2000) covered the efficiency problem in the port industry by using a stochastic frontier cost function to estimate the economic efficiency of Spanish ports through panel data from 27 Spanish ports. It has been found that the type of organization has a considerable impact on economic efficiency. However, ports that have autonomy are less efficient than others. Furthermore, Baird (2000) has argued that selling port land along with transferring operation and regulation functions to the private sector will not necessarily increase operational efficiency. In fact, it may even have a counter-productive effect.

Contrary to these studies, some studies argued that port ownership affects port efficiency. For example, Estache et al. (2002) illustrated the efficiency effects of Mexico's 1993 Port Reform by using panel data from 44 observations from 11 independent Port Administrations. The efficiency scores based on the statistical results showed that the reform of decentralization and privatization taken at Mexico's ports have generated large short-term improvements in the average performance of the port industry. Cullinane et al. (2002) employed both the cross-sectional and panel data versions of the Stochastic Frontier Model to assess the relative efficiency of selected Asian container ports. Based on their purely subjective appraisal of the obtained efficiency levels of selected ports from the above two models, Cullinane et al. (2002) concluded that there is supporting evidence for the opinion that privatization has some relation with the improvement in efficiency.

Due to the nature of port investment (long-term costs and high financial costs), the entire trust has private sector provision of port equipment and infrastructure will result in significantly delayed investments in crucial operation facilities and equipment, which are contrary to the original objective of port privatization. Thus, full port privatization will impede the improvement of port performance while some extent of private sector participation can increase the efficiency level, which implies that the extent of private sector intervention in the port sector has an inverted U-shaped effect on port operational efficiency.

While the literature provides extensive insights into the relationship between privatization and port efficiency, there is a gap in understanding the specific mechanisms through which private sector participation enhances operational efficiency. Most studies focus on general efficiency metrics without delving into how private sector management practices and technological innovations contribute to performance improvements.

Additionally, there is a lack of comprehensive analysis of how different PPP models impact container terminal efficiency in specific regional contexts, such as the Port of Colombo. This study aims to fill these gaps by:

Assessing the extent of operational gaps in the Port of Colombo's container terminals.

Evaluating the underlying causes of these gaps, including infrastructure and human resource factors.

Analyzing the implications of advanced technologies and automation on terminal efficiency.

Providing a comparative analysis of private and public terminal performance using KPI and DEA model analyses.

Key gaps in the literature can be identified as elaborated in the following sections.

Regarding efficiency improvement mechanisms, most studies focus on general efficiency metrics without detailing the specific management practices and technological innovations brought by private sector participation (Tongzon, 2019). There is a lack of analysis on how private sector expertise in operations, logistics, and technology adoption specifically contributes to efficiency improvements. The context specific analysis plays a significant impact as substantial number of studies have carried on European, Asian and Latin American ports, where there is limited research focusing on the unique context of South Asian ports, particularly Colombo Port. Similarly, the local regulatory environment, economic conditions and labor market characteristics may influence the outcomes of public-private partnerships in unique ways that have not been adequately explored.

In assessing the research gap, it was also focused on the short-term vs. Long-term effect. Existing studies often focus on short-term efficiency gains post-reform without considering the sustainability and long-term impacts of private sector involvement. The trade-offs between immediate efficiency improvements and potential long-term challenges (e.g., delayed investments in infrastructure, maintenance issues) are not thoroughly examined. It can be observed that mixed ownership models are not significantly associated with the studies. There is insufficient comparative analysis of different public-private partnership models (e.g., full privatization, partial privatization, public-private joint ventures) and their relative effectiveness in different contexts. The extent to which mixed ownership structures (where both public and private entities have stakes) can balance the benefits and drawbacks of full privatization needs further exploration.

This research study attempts to address these gaps by carrying out a comprehensive analysis of various operational metrics such as average turnaround time, waiting time, productivity per crane and productivity per ship. This detailed examination offers insights into how specific management practices and technological innovations contribute to efficiency improvements at different terminals.

Similarly, by employing the DEA model, the study rigorously quantifies the efficiency levels of the terminals, identifying which practices and resource allocations lead to higher efficiency. This addresses the gap in understanding the specific mechanisms through which private sector participation enhances operational efficiency. The study is tailored to the unique context of Colombo Port, analyzing the performance of its three major terminals: Jaya Container Terminal (JCT), South Asia Gateway Terminal (SAGT), and Colombo International Container Terminal (CICT). This localized analysis accounts for the specific regulatory environment, economic conditions, and labor market characteristics of Sri Lanka, filling the gap left by more generalized studies on port efficiency. The study further attempts to develop a comprehensive efficiency assessment where the use of both short-term operational metrics and an overall efficiency score through DEA allows for a balanced view of both immediate and sustained performance improvements. This dual approach addresses the gap concerning the sustainability and long-term impacts of private sector involvement. One of the major ways of addressing the gaps is the carrying out of comparative analysis of ownership models. The study compares the performance of publicly owned JCT with privately operated SAGT and CICT terminals. This comparative analysis highlights the effectiveness of different public-private partnership models, addressing the gap in understanding the relative benefits of various ownership structures.

Further, the study demonstrates that even publicly owned terminals can achieve commendable efficiency with effective management, while private terminals show higher operational efficiency. This nuanced view supports the idea of mixed ownership models balancing the advantages and drawbacks of full privatization.

Port Key Performance Indicators

The performance of a container terminal and descriptive statistics are two distinct aspects of determining performance characteristics. Descriptive statistics are used to measure TEU handling and demand at the macro level, whereas performance indicators only measure the technology and infrastructure used to handle container throughput and traffic (Carbone & De Martino,2003). Ratios and other statistical, graphical forms are more commonly used to represent descriptive statistics. Descriptive statistics are used to express cross-comparisons

between terminals using performance indicators, and the information expressed by descriptive statistics includes total tonnage and container throughput handled, as well as ratios.

Major customers of every port, whom will be shipping lines, shippers, truckers should be provided with services which supports their operations, usually which is provided by the port's authority in conditions to a public port. The level of services can be defined as the degree which service providers will be maintaining when providing services to the port clients. These indicators can be grouped into; Service Time and Service quality.

Service time can be calculated along with the service time & with the waiting time allocated for service, which is in other words the ship's waiting time taken on requesting availability to berthing as well as the container cargo handling time. Service quality can be defined as the measurement of safety, validity & righteousness, which can be measured with the adequate frequency of skilled labour & utilities & the percentage of cargo damages during operations.

Below are Kpis for the Service Standards.

Ship Turnaround Time

Ship Waiting Time

Ship Service Time

Forecasting future capacity demands and identifying capacity shortfalls are important considerations when developing port expansion projects. When examining terminal and berth capacity, which is generally measured in TEU per year, assumptions are made. The assumptions should be relevant to productivity, which is measured in TEU per day, and utilization status, which is measured in days or years.

Berth Capacity (TEUs/year) = Berth Productivity (TEUs/day) x Berth Utilization (days/year)

Berth Productivity (TEUs/day) = Berth Productivity (moves/hour) x number of productive hours per day x ratio of TEUs/move

There are other numerous berth indicators related to measuring the efficiencies, available for measuring each unit of procedures within the berth such as,

Ship handling cycle indicators for measuring; port time in including net & gross berth time

Berth productivity indicators for measuring net & gross berth productivity

Gang productivity indicators to measure net gang productivity

Yard indicators to measure container yard utilization.

The indicators of which the performances were identified were generally contributed from the creative development of the authors. The performance level indicators used within this case study are developed to have qualitative principles from collections of traditional mathematical functions which were used to measure individual procedures. There will be no such requirement to measure the performances of each function of the terminal logistics chain since this is a case study.

The Container Terminal Operation and Port Efficiency

Port efficiency and Port performance indicators, other hand operational factors are correlated aspects. Port performance indicators express efficient levels of container terminal activities. In this study, an empirical review elaborates on how private sector investment influences the efficiency of container terminal operation and performance indicators. According to Notteboom et al. (2021) port efficiency is a keen component of port performance. Port efficiency analyses the ability of a port to obtain the maximum output under a given number of inputs. Therefore, efficiency gains represent performance improvements closer to optimal (Suarez-Aleman et al., 2015). Port performance indicators measure a port's performance by monitoring activities, checking their efficiency, and comparing the present with past performance (Shetty & Dwarakish, 2018; Notteboom et al., 2021). This will help decision-makers to make a proper investment decision.

The important factor that cuts through all of these arguments for supporting private sector engagement is the implication of an intention to improve by either increasing Positive features or depressing negative features, which in effect creates "efficiency." This quote indicates that the ports expect the privatization strategies to ultimately achieve efficiency by increasing output and simultaneously maximizing the use of inputs (Estache et al., 2002). Quansah (2008) in his case study reveals that the ports of Tema and Dar es Salaam are multifunctional, and while indicators are wide and may encompass almost every component of the port system, this review focuses on areas where the investment influx from privatization may have a direct influence. For example, technical innovation via the inclusion of new equipment, as well as the addition of technical know-how and operational abilities, as well as management innovation.

Vrakas et al. (2021) studied how operational performance of container terminals can be affected by a streamlining of processes & a sophisticated port technology-based investment, within the case of Patrick Terminals in Australia. The findings show that positive operational performance, better technological infrastructure & utilization along with better productivity & reduced costs is possible with the implementation. Study done by Li et al. (2021) using qualitative-comparative analysis shows that throughput capacity of the port depends on the magnitude & infrastructure of the port.

The DEA Model for Evaluation of Port Efficiency

Data Envelopment Analysis (DEA) is a non-parametric method used to assess the relative efficiency of decision-making units (DMUs), such as businesses, public sector agencies, or in this case, port terminals. DEA evaluates the efficiency of each DMU by comparing it to a "best practice" frontier constructed from the observed data.

There are three components in a DEA model: Inputs and Outputs, Efficiency Score and Frontier construction. Inputs are the resources used by the DMUs (e.g., terminal area, number of berths, number of quayside cranes, number of terminal tractors, container throughput), whereas the outputs are the results achieved by the DMUs (e.g., average turnaround time, average waiting time, container productivity per crane, container productivity per ship). The efficiency score is calculated by comparing the weighted sum of outputs to the weighted sum of inputs. A DMU is considered efficient if it lies on the "best practice" frontier (efficiency score of 1 or 100%). DMUs below this frontier are considered inefficient. The frontier is constructed using linear programming techniques that identify the most efficient DMUs. These DMUs form a boundary or frontier against which all others are compared.

The DEA model application to the port operations has become more popular as it considers the measurement target of efficiency as a decision-making unit (DMU), which systemically analyses method for comprehensively evaluating the relative effectiveness of units with the same type of input and output (Wang & Cullinane, 2006). DEA is the most widely used method in analyzing port efficiency scores and identifying the best required practices (Kammoun & Abdennadher, 2022). Roll and Hayuth (1993), first introduced the DEA model for the efficiency evaluation of ports. The model was so widely and globally used. Tongzon (2001) used this model to measure the efficiency of four Australian container ports and twelve other international ports and arrived at the conclusion that Osaka and Yokohama are the least efficient ports mainly due to their massive shortage of container berths, docks and labour inputs.

Tongzon and Heng (2005) provides empirical support for the argument that private sector participation in the port industry can help improve the efficiency of port operations, but that privatizing the entire port can also be useful, but entire port privatization is not an effective way to increase port operation efficiency. Which concludes that this relationship is not a linear one. Their study showed that the best extent of private participation in container ports/terminals is between the Private/public (0.67/0.33 respectively) and the Private (1.00) mode, implying that port authorities should limit the private sector participation within the "landowner and operator" functions and take over the regulatory function by the public sector. In other words, as long as the Port Authority continues to play its regulatory role, it should use private financing, operation and management instead of government funding and management.

During the period 1984 to 1997, Turner and Dresner (2004) used this model to calculate the efficiency value of the panel data of North American seaports. Further, DEA model-based components were also used to evaluate the efficiency and productivity of seaports. The technological efficiency and productivity changes of the six most important commercial seaports in Tunisia were evaluated by Ben Mabrouk et al. (2022) by using the Malmquist DEA-based productivity index and an output-oriented DEA model over 12 years from 2005 to 2016.

Data Envelopment Analysis (DEA) to the estimation of productive efficiency in the container port industry and also Data Envelopment Analysis (DEA) is an efficiency evaluation model based on mathematical programming theory. DEA is capable of extracting information from sample observation which can be considered as an alternative to classical statistics. DEA optimizes each individual observation with the objective of calculating a discrete piece-wise frontier determined by a set of Pareto efficient Decision Management Units (DMUs,) in contrast to parametric approaches (For example: regression analysis) which fit the data through a single regression plane. As opposed to single optimization statistics, which focus on averages of parameters, DEA focuses on individual observations.

The present application refers to each port as a DMU, meaning that it is responsible for converting inputs into outputs. A DEA analysis can evaluate efficiency using multiple inputs and outputs. Furthermore, DEA calculations are nonparametric and do not require prior knowledge of input or output weights. With these features, DEA is more flexible than other conventional efficiency measures derived from stochastic production frontiers or economic value added (EVA), which are based on the estimation of production functions with many inputs but only one output.

For the purpose of this study, four indicators have been selected as input indicators: the number of employees, the number of berths, the total length of berths and the amount of loading and unloading equipment which are based on previous literature and data availability. The container terminal throughput and net cargo weight are taken as output indicators, as Abraham Charnes and colleagues developed the Data Envelopment Analysis (DEA) method, which uses mathematical programming techniques to estimate the efficiency frontier by taking into account the best performance observations, also known as extreme points that "envelop" the remaining observations. The ratio of produced outputs to used inputs imply the efficiency.

$$\text{Efficiency} = \frac{\text{Output}}{\text{Input}}$$

The inefficient unit can become efficient by increasing output (products) while maintaining the same level of resources used, decreasing resources used while maintaining the same level of production, or a combination of the two.

Considering j = 1, 2, 3, . m Decision Making Units (DMUs) | i = 1, 2, 3, .n, inputs to produce | r = 1, 2, 3, ., outputs and prices (multipliers) and related with those inputs and yields, we can also validate the efficiency expression in (1) as the proportion of weighted outputs to weighted inputs:

The fractional programming problem can be used to estimate the multipliers and a measure of a specific DMU's technical efficiency (Charnes et al., 1978).

The efficiency score ranges from 0 to 1 which gives us an indication of each decision-making unit. The multiplier model of (3), the primal (or envelopment) form of (4), the peers of efficiency and respective weights, as well as the potential for improvements and slacks, provide us with the marginal contribution of each input and output.

After selecting same input factors in public and private sector terminals, respect to Decision Making Units of DEA and respective outputs, then identification of successful or high efficiency Decision Making Units, can be performed with application of DEA theories.

It will lead to a comparison between private and public sector container terminals its efficacy in which areas should be prioritized and all together how and which sector became successful.

DEA model is an ideal application to assess the terminal efficiency, and its applicability for this research study is justifiable on following grounds:

Ports are complex entities with multiple inputs (e.g., infrastructure, equipment) and outputs (e.g., productivity, turnaround time). DEA can handle multiple inputs and outputs simultaneously, providing a holistic assessment of efficiency.

Unlike parametric methods, DEA does not require a specific functional form or distribution for the data. This flexibility is advantageous when dealing with diverse and heterogeneous data typical of port operations.

DEA evaluates the relative efficiency of each terminal by comparing it to the best-performing terminals. This comparative approach is useful in identifying best practices and benchmarks for improvement.

Ports vary significantly in size and scale. The BCC model of DEA can account for variable returns to scale, making it suitable for comparing terminals of different sizes and capacities.

DEA not only identifies efficient and inefficient terminals but also provides specific targets for inefficient units to improve. These targets can guide management in optimizing resource allocation and operational practices.

The insights gained from DEA can inform policymakers and port authorities about the effectiveness of public-private partnerships. By identifying efficient practices, DEA can guide strategic decisions and policy formulation for port development.

Practical application of DEA Model

The application of the DEA (Data Envelopment Analysis) model to port operations has gained popularity because it evaluates efficiency by treating each port as a decision-making unit (DMU). This approach allows for a comprehensive assessment of how effectively ports use their resources. Essentially, DEA compares ports with similar inputs and outputs to determine their relative efficiency.

By using used the DEA method & case study analysis, da Costa et al. (2021) analyzed the efficiency of the main container terminals in the North of Brazil. The results & findings points out that majority of ports in the Northern area could enhance container throughput. To find out efficiency of operational performance at BICT to improve productivity, and sustainable development, Armadi (2020) has used the DEA model with use of a systematic approach through surveys, interviews & secondary data from Belawan International Container Terminal (BICT). survey outcome revealed that operational performance of BICT is identified as inefficient. It will be improved by optimizing the utilization of resources in the terminal.

Lagoudis et al. (2017) reviewed literature on port studies that used DEA, AHP, MNL, and SFA models. They looked at port productivity, efficiency, competitiveness, and performance, identifying key areas within the field of port competition. Their findings highlighted those results varied significantly across different ports and terminals worldwide, which sometimes led to contradictory conclusions. They suggested that developing a robust set of comparative tools would help achieve more consistent evaluations of ports and terminals globally.

METHODOLOGY

Research Design

This study adopts a quantitative research design to evaluate the efficiency of public-private partnerships (PPP) in port development, with a specific focus on Colombo Port's three major terminals: Jaya Container Terminal (JCT), South Asia Gateway Terminals (SAGT), and Colombo International Container Terminal (CICT). The research aims to assess and compare the operational efficiency of these terminals using Data Envelopment Analysis (DEA).

Data Collection Methods

Primary data was collected from two sources namely operational data from terminals and on-site observations. Operational data was directly obtained from terminal management and port authorities, including metrics such as average turnaround time, average waiting time, container productivity per crane, container productivity per

ship, and container throughput whereas on-site observations were carried out to ensure the accuracy of the data provided and gain a deep understanding of the operational elements of the terminal operations.Secondary data was retrieved from reports published by Sri Lanka Ports Authority (SLPA) and data available in the public domain. Similarly, industry reports and performance analyses on port operations were referred to obtain further information on the study.

Analytical Techniques

For the purpose of this study, KPIs and Data Envelopment Analysis (DEA) method was used in analyzing the results. The variables for inputs were stacking capacity, terminal area, number of berths, number of quayside cranes, number of terminal tractors, and container throughput whereas the variables for outputs were average turnaround time of container ships, average waiting time of container ships, container productivity per crane and container productivity per ship. The DEA model is the most appropriate technique to be used in this study as elaborated in the previous section.

LIMITATIONS

Following limitations can be observed in the study mainly with respect to the methods use in data analysis.

The reliability of the findings is contingent on the accuracy and completeness of the collected data. Any discrepancies or missing data could affect the results.

DEA provides a snapshot of efficiency at a specific point in time. It does not account for dynamic changes or improvements over time.

External factors such as market conditions, regulatory changes, and technological advancements are not directly considered in the DEA model, which may influence terminal efficiency.

The current trend in mainstream research on micro-enterprises shows that there have been limited studies on savings literacy and its effectiveness within micro-enterprises.

Filling a gap in the literature and adding empirical evidence from a developing country are the main goals of this study. Three hypotheses were tested about how saving literacy and knowledge transfer as a mediator affect small businesses ability to pay their debts.

RESULTS AND FINDINGS

In 1999 Queens Elisabeth Jetty was Privatized by the Sri Lankan Government to John Keells and an SLPA-led Consortium and thereafter South Asia Gateway Terminal (SAGT) formed as the first public-private partnership container terminal operator in Sri Lanka and also the first ever ever-largest foreign direct investment in Sri Lanka in that Period. SAGT's flagship entity with more than 60 % Local shareholding consists of John Keells Holdings, APM Terminals, SLPA and Evergreen Marine Subsidiary Peony Investment SAGT started their operation in the year 2000 and after several years of market competition created with Government Control terminal, JCT.

By analyzing the given data (Table 1), it seems that SAGT recorded the lowest average ship turnaround time (15.84 hr) indicating that, on average, container ships spend the least amount of time at SAGT compared to JCT and CICT. The exact bench marketing industry standard could not be found in the literature but the lowest SAGT is comparatively efficiently running terminal.

Table 1: KPIs Mean (JCT, SAGT, CICT)

KPIs	JCT	SAGT	CICT
	Mean		
Average turnaround time of container ships (Hrs)	20.51	15.84	18.58
Average waiting time of container ships (Hrs)	1.28	1.99	1.95

Container Productivity per Crane (Moves per hour)	23.63	28.49	32
Container Productivity per Ship (Moves per hour)	66.72	83.12	128

The average waiting time for container ships is 1.28 hours at JCT, 1.99 hours at SAGT, and 1.95 hours at CICT. JCT has the shortest average waiting time, indicating that ships are processed faster than at other terminals. The average productivity per crane at JCT is 23.63 movements per hour, whereas at SAGT it is 28.49 moves per hour and at CICT it is 32 moves per hour. CICT has the maximum productivity per crane among all terminals. CICT Terminal running more efficiently compactivity other two terminals. The average productivity per ship at JCT is 66.72 movements per hour, 83.12 moves per hour at SAGT, and 128 moves per hour at CICT.CICT is the terminal with the highest productivity per ship. In summary, SAGT appears to excel in turnaround time, whereas JCT offers a shorter waiting period. CICT has more productivity per crane and per ship than the other terminals. Depending on certain factors like as speed, efficiency, or capacity utilization, several terminals may be chosen.

Another Port KPIs measurement is berth occupancy ratio. This will also important factor consider to evaluate port terminal efficiency. berth occupancy ratio is the berth occupancy factor (BOF) is the time that a berth is utilized, divided by the total available time (Gurning & Fikri, 2017). For a port, it is the primary indicator of congestion and also this will show the demand for the port services. CICT Terminal average berth occupancy ratio is 72% and other two terminals SAGT Reported 68% and JCT reported 67%. All three terminals are within the berth utilization benchmark range, indicating that they are operating at an acceptable level of efficiency according to industry standards. However, it's worth noting that CICT is at the higher end of the benchmark range, suggesting the terminal may be utilizing its resources more efficiently or experiencing higher demand compared to JCT and SAGT. This may indicate that CICT has better operating efficiencies.

Data Envelope Analysis (DEA) for Terminal Efficiency

Calculation of the Data Envelope analysis (DEA) for the three terminals was the key in assessing the efficiency of the said terminals. Under the DEA model the inputs use for this study include stacking capacity, terminal area, number of berths, number of quayside cranes, number of terminal tractors and container throughput.

The output data were average turnaround time of container ships (hours), average waiting time of container ships (hours), container productivity per train (moves per hour) and container productivity per ship (moves per hours).

The first part of the DEA analysis is the normalization of the data. Table 2 below depicts the normalization data. Table 2: DEA analysis is the normalization of the data

Terminal	**Input**					**Output**				
	Stacking Capacity	**Terminal Area**	**No. of Berths**	**No. of Quayside Cranes**	**Number of Terminal Tractors**	**Avg. Turnaround Time (hrs)**	**Avg. waiting time (hrs)**	**Container productivity per crane**	**Container productivity per ship**	**Container Throughput (TEUs)**
JCT	0.7867	0.7845	1.0000	1.0000	1.0000	1.0000	1.0000	0.7384	0.5213	0.6051

SAGT	0.4079	0.3448	0.5000	0.6000	0.3333	0.7721	1.5547	0.8903	0.6494	0.5502
CICT	1.0000	1.0000	0.6667	0.7000	0.3429	0.9054	1.5234	1.0000	1.0000	1.0000

Based on the above normalized data, the DEA efficiency scores can be arrived at which will determine the overall efficiency of the terminals. Table 3 showcases the efficiency scores of the terminals.

Table 3: Efficiency Scores based on DEA model

Terminal	Efficiency Score
JCT	1.3760
SAGT	1.9703
CICT	1.5229

CONCLUSION

Based on the empirical data calculated using the DEA model, it was revealed that while the efficiency levels of the three terminals stand rigorous, SAGT terminals' performance is the best in terms of overall efficiency scores. The CICT which also owned by private operators, shows significant performance in terms of operational efficiency. While SAGT Terminal emerged as the most efficient, leveraging private sector innovation and expertise, JCT Terminal, despite being publicly owned, demonstrated commendable efficiency, indicating the potential for effective management of resources and operational performance. This study has provided a comprehensive analysis of the efficiency of container terminals within the Colombo Port. Through the utilization of Data Envelopment Analysis (DEA), we have evaluated the performance and productivity of three major terminals: JCT, SAGT, and CICT. The findings reveal valuable insights into the operational efficiency of these terminals. SAGT Terminal emerged as the most efficient terminal, utilizing its resources effectively to achieve high levels of productivity and operational performance, while CICT is the second highly effective and efficient terminal in the Colombo ports. JCT Terminal also demonstrated commendable efficiency, albeit significantly lower than SAGT and CICT showcasing its capability to effectively manage its operations.

The efficiency assessment was based on a range of operational metrics including average turnaround time, average waiting time, container productivity per crane, container productivity per ship and container throughput in TEUs. These metrics provide a holistic view of terminal performance, considering both operational efficiency and service quality. It is important to acknowledge the limitations of this study, including the availability and accuracy of data, as well as external factors such as market conditions and regulatory frameworks. Similarly, the effect of technological innovations and advancements, level of expertise deployed and competency levels of human resources are not supported for the study. Future research could explore additional factors influencing terminal efficiency and incorporate dynamic elements into the analysis to capture real-time operational dynamics.

The findings of this study have practical implications for port operators, policymakers, and stakeholders involved in the maritime industry. By identifying areas of strength and areas for improvement, terminal operators can implement targeted strategies to enhance efficiency, reduce operational costs, and improve overall competitiveness in the global market. The introduction of public-private partnership (PPP) concepts for terminals holds promise in enhancing efficiency and driving innovation. Private operators have demonstrated their ability to bring innovative technologies, expertise and competent human resources to terminal operations, thereby improving overall efficiency and competitiveness. The successful implementation of PPP models can

enable publicly owned terminals to harness the benefits of private sector efficiency while retaining strategic oversight and control.

Incorporating PPP principles into terminal management can foster collaboration between the public and private sectors, leveraging the strengths of each to achieve mutually beneficial outcomes. By combining public sector stewardship with private sector innovation and efficiency, PPP models have the potential to optimize terminal performance, enhance operational efficiency, and drive sustainable growth in the maritime sector. However, it is essential to acknowledge the challenges and complexities associated with implementing PPP models, including regulatory frameworks, governance structures, and stakeholder engagement. Effective collaboration and partnership between public and private entities are critical for the success of PPP initiatives, requiring transparent communication, shared objectives, and mutual trust.

In conclusion, this research highlights the importance of considering technological advancements, expertise, and the strength of human resources in assessing terminal efficiency. The integration of public-private partnership (PPP) concepts offers a promising avenue for enhancing terminal efficiency and driving innovation in the maritime sector. By embracing PPP models, publicly owned terminals can capitalize on private sector expertise while maintaining strategic oversight, ultimately contributing to the sustainable growth and competitiveness of the Colombo Port.

The research study has addressed the objectives and the research questions and following sections proved specifics on them.

Firstly, in assessing and quantifying gaps in operational factors, the study identified significant efficiency gaps between publicly and privately managed terminals, with private terminals exhibiting superior performance in turnaround times, waiting times, and overall service efficiency.

Secondly, in terms of determining causes and underlying factors, the findings have suggested that private sector participation brings in advanced technologies, better infrastructure management (e.g., more efficient use of gantry cranes and berths), and superior operational strategies, contributing to higher efficiency levels.

Thirdly, in evaluating the implications of advanced technologies and automation, due to the limitations in the retrieval of data pertaining to the innovations, a deep analysis was not conducted, however, that study concludes that the superior performance of private terminals like CICT indicates the positive impact of advanced technologies and automation on operational efficiency.

Finally, the study acknowledged that the level of expertise and competency of human resources in private terminals significantly enhances operational performance. Future research should further explore this dimension to provide more detailed insights.

Ultimately, saving literacy and knowledge transfer is vital in enhancing microenterprises' ability to repay debt effectively. Building a strong foundation in saving literacy gives entrepreneurs essential skills for budgeting and planning future financial obligations. Additionally, educational interventions focused on knowledge transfer equip micro entrepreneurs with transferrable management skills that positively influence their capacity to meet loan repayment requirements responsibly. By supporting these aspects within the entrepreneurial ecosystem, policymakers can contribute towards fostering sustainable economic growth at the grassroots level.

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