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TERMINAL PRICING DECISIONS OF THE PORT AUTHORITY AND THE GLOBAL TERMINAL OPERATOR OF THE COMPETING PORTS IN SRI LANKA

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ABSTRACT

This study analysed competition at port and terminal levels resulting from the involvement of a port authority, Sri Lanka Port Authority (SLPA), and a Global Terminal Operator, China Merchant Port Holdings (CMPH), in the Colombo and Hambantota ports. It also considered the operators' disparate interests in the two ports. The terminals' pricing decisions of SLPA and CMPH were analysed taking into account the cooperation among the terminals in one port and the terminals owned by the same Global Terminal Operator and the competition from their different ownership types. Results revealed significantly different pricing decisions attributable to seven possible objectives of the SLPA along with profit and demand maximisation objectives of CMPH.

Findings suggest that, if the SLPA reduces the terminal price charged by the Colombo International Container Terminal operated by the CMPH, the latter would behave as a "free rider". Moreover, both the SLPA and CMPH would try to balance their interests in both ports, especially with their profit maximisation objective, which would result in less profits for both Colombo and Hambantota ports. The demand maximisation objective of CMPH would reduce charges at its terminals as opposed to its profit maximisation objective. Colombo Port would receive higher demand if the SLPA focuses on user surplus maximisation.

Keywords: *Terminal Pricing, Global Terminal Operator, Port Authority, Competition, Port-level, Terminal-level*

1. INTRODUCTION

Sri Lanka is strategically located on the East-West trunk sea route, one of the busiest sea routes in the world, thus having huge potential for growth as a logistics hub. As the main administrator of all Sri Lankan ports, Sri Lanka Port Authority (SLPA) executes port infrastructure developments, including the national port master plan, especially targeting Colombo and Hambantota ports in Sri Lanka [1].

The Port of Colombo is a transhipment hub in South Asia, and transhipment cargo accounts for over 75% of its throughput. The port ranks among the top 25 container ports worldwide [2] and serves as the SLPA's primary source of revenue. Colombo plays a significant role in the Indian feeder market because most mainline services do not call at Indian ports. These ports have limited infrastructure that cannot accommodate larger vessels and entail high deviation from the trunk sea route. In 2019, the Port handled over 7.23 million TEUs (Twenty-foot Equivalent Units): a significant growth over the previous decade. Development projects currently underway at the Port of Colombo aim to increase its capacity from the present 6.8 million TEUs to over 20 million TEUs by 2040 [3]. The Port of Colombo also provides husbandry services such as ship repair and bunkering for many vessels.

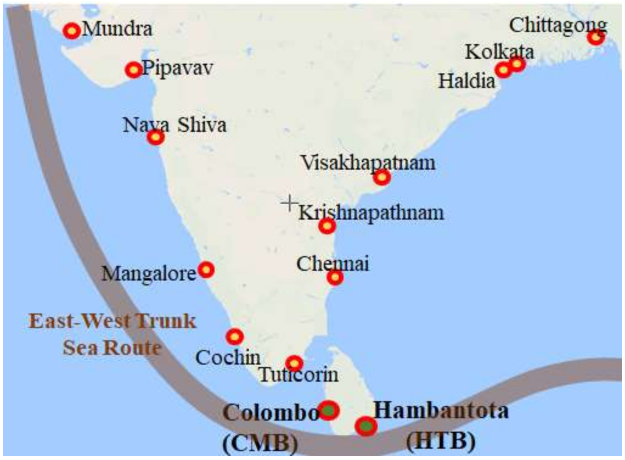

Figure 1: Study Area

Port of Hambantota is located in the Southern province of Sri Lanka with nearly ten nautical miles of short deviation from the East-West trunk sea route (Figure 1 above). In 2008, SLPA initiated the development of the Hambantota Port as an industrial port. The China EXIM Bank funded 85% of Phase-I of this development, as a loan, and SLPA funded the remaining 15% [4]. However, the port did not make the anticipated profits and incurred losses for years: resulting in an accumulated financial liability to China from outstanding loans [5]. Hence, the private sector was invited to source the substantial investment that was required to bring the port to an operational level [6].

Consequently, in 2017, Sri Lanka signed an agreement with China Merchant Port Holdings (CMPH), a reputable Global Terminal Operator (GTO), to lease Hambantota port for 99 years. This agreement was expected to bring foreign investment for Port development [6]. Two private-public partnership companies were formed; namely, the Hambantota International Port Group (Pvt) Ltd, for planning, operations, and management of commercial port functions, and the Hambantota International Port Services (Pvt) Ltd, to provide common user facilities [1]. SLPA owns a 50.7% share in Port Services (Pvt) Ltd and a 15% share in the Port Group (Pvt) Ltd; the latter company directly receives cargo-handling revenues [4]. SLPA receives fewer benefits from Hambantota Port than from Colombo Port: in Colombo, it receives revenue from public terminals and common user facilities and terminal fees from private terminals.

CMPH, a globally competitive port operator, owns the majority share of the Hambantota Port. It has a worldwide port network, including ports across China, Hong Kong, South Asia, Africa, Mediterranean, and South America, with a network portfolio spanning 36 ports in 18 countries across five continents. Being a subsidiary of the China Merchant Group, CMPH is an award-winning logistics operator with an international track record for best practices.

Sri Lanka is strategically positioned vis-à-vis China's Belt and Road Initiative, with Hambantota Port lying almost at the halfway point, connecting major Chinese ports with the Mediterranean Sea and African gateway ports [7]. Hence, although Hambantota Port was planned as an industrial port, CMPH may have strong interest in developing Hambantota as a large-scale container port due to its 99-year lease agreement.

Given the significant contribution of seaports to the country's economy, their ineffective management would lead to devastating economic losses [8], [9]. Considering the Colombo Port's role as a transhipment hub, it should have strong network connectivity from liner services. Thus, the presence of another large-scale container port would potentially split the liner services between the two, possibly leading to a decrease in Colombo Port's connectivity. Hence, port operators have a significant responsibility in determining sustainable policies to manage competition between Ports and ensure the country's economic well-being.

Although Kavirathna et al. [1] analysed the impact of transhipment cargo flows on local shippers and consignees; but they did not discuss the implications on terminal operators of these ports. However, they highlighted the possibility of fostering stronger competition between Colombo and Hambantota ports in transhipment handling than in domestic cargo handling. This is because Colombo Port secures over 85% of domestic cargo handling.

In the light of the above, the present study was conducted with the aim of analysing the behaviour of a port authority and a GTO involved in two competing ports and their terminals located in the same market, focusing on the Colombo and Hambantota ports as a case study. Here, CMPH and SLPA are involved as the GTO and the port authority, respectively. The behaviour of SLPA and CMPH were thus examined, considering the potential competition between the two ports for handling transhipment cargo from twelve feeder ports in the Indian sub-continent (Figure 1). To analyse the behaviour of port operators, a terminal pricing scenario was assumed because terminal prices (terminal handling charges) significantly influence overall port competitiveness. SLPA and CMPH were assumed to be decision-makers on terminal prices due to their involvement in both ports, as explained in Section 2. Two logit models were developed to estimate the market share at the port and terminal levels following an approach similar to [1] and [10], where the port and terminal prices decided by SLPA and CMPH were considered along with other criteria on transhipment port selection. The behaviour of SLPA and CMPH were analysed with several possible objectives considering a multi-period non-linear optimisation model to understand their impacts and significant policy implications arising from the analysis were discussed.

2. TERMINAL PRICING DECISIONS OF A PORT AUTHORITY AND A GTO

Port operators in a competitive market may enhance their port competitiveness with different strategies such as reducing port charges by incentives/rebates. Thus, a hypothetical scenario could be assumed based on terminal pricing decisions made by the port authority and GTO to enhance the competitiveness of their respective ports and/or terminals.

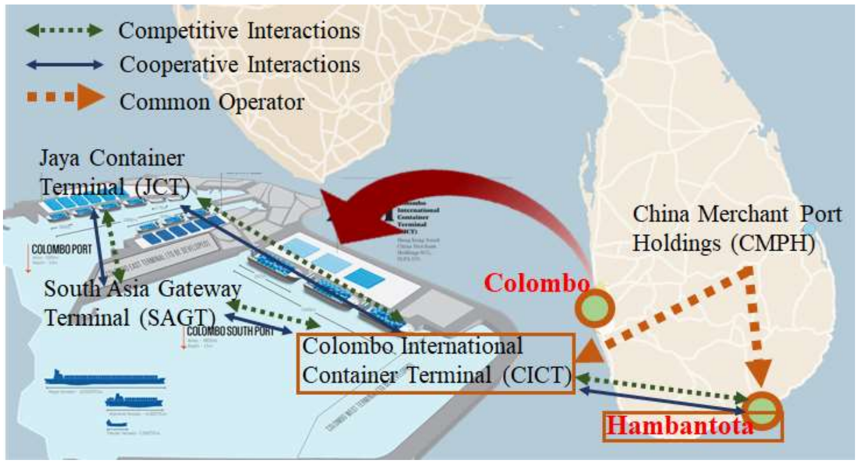

Figure 2: Terminal Ownership and Interactions

As illustrated in Figure 2 above, Colombo Port has three main terminals, namely, the Jaya Container Terminal (JCT), the South Asia Gateway Terminal (SAGT), and the Colombo International Container Terminal (CICT). JCT is a public terminal directly operated by SLPA, while the SAGT and the CICT are two concession terminals. CMPH operates Hambantota Port due to its majority share in Hambantota International Port Group (Pvt) Ltd. Although Hambantota Port's container handling facilities are still under construction, this study assumed two container terminals, HBT1 and HBT2, at Hambantota Port for model development (Figure 3). In the Port of Colombo, three terminals could cooperate to enhance the overall port competitiveness, and they could compete because they are operated by three different parties as separate economic entities. When considering CMPH, on top of the Hambantota port's terminals, CMPH operates CICT in Colombo. Therefore, CICT in Colombo and HBT1 and HBT2 in Hambantota could cooperate as they belong to the same GTO while they could compete as they are located in two competing ports. Since the behaviour of the port authority and GTO are analysed in the context of terminal pricing, SLPA could influence the prices of JCT, SAGT, and CICT by offering rebates/incentives to maintain a competitive terminal price. Similarly, CMPH could influence the prices of HBT1, HBT2, and CICT because it operates them all.

GTOs face a challenge in balancing their company's interest and the interest of the port to which their terminals belong, especially when these are operated in competing ports. Meanwhile, a port authority, having both a public terminal directly operated by it and a concession terminal operated by a GTO in the same port, may have a conflict of interest in balancing its own interest and the interest of the entire port. This study therefore focused on analysing the possible pricing behaviours of SLPA and CMPH amidst their potentially conflicting interests and multitude of objectives (Figure 3).

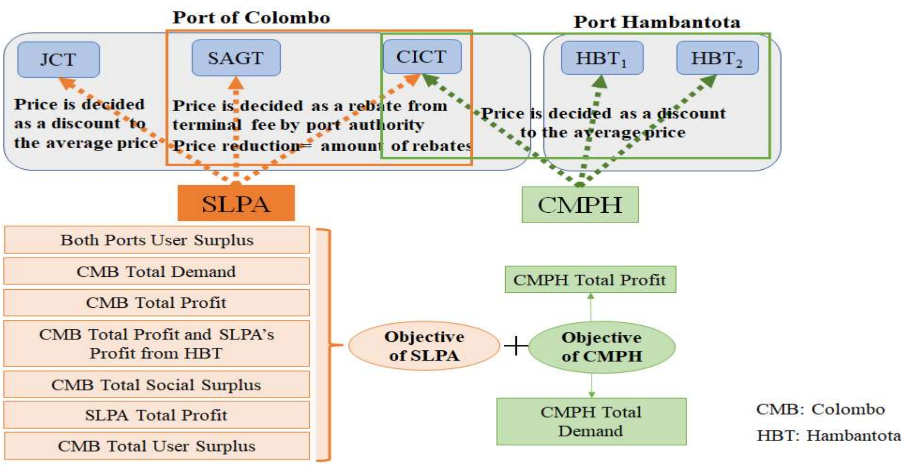

Figure 3: Objectives for Decision-making of SLPA and CMPH

In this regard, the SLPA was assumed to make pricing decisions for JCT, SAGT, and CICT with seven possible objectives, which were analysed as separate scenarios along with the profit or demand maximisation objectives of CMPH when deciding prices at HBT1, HBT2, and CICT. These objectives are explained in detail in sections 4.2 and 4.3.

As its significant contribution, this paper, having analysed the competition at port- and terminal- levels caused by terminal pricing decisions of a GTO that has terminals in two competing ports and the port authority of a port with both public and concession terminals, summarises the significant implications of the behaviour of SLPA and CMPH, which would be helpful in deriving sustainable policy guidelines on port and terminal competition. Being among the first few studies on analysing such behaviour of a port authority and a GTO considering their reactions to each other's decisions, it was conducted with the intention of fathoming the possible scenarios of decision combinations which would help increase the competitiveness of a port. Moreover, this study was also conducted with the aim of making a significant theoretical contribution towards analysing behaviour of port authorities and GTOs having conflicting interests and interactions related to two competing ports.

3. LITERATURE REVIEW

A port may be governed by the private or public sector, which eventually influences its objectives and operating principles [11]. A port devolution matrix was discussed by Baltazar and Brooks [12] including three groups for port governance: public, mixed and private. Further, they divided port functions into regulatory, landlord, and operator/cargo handling functions. However, depending on the port's ownership and governance, these functions would be transferred from one party to another [13]. Port governance would be influenced by multiple factors, including the relevant country's socioeconomic aspects, port's location, and development strategies, among others. The World Bank, in 2007, introduced four port administration models: (i) public-service port, (ii) tool port, (iii) landlord port, and (iv) fully privatised port [14]. Accordingly, the public sector carries out the governance and operations of a public-service port and the majority of port functions of a tool port. However, a tool port utilises private labour. Therefore, public-service and tool ports aim at maximising public welfare rather than individual profits.

Although the public port authority still acts as the regulator and policymaker in a landlord port, the private operators carry out the cargo handling functions. Hence, the port authority provides infrastructure, and the private operators build and maintain own superstructures to carry out port operations, usually with a concession agreement such as build-operate-transfer (BOT) for a fixed term. Therefore, a landlord port model aims at balancing the interests of public and private sectors, focusing on both profit and non-profit objectives. Lastly, in a fully privatised port, the private sector provides infrastructure, superstructure, and labour, aiming at profit maximisation. However, depending on the port administration of individual countries, these objectives would differ, highlighting the importance of analysing these scenarios in relation to Sri Lanka.

In terms of port competition, Kavirathna et al. [15] addressed the competition between Colombo and the major ports in Southeast Asia by constructing a logit model. They estimated the market share of hub ports in handling transhipment containers coming from the Indian sub-continent feeder market, separately for hub-and-spoke and relay networks. The competition/cooperation among Northern Adriatic ports was discussed by Twrdy and Batista [16] incorporating three different container throughput characteristics, namely, relative growth, market share, and container shifts among ports. Results identified different absolute growth factors of container throughput, container shifts, and asymmetric cooperative/competitive relationships among these ports.

The competition between Busan and Kobe ports, when changing port charges and capacities, was analysed by Ishii et al. [17] with a game-theoretical approach. The significance of port charges was highlighted with a high demand elasticity because a port lost its profit and market share after setting its port charges higher than the market equilibrium level. Hoshino [18] discussed the competition and collaboration among ports and emphasised the significance of cooperation (in contrast to competition) among minor ports in Japan, in ensuring their survival in the face of competition from ports in China and Korea. Thus, ports have adopted competition and cooperation approaches with different market dynamics, reflecting the significance of analysing the most suited approach for Sri Lankan ports.

Do et al. [19] adopted Game Theory and Uncertainty Theory to examine competition between Hong Kong and Shenzhen ports with reference to long-term investments in port capacities. Results revealed that Shenzhen port will continuously develop container cargo throughput and possibly surpass the Hong Kong port in the future. Oliveira and Cariou [20] developed a truncated regression with a parametric bootstrapping model including 200 container ports. Accordingly, the port efficiency was found to decrease when the inter-port competition increased at the regional level (400-800km), but was not significant at the local (less than 300km) or global (more than 800km) level. Dong et al. [21] deployed Game Theory to study port integration in Ningbo-Zhoushan, where each port decides its container throughput considering the port integration effort in the multiport region. The results revealed that lower handling charges and larger container throughputs could be derived from higher port integration. Yang et al. [22] examined the integration among ports in a multiport gateways region while discussing the industry transformation and upgrades of ports with overcapacity. They suggested an optimal scale for a port cluster. Ignatius et al. [23] used a game-theoretical approach to analyse possible means of competition or cooperation among major ports in Southeast Asia to generate more benefit for the entire region. Accordingly, the cooperation between Singapore and Tanjung Pelepas was found yielding higher profitability. Thus, previous studies suggest that the role and position of individual ports in the global maritime network would change with time, which can also be expected from Sri Lankan ports.

Relating to terminal operators, Ng et al. [24] have analysed the relationship between space and institutional changes as a case study on Hong Kong International Terminal. They have investigated its development as a global player accessing its evolution with time, regional expansion, and changes in institutional, operational, and management factors. Munim et al. [25] examined the impacts of the transformation of port governance from tool port to landlord port as a case study on Chittagong and Mongala ports in Bangladesh. Results indicated that the port authority achieved the highest profit with a high user surplus by privatising only one container terminal. However, less user surplus was found to be generated by privatising both. Kavirathna et al. [10] developed an intra-port coopetition model considering different terminal ownership types. The results indicated the advantages of cooperative interactions among terminals in one port to outperforming external competitors. Incorporating a game-theoretical approach, Saeed and Larsen [26] analysed the possible ways of cooperation, including partial and grand coalitions among container terminal operators in Karachi port. As per the results, external competitors obtained larger market shares while acting as orthogonal free riders due to the high prices of terminals under the coalition.

Yu et al. [27] examined competition in a dual gateway port system using Hotelling's game model with two competing ports and their terminals. Although the government preferred terminals' competition, their concentration generated more profits for the terminal operators in the absence of competitive advantages with individual terminals. Yuen et al. [28] discussed the impacts of foreign and local ownerships of terminals on their efficiency in China, and the results revealed that competition could enhance the efficiency of container terminals.

Since the present study intended to focus on the involvement of a GTO and the port authority in two competing ports in Sri Lanka with a port development issue, several related studies were also examined. Kavirathna et al. [1] was one such study, which analysed competition and port development issues of Colombo and Hambantota ports in Sri Lanka. They highlighted the advantages of Colombo in import/export handling and Hambantota for transhipment container handling. Jung [29] studied the economic contribution of Korean ports and examined the failure of a few port cities, which revealed that the availability of facilities alone could not be able to ensure their high economic performance. Wilmsmeier et al. [30] discussed port development in Uruguay under the influence of geographical, functional, and operational characteristics. Having considered the role of a port in the regional port system, they identified the presence of economies of scale in transportation, port infrastructure, and port connectivity as the determinants of port development. As discussed, the impacts of port development would vary depending on the practical context, especially based on the factors related to the countries, including port ownership and management. Besides, these impacts would differ as each port had a distinct role in the hinterland or transhipment market.

Despite previous studies having examined port competition issues, none appear to have considered the competition between two ports with the involvement of a GTO and the port authority in both ports, which is a unique situation in Sri Lanka. Thus, port competition models developed in previous studies could not be directly applied to the Sri Lankan context. Also, there is a dearth of studies pertaining to the conflict of interests of GTO. Even though previous studies have delved on different port administration structures, the cases in the Ports of Colombo and Hambantota differ due to their port development issues, concession and leasing agreements. Hence, their objectives are complicated, particularly because of the involvement of both public and private sectors. This underlines the importance of studying the two cases recognising their different combinations of profit and non-profit focuses.

The present study therefore aims to bridge this research gap by examining the behaviour of a port authority with multiple objectives and also discussing the conflict of interests a public port authority would have over public and concession terminals. The importance of this research effort is further accentuated as its outcomes would have significant implications on ensuring the country's long-term economic well-being.

4. MODEL DEVELOPMENT

4.1. Port and Terminal Level Analysis

This study analyses a terminal pricing scenario of the port authority and GTO which eventually influences overall port competitiveness. Thus, for the port-level analysis, this study follows the approach used in 2020 by Kavirathna et al. [1] in their transhipment cargo flow analysis. However, this study deviates by considering a multi-period decision-making model to understand the port authority and GTO reactions to each other's terminal pricing decisions. The Generalised cost (GC) for transhipment hub port selection of shipping lines in period *t* consists of port charges (MPC_t^h), journey cost ($\mathrm{JC}_t^{f,h}$), time cost ($\mathrm{TC}_t^{f,h}$) and the value of non-quantitative criteria (VNQC_t^h) as given in Equation (1). The first component gives the average port charge, MPC_t^h which is calculated in each period using the terminal price MPC_t^i at each terminal located in that port and terminal's market share (Share_t^i) (Equation 2). Thus, when the port authority and GTO make pricing decisions for their associate terminals, the MPC_t^i and Share_t^i of the terminals are changed in each period, which eventually changes the MPC_t^h of the entire port. Equation (3) estimates the journey cost ($\mathrm{JC}_t^{f,h}$), which is the cost of the journey when using a hub port for transhipment operation by shipping lines, and this consists of deviation cost and feeder-link cost. Journey cost is estimated by incorporating the journey cost of one nautical mile, $\mathrm{UDC}_t^{(j,f,h)}$. Equation (4) calculates the $\mathrm{UDC}_t^{(j,f,h)}$ incorporating the average port charge, MPC_t^h in that period. Similarly, Equation (5) estimates the time cost ($\mathrm{TC}_t^{f,h}$) which reflects the time-related cost of shipping lines when using a transhipment port encompassing four components: deviation time, vessel turnaround time, waiting time, and feeder-link time. This time cost is estimated by incorporating the $\mathrm{VOT}_t^{(w,f,h)}$, which reflects the value of time. Equation (6) estimates the $\mathrm{VOT}_t^{(w,f,h)}$ with the average port charge. Therefore, journey and time costs are changed in each period based on the terminals' pricing decisions since their monetisation is based on the average port charge (MPC_t^h).

$$\mathrm{GC}_t^{f,h} = \mathrm{MPC}_t^h + \mathrm{JC}_t^{f,h} + \mathrm{TC}_t^{f,h} - \mathrm{VNQC}_t^h \quad (1)$$

$$\mathrm{MPC}_t^h = \sum_{i=1}^{i=m^h} (\mathrm{Share}_t^i * \mathrm{MPC}_t^i) \quad (2)$$

$$\mathrm{JC}_t^{f,h} = \sum_{j=1}^{j=2} \left[\mathrm{D}^{(j,f,h)} * \mathrm{UDC}_t^{(j,f,h)} \right] \quad (3)$$

$$\mathrm{UDC}_t^{j,f,h} = \frac{\left(\frac{\mathrm{MPC}_t^h}{\mathrm{SS}_{(\mathrm{Port\ Charges})}}\right) * \mathrm{SS}_{(j)}}{\left(\sum_{h=1}^{h=2} \mathrm{D}^{(j,f,h)}/2\right)} \quad (4)$$

$$\mathrm{TC}_t^{f,h} = \sum_{w=1}^{w=4} \left[\mathrm{T}^{(w,f,h)} * \mathrm{VOT}_t^{(w,f,h)} \right] \quad (5)$$

$$\mathrm{VOT}_t^{(w,f,h)} = \frac{\left(\frac{\mathrm{MPC}_t^h}{\mathrm{SS}_{(\mathrm{Port\ Charges})}}\right) * \mathrm{SS}_{(w)}}{\left(\sum_{h=1}^{h=2} \mathrm{T}^{(w,f,h)}/2\right)} \quad (6)$$

Where;

$GC_t^{f,h}$ Shipping lines' generalised cost when using hub port *h* to serve feeder port *f* (USD) in t[th] decision-making period;

MPC_t^h Average port charges paid by shipping lines for using hub port *h* to serve feeder port *f* (USD) in t[th] period;

MPC_t^i Average container handling charge/terminal price of terminal i in t[th] period;

$JC_t^{f,h}$ Shipping lines' journey costs for using hub port *h* to serve feeder port *f* (USD) in t[th] period;

$TC_t^{f,h}$ Shipping lines' time costs for using hub port *h* to serve feeder port *f* (USD) in t[th] period;

$VNQC_t^h$ The value of non-quantitative criteria (USD), which indicates shipping lines' perceived generalised cost reduction due to the high performance of hub port h in t[th] period;

$Share_t^i$ Market share of terminal *i* in t[th] period;

j Any journey cost-related criterion, *j* = {feeder link cost, deviation cost};

$D^{(j,f,h)}$ The journey distance (nm) related to the *j*[th] criterion of port *h*. When *j* equals the deviation costs, $D_{(j,f,h)}$ indicates the quantitative deviation distance of port *h*

$UDC_t^{(j,f,h)}$ Unit distance cost, which indicates the journey cost of one nautical mile of the *j*th criterion (USD) in the t[th] period;

$SS_{(j)}$ The "significant score" of the *j*th journey cost-related criterion, which reflects its level of significance in the hub port selection decision. Similarly, $SS_{(Port\ charges)}$ indicates the significance of "port charges";

w Any time cost-related criterion, *w*= {deviation time, vessel turnaround time, waiting time, feeder link time};

$SS_{(w)}$ The "significant score" of the *w*[th] journey cost-related criterion, which reflects its level of significance in the hub port selection decision;

$VOT_t^{(w,f,h)}$ Value of time, which indicates the value of one hour for the *w*[th] criterion (USD/hour) in the t[th] period;

$T^{(w,f,h)}$ The quantitative time value (hours) related to the *w*[th] criterion of port *h*. When *w* equals the deviation time, $T^{(w,f,h)}$ indicates quantitative "deviation time";

m^h The number of terminals operated in port h.

The last component of the GC function is the value of non-quantitative criteria, VNQC_t^h, which represents the shipping lines' perceived generalised cost reduction due to the hub port *h*'s performance in period *t*. VNQC_t^h is calculated with the "port performance index" (PPI) based on a questionnaire survey conducted with shipping lines by Kavirathna et al. [1]; thus, the PPI at the initial period (*t=0*) is taken directly from them. Although journey distance and time values are fixed in each period, the PPI can be varied as it is calculated with a range of port selection criteria. Thus, the port demand is assumed as a proxy for PPI, hence PPI changes in each period when changing the port's total demand (Equation 7), which is reasonable because a port with high performance receives high demand. Also, this leads to a positive impact of cooperation among terminals in one port. Since VNQC_t^h depends on the port's PPI in period t (PPI_t^h) and MPC_t^h (Equation 8), VNQC_t^h varies when changing the total port's demand and average port charges in each period, which are decided by the pricing decisions of the port authority and GTO.

$$\mathrm{PPI}_t^h = \mathrm{PPI}_0^h + e \sum_{i=1}^{i=m^h} (\mathrm{Q}_{t-1}^i - \mathrm{Q}_0^i) \tag{7}$$

$$\mathrm{VNQC}_t^h = \left[\left(\frac{\mathrm{MPC}_t^h}{\mathrm{SS}_{(\text{Port Charges})}}\right) * \mathrm{PPI}_t^h\right] \tag{8}$$

Where;

PPI_t^h The port performance index in t[th] period;

e Degree of influence of the port demand on its PPI_t^h;

Q_t^i The number of vessel calls at terminal *i* in t[th] decision-making period.

After estimating GC, the transhipment volume handled by each hub port can be estimated with a logit model (Equations 9 and 10). Therefore, in the port level analysis, the port's estimated demand (Equation 10) varies in each period due to the changes in pricing decisions of the port authority and GTO because the average port charge is affected by the individual terminal prices. Thus, the competition between Colombo and Hambantota ports can be analysed by estimating their market share variation based on the shipping lines' generalised costs.

$$\mathrm{Utility}_t^{(f.h)} = \frac{1}{\frac{\mathrm{GC}_t^{(f.h)}}{\mathrm{GC}_t^{(f.least)}}} \qquad \forall f, \forall h \tag{9}$$

$$\mathrm{TS}_t^h = \sum_{f=1}^{f=12} \mathrm{TS}^f * \frac{e^{\mathrm{Utility}_t^{(f.h)}}}{\sum_{h=1}^{h=2} e^{\mathrm{Utility}_t^{(f.h)}}} \qquad \forall h \tag{10}$$

Where;

f	Any of the twelve feeder ports in Figure 1;
Q^f	Total TEUs given by feeder port *f* to Sri Lanka;
TS_t^h	Total TEUs given by all feeder ports to the hub port *h* in period t;
$GC_{t,f}^{(f,least)}$	The lowest generalised cost across two alternative hub ports when serving feeder port *f* in period t.

Besides the port-level competition, this study analyses its impacts on terminals due to their different ownership types. Figure 4 illustrates the relationship between port- and terminal-level analysis.

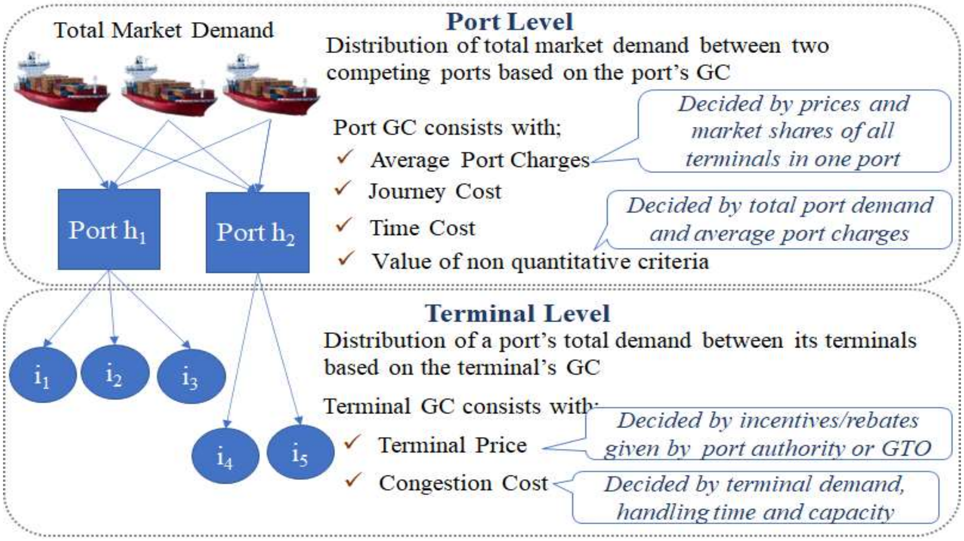

Figure 4: Port-level and Terminal-level Analysis

Accordingly, the port-level analysis estimates the entire port's demand, which is distributed among terminals in that port based on the generalised cost related to individual terminals. This has two main components: terminal handling charges/terminal price and congestion cost [10].

Hence, at the terminal level, the port authority and GTO decide the terminal prices for their associated terminals, which influence the terminals' market share. These individual terminals' prices and market shares determine the average port charge at the port-level, thus influencing other components of the shipping lines' GC function for hub port selection. Thus, terminal pricing decisions influence both port- and terminal- levels analysis. Since the port authority's and GTO's pricing decisions are analysed with multiple objectives, the results would be changed with those objectives.

For the terminal-level analysis, Equation (11) gives the shipping lines' GC function, which has two main components: terminal price and congestion cost. Here, the demand is measured by the number of vessels calls such that V indicates the average number of TEUs handled during a vessel call [10], [31]. Moreover, a terminal's usage above 80% of its capacity generates congestion costs for shipping lines [26], [31] where T^i and Q^i_{t-1} are the average handling time and the number of vessel calls at terminal i in period *t-1*. Equation (14) gives the terminal's capacity, K^i in number of berth hours. After calculating each terminal's GC in a period, Equation (12) estimates the terminals' market shares ($Share^i_t$) in that period with a logit model [10]. Equation (13) calculates the terminal's demand (number of vessel calls), where Q^h_t indicates the port's total demand, estimated with port-level analysis. Thus, terminal-level analysis distributes the total port's demand among its terminals based on the terminal's generalised cost. Thus, the pricing decisions of the port authority and GTO also influence the profit of terminal operators.

$$GC^i_t = \left(V * MPC^i_t\right) + a\left(\frac{Q^i_{t-1} * T^i}{0.8 * K^i}\right)^b \tag{11}$$

$$Share^i_t = \frac{e^{-\theta GC^i_t}}{\sum_{i=1}^{i=m^h} e^{-\theta GC^i_t}} \tag{12}$$

$$Q^i_t = Share^i_t * (TS^h_t / V) \tag{13}$$

$$K^i = \text{no of berths}^i * 24 * 365 \tag{14}$$

Where,

GC^i_t	Shipping lines' generalised cost (USD) when using terminal *i* in t^th period;
V	Average volume (TEUs) handled per one vessel call;
a, b	Parameters to estimate the additional generalised cost perceived by shipping lines due to terminal congestion and delays;
T^i	Average handling time per vessel at the berth (hours) of terminal *i*;
K^i	The capacity of terminal *i* (available berth hours);
θ	Scale parameter of the logit model.

4.2. Decision Making by the Port Authority

Since SLPA can influence the Colombo Port's terminal prices, it can maintain a competitive average port price, enhancing its competitiveness over other competing ports. However, SLPA's pricing decisions for the public and concession terminals could be different due to their different ownerships. As per the landlord port governance model, the port authority collects terminal fees based on the number of containers handled at concession terminals [10]. Thus, as pricing decisions for concession terminals, SLPA is assumed to offer rebates on the terminal fee, which is paid by concession terminals. This means, SAGT and CICT receive concession fee rebates from the SLPA equal to a certain amount, and these terminals reduce their container handling charges/terminal price by an equal amount, which creates benefits for shipping lines as they can use terminals at low prices. Moreover, concession terminals benefit from this policy as they do not lose any revenue with discounted prices because they receive equal savings as terminal fee rebates given by SLPA. Besides, they can attract more demand from shipping lines with discounted terminal prices. In case of JCT, since SLPA directly operates it, the terminal price is decided as a direct discount on the initial price.

$$\mathrm{MPC}_{\mathrm{t}}^{i} = \mathrm{MPC}_{\mathrm{avg}}^{i} - \gamma * \ln(\mathrm{x}_{t}^{i}) \qquad i = \mathrm{JCT, SAGT, CICT} \tag{15}$$

$$\mathrm{TF}_{t}^{i} = \mathrm{TF}_{\mathrm{avg}}^{i} - (\mathrm{MPC}_{\mathrm{avg}}^{i} - \mathrm{MPC}_{\mathrm{t}}^{i}) \qquad i = \mathrm{SAGT, CICT} \tag{16}$$

$$0 \leq \mathrm{x}_{t}^{i} \leq \mathrm{M} \tag{17}$$

Where,

$\mathrm{MPC}_{\mathrm{avg}}^{i}$	Average price/handling charges of i^{th} terminal (USD) at the initial period;
$\mathrm{TF}_{t}^{i}, \mathrm{TF}_{\mathrm{avg}}^{i}$	Terminal fee (USD) charged by the port authority from terminal i in t^{th} period and the average terminal fee when no rebates/incentives;
γ	Parameter to decide incentive/rebates level;
x_{t}^{i}	The decision variable, which decides the terminal prices;
M	Large positive M value as the upper bound of x_{t}^{i}.

As given in Figure 3, seven possible objectives are assumed for the decision-making of SLPA, which are expressed by Equations (18) to (24). As the first objective, SLPA is assumed to maximise the Colombo Port's total demand, which is calculated as the summation of vessel calls at its three terminals (Equation 18). This is reasonable because port authorities usually aim to increase total port demand by competing with other ports. Second, SLPA aims to maximise the Colombo Port's total profit (Equation 19). Thus, the profit functions of Colombo Port's three terminals are given by Equations (25) to (27). Since the public terminal is directly operated by the port authority, both are assumed to be represented by the same economic entity [25], [26]. Thus, besides its direct operating profit, JCT can receive revenue from navigation services provided to all vessels calling at Colombo port as given in the second component of Equation (25). Moreover, because both the public and concession terminals are operated in the same port, the SLPA or public terminal collects the terminal fee from concession terminals as given in the last two components of Equation (25). Although a port governance model defines the profit or non-profit objectives of port operators, those objectives could be varied across countries [13]. Therefore, although public sectors, including port authorities, generally have non-profit objectives, analysing their behaviour with other alternative objectives would help to discuss the appropriate recommendation for them. Since the public sector aims to offer its services at a lower cost for many users rather than having extreme profit concerns [12], SLPA is assumed to maximise the total user surplus from Colombo as its third alternative objective. Equation (20) estimates the total user surplus considering shipping lines' generalised cost reduction. Then, SLPA can maximise the total social surplus from Colombo, estimated as a summation of total profit and user surplus generated from three terminals at Colombo (Equation 21).

Despite the SLPA's more significant role in Colombo than in Hambantota, SLPA still has an interest in the Hambantota Port as the main public administrator of all Sri Lankan ports. Hence, as another objective, SLPA may maximise the total user surplus from both Colombo and Hambantota ports (Equation 22). Moreover, the behaviour of SLPA when it maximises own profit is analysed with Equation (23) to understand the related outcomes. Since SLPA has a limited share from Hambantota Port, the second and third components of Equation (23) give SLPA's share of terminal operating profit and SLPA's share of navigation services' profits from Hambantota Port. However, SLPA's profit does not include the operating profit of two concession terminals at Colombo. As the last objective, SLPA can maximise the Colombo Port's total profit and the SLPA's share of profit from Hambantota Port as given by Equation (24).

$$\text{Max; } \mathrm{Q}_{\mathrm{t}}^{\mathrm{CMB}} = \sum_{\mathrm{i}=1}^{\mathrm{i}=3} \mathrm{Q}_{\mathrm{t}}^{\mathrm{i}} \qquad i = \mathrm{JCT, SAGT, CICT} \tag{18}$$

$$\text{Max; } \pi_{\mathrm{t}}^{\mathrm{CMB}} = \sum_{\mathrm{i}=1}^{\mathrm{i}=3} \pi_{\mathrm{t}}^{\mathrm{i}} \qquad i = \mathrm{JCT, SAGT, CICT} \tag{19}$$

$$\text{Max; } \mathrm{US}_{\mathrm{t}}^{\mathrm{CMB}} = \sum_{\mathrm{i}=1}^{\mathrm{i}=3} \mathrm{US}_{\mathrm{t}}^{i} \qquad i = \mathrm{JCT, SAGT, CICT} \tag{20}$$

$$\text{Max; } \mathrm{SS}_{\mathrm{t}}^{\mathrm{CMB}} = \sum_{\mathrm{i}=1}^{\mathrm{i}=3} \left[\mathrm{US}_{\mathrm{t}}^{\mathrm{i}} + \pi_{\mathrm{t}}^{\mathrm{i}}\right] \qquad i = \mathrm{JCT, SAGT, CICT} \tag{21}$$

$$\text{Max; } \mathrm{US}_{\mathrm{t}}^{\mathrm{CMB+HBT}} = \sum_{h=1}^{h=2} \sum_{\mathrm{i}=1}^{\mathrm{i}=\mathrm{n}} \mathrm{US}_{\mathrm{t}}^{i} \quad i = \mathrm{JCT, SAGT, CICT, HBT_1, HBT_2} \quad h = \mathrm{CMB, HBT} \tag{22}$$

$$\text{Max; } \pi_{\mathrm{t}}^{\mathrm{SLPA}} = \pi_{\mathrm{t}}^{\mathrm{JCT}} + \rho \sum_{\mathrm{i}=1}^{\mathrm{i}=2} \pi_{\mathrm{t}}^{\mathrm{i}} + \omega \sum_{\mathrm{i}=1}^{\mathrm{i}=2} \mathrm{Q}_{\mathrm{t}}^{\mathrm{i}} * (\mathrm{N}^{\mathrm{HBT}} - \mathrm{N}_{\mathrm{cost}}^{\mathrm{HBT}}) \qquad i = \mathrm{HBT_1, HBT_2} \tag{23}$$

$$\text{Max; } \pi_{\mathrm{t}}^{\mathrm{CMB+SLPA}} = \sum_{\mathrm{i}=1}^{\mathrm{i}=3} \pi_{\mathrm{t}}^{\mathrm{i}} + \rho \sum_{\mathrm{i}=1}^{\mathrm{i}=2} \pi_{\mathrm{t}}^{\mathrm{i}} + \omega \sum_{\mathrm{i}=1}^{\mathrm{i}=2} \mathrm{Q}_{\mathrm{t}}^{\mathrm{i}} * (\mathrm{N}^{\mathrm{HBT}} - \mathrm{N}_{\mathrm{cost}}^{\mathrm{HBT}}) \quad i = \mathrm{SAGT, CICT} \tag{24}$$

$$\pi_t^{JCT} = V * \left[Q_t^{JCT} * \left(MPC_t^{JCT} - C^{JCT}\right) + \sum_{i=1}^{i=n} Q_t^i * \left(N^{CMB} - N_{cost}^{CMB}\right) + \left(Q_t^{SAGT} * TF_t^{SAGT}\right) + \left(Q_t^{CICT} * TF_t^{CICT}\right) \right] \tag{25}$$

$$\pi_t^{SAGT} = V * \left[Q_t^{SAGT} * \left(MPC_t^{SAGT} - TF_t^{SAGT} - C^{SAGT}\right)\right] \tag{26}$$

$$\pi_t^{CICT} = V * \left[Q_t^{CICT} * \left(MPC_t^{CICT} - TF_t^{CICT} - C^{CICT}\right)\right] \tag{27}$$

$$US_t^i = 0.5\left[\left(GC_{t-1}^i - GC_t^i\right)\left(Q_{t-1}^i + Q_t^i\right)\right] \tag{28}$$

Where;

π_t^i Terminal *i* profit (USD) in t^th^ period. π_t^{CMB} and π_t^{SLPA} represent Colombo port's total profit and SLPA's profit, respectively;

US_t^i User surplus (USD) from *i^th^* terminal in t^th^ period; US_t^{CMB} indicates Colombo port's user surplus and $US_t^{CMB+HBT}$ indicates the total combined user surplus of Colombo and Hambantota ports;

SS_t^i Social surplus (USD) from *i^th^* terminal in t^th^ period; SS_t^{CMB} indicates Colombo port's total social surplus;

ρ SLPA's share of terminal operating profit from Hambantota port;

ω SLPA's share of navigation services' profits from Hambantota port;

N^h Navigation charges (USD) of port *h* paid by shipping lines to the SLPA;

N_{cost}^h Cost of the port authority for providing navigation services;

C^i Operating cost of terminal *i* (USD/TEU).

4.3. Decision Making by the GTO

As given in Figure 3, GTO makes terminal pricing decisions with profit or demand maximisation objectives. Thus, CMPH decides the prices of HBT1, HBT2, and CICT which are directly operated by CMPH. As the main port operator, CMPH can decide the prices of HBT1 and HBT2 of Hambantota Port as a discount to the initial terminal price (Equation 29). However, CICT's price is influenced by the decisions of both SLPA and CMPH. Since the Hambantota Port's administrative structure is different from a landlord port due to its 99-year lease agreement, this study assumed that HBT1 and HBT2 are not required to pay terminals fees to the SLPA. The profit and demand maximisation objectives of CMPH are given by Equations (30) and (31), respectively considering HBT_1, HBT_2, and CICT. The profit for CMPH is calculated by its shares from terminal operations and navigation services of Hambantota port in addition to the CICT's profit. However, as an emerging player in the South Asian market, CMPH would consider maximising its total demand because GTOs have a strong interest in expanding their share by entering new markets.

$$\mathrm{MPC}_t^i = \mathrm{MPC}_{avg}^i - \gamma * \ln(x_t^i) \qquad i = \mathrm{HBT_1}, \mathrm{HBT_2}, \mathrm{CICT} \tag{29}$$

$$\begin{aligned}\text{Max; } \pi_t^{CMPG} = \Big[& V * \Big[(1-\rho)\Big[\big[Q_t^{HBT_1} * \big(MPC_t^{HBT_1} - C^{HBT_1}\big)\big] + \big[Q_t^{HBT_2} * \big(MPC_t^{HBT_2} - C^{HBT_2}\big)\big]\Big] \\ & + \big[Q_t^{CICT} * (MPC_t^{CICT} - TF_t^{CICT} - C^{CICT})\big]\Big]\Big] \\ & + (1-\omega)\big[(Q_t^{HBT_1} + Q_t^{HBT_2}) * (N^{HBT} - N_{cost}^{HBT})\big]\end{aligned} \tag{30}$$

$$\text{Max; } Q_t^{CMPG} = \big[Q_t^{HBT_1} + Q_t^{HBT_2} + Q_t^{CICT}\big] \tag{31}$$

Where;

π_t^{CMPG} CMPH's profit (USD) in t^{th} period;

Q_t^{CMPG} Total demand at terminals operated by CMPH in t^{th} period;

4.4. Decision-making Framework

Since this study focuses on a theoretical contribution by analysing the behaviour of the port authority and a GTO, a unilateral decision-making process is assumed. Hence, only one decision-maker per period - SLPA or CMPH makes a pricing decision in one period and the other decides in the following period. For example, if four decision-making periods are assumed for the terminal pricing scenario, starting from $t = 0 < 1 < 2 < 3 < 4$, where $t = 0$ represents the initial stage, the first mover makes pricing decisions in periods 1 and 3, and the follower decides in periods 2 and 4 [17]. For simplicity, this study assumed that they make pricing decisions in yearly decision-making periods because the port of calls in liner services are planned yearly. The port authority is assumed as the first decision-maker due to its strong interest in creating benefits for port users and the GTO is the follower of this pricing game. As in Figure 5, with a given market condition in the initial period n ($n = 0$), SLPA makes the pricing decisions for the Colombo Port terminals in period $n+1$ based on one each of its seven alternative objectives, selecting one at a time. SLPA's pricing decision would change the terminal prices at Colombo Port while changing the market share and profits of all terminals located in both competing ports. The results of the SLPA's decision in period $n+1$ are used to update the market condition exogenously for period $n+2$.

In period *n+2*, CMPH decides the prices of HBT_1, HBT_2, and CICT, considering the updated market condition received from SLPA's decisions made in the previous period. Thus, CMPH's pricing decision would change the prices of HBT_1, HBT_2, and CICT, while influencing the market shares and profits of all terminals in both ports, and these results are used to update the market condition. Next, in period *n+3*, SLPA modifies its previous decisions considering the reaction observed from CMPH from period *n+2*. However, since the CICT's price is affected by the decisions of both SLPA and CMPH, when deciding on CICT's price, both SLPA and CMPH consider the updated price of CICT given by the other decision-maker in the previous period. Since all other terminals' prices are influenced by only one decision-maker either SLPA or CMPH, those prices are decided in each period as an adjustment to the initial price, which is the terminal price in the absence of this pricing game. This process continues for several periods until both SLPA and CMPH cannot improve their objectives any further. Thus, the model is assumed to be converged if the difference in pricing decisions made by each decision-maker between its two consecutive decision-making periods $\left|\frac{(x_{n+2}^i - x_n^i)}{x_n^i}\right|$ is less than 0.001% for each terminal (Lin et al. 2017). This is reasonable as both decision-makers do not modify their previous decisions at this stage because the other decision-maker did not change the market condition. The developed optimisation model is solved with the Analytical Solver platform 2016-C version incorporating the generalised reduced gradient method.

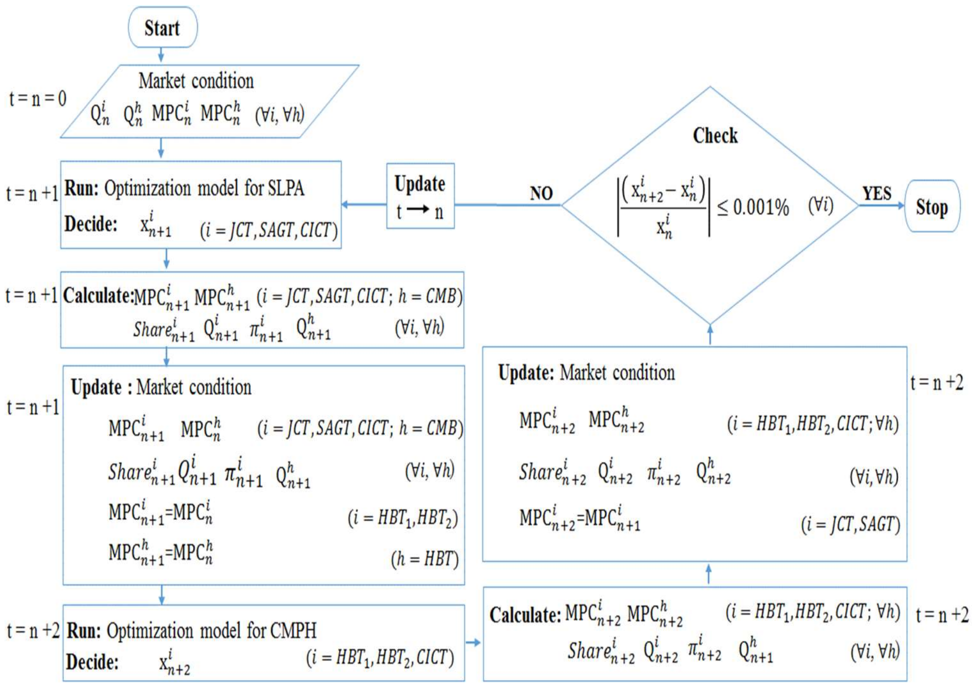

Figure 5: Terminals' Pricing Decisions with Multiple Periods

5. INPUT DATA AND MODEL VALIDATION

5.1. Input Data

This section summarises the input data used for this study and the validation of the model. The input data and parameters used are summarised in Table 1, together with their sources or estimation methods.

Table1: Input data and parameters for the model

Inputs and Parameters	Value	Source or estimation method
$\mathbf{MPC_t^h}$	42 USD/TEU	SLPA Port tariff
$\mathbf{D^{(Deviation,h)}}$	CMB=90nm, HBT=10nm	Estimated by authors based on www.marinetraffic.com
$\mathbf{W^{(Deviation\ time,h)}}$	CMB=5 hours, HBT=0.56 hours	Estimated by authors based on www.marinetraffic.com
$\mathbf{W^{(Vessel\ turnaournd\ time,h)}}$	CMB=20hours, HBT=24hours	[1]
$\mathbf{W^{(Waiting\ time,h)}}$	CMB=2hours, HBT=4hours	[1]
$\mathbf{SS_{(Port\ charges)}}$, $\mathbf{SS_{(j)}}$, $\mathbf{SS_{(w)}}$	See Appendix A	[1]
$\mathbf{W^{(Feeder\ link\ time,f,h)}}$	See Appendix B	[1]
$\mathbf{D^{(Feeder\ link\ time,f,h)}}$	See Appendix B	www.searoute.com
a	0.5	[10]
b	4	[10]
no of berths^i	JCT=4, SAGT=3, CICT=3	https://www.slpa.lk/port-colombo/terminals
$\boldsymbol{\theta}$	0.003	Estimated by authors using data collected from SLPA
$\mathbf{N^h}$	800 USD/Vessel	[10]
$\mathbf{N_{cost}^h}$	780 USD/Vessel	[10]
$\mathbf{C}^i$	20 USD	[10]
$\boldsymbol{\rho}$	0.15	[4]
$\boldsymbol{\omega}$	0.507	Calculated by authors based on [4]
v	1,200	Calculated by authors using data collected from SLPA
$\mathbf{TS^f}$	See Appendix C	[1]

For the input data and assumptions, first, the average handling volume per vessel call is assumed as 1200 TEUs based on the data collected from SLPA. $\gamma = 0.05$ is assumed considering a hypothetical market scenario associated with pricing decisions and a sensitivity analysis was considered for the impact of γ on the results. However, since all scenarios are treated with similar parameters and calculation process, this study focuses on the variations of significant results among different objectives rather than interpreting exact numerical values. To decide the logit model parameter, θ, this study incorporates the actual vessel handling statistics of Colombo Ports' three terminals. Given the small number of data points, θ is estimated to be 0.003 with a goal programming approach to minimise the difference between model's estimated market share and actual market shares of a terminal. All terminals are assumed to have an equal price (USD 42) and equal demand at the initial stage. To understand the behaviour of the port authority and a GTO precisely, it is important to assume equal values for each terminal at the initial market condition, thus, pricing decisions are not greatly affected by the initial condition but affected by the reactions of each other. The cost parameters for the logit model; $SS_{(\text{Port charges})}$,$SS_{(j)}$ and $SS_{(w)}$ are decided based on interviews with 17 decision makers of 12 mainline and one feeder shipping company in the region. This selected group of shipping lines accounts for 75.26% of the transhipment handling in feeder ports related to the current study and 63.09% of the container shipping industry market share in the world [15], confirming the validity of this approach.

5.2. Model Validation

Before using the model, it is important to discuss the model validation which confirms the reliability of results. However, this study analyses a future scenario assuming potential competition between Colombo and Hambantota ports; the actual market shares of ports are not available because the container handling facilities of Hambantota Port are still under construction. Hence, it is not possible to validate by comparing estimated results with actual results. Therefore, the model is validated by applying the same logit model to existing hub ports in Asia, which are also competing in this transhipment market.

To validate the proposed model, Kaviratnna et al. [15] compared the predicted market share from a regression analysis with the proposed logit model's results. In their paper, they have found that a simple linear regression using the number of vessels deployed in services as the explanatory variable was the best-fitted model for ports' transhipment volume (adjusted R-square value: 0.79, p-value: 0.000, coefficients:9395.27, intercept: 584273). Accordingly, in this paper, the estimation of transhipment volume was done using the same approach considering the numbers of vessels deployed in common services calling on both the respective hub port and feeder port as the explanatory variable. When considering the association between the predicted market share from the regression approach and the proposed logit model's results, R-square values of 0.72 and 0.80, respectively were reported for the Singapore and Kelang ports, which implies reasonable acceptability of the results. Therefore, it is considered to be adequate justification to apply this model for estimating the transhipment market share of competing ports in the market considered in this study.

6. RESULTS AND DISCUSSION

This section discusses the results of the model and related implications. Since the calculations for all objectives were done in a similar manner, this study mainly focuses on comparing the results related to different objectives to understand their implications rather than interpreting the exact quantitative values.

6.1. Decision-making when CMPH Maximises the Total Demand

This section discusses the results of pricing decisions made by SLPA and CMPH when CMPH maximises its demand together with the different objectives of SLPA. Table 2 summarises the prices of three terminals in Colombo decided by SLPA, considering each objective.

Table 2: Rebates/ Incentives Given by SLPA when CMPH Maximises Total Demand

<table>
<tr><th>Rebates</th><th>Both Ports US</th><th>CMB Total Demand</th><th>CMB Total Profit</th><th>CMB Total Profit and SLPA's HBT Profit</th><th>CMB Total SS</th><th>SLPA Total Profit</th><th>CMB Total US</th></tr>
<tr><td>Highest</td><td>CICT</td><td>CICT</td><td>CICT</td><td>CICT</td><td>CICT</td><td>JCT</td><td>CICT</td></tr>
<tr><td>↓</td><td>SAGT</td><td>SAGT</td><td rowspan="2">JCT/SAGT</td><td rowspan="2">JCT/ SAGT</td><td>SAGT</td><td rowspan="2">CICT/SAGT</td><td>SAGT</td></tr>
<tr><td>Least</td><td>JCT</td><td>JCT</td><td>JCT</td><td>JCT</td></tr>
</table>

The terminals that received the highest to least amounts of rebates/ incentives are listed from top to bottom, and terminals with no rebates are highlighted in Gray. Accordingly, CICT receives the highest rebates on terminal fees for all objectives of SLPA except the profit maximisation objective. This is reasonable because, with SLPA's user surplus maximisation and Colombo's profit and demand maximisation objectives, SLPA has a high motivation to offer rebates on CICT, which has a lower operating cost and higher time efficiency than other terminals in Colombo. Similarly, SLPA does not offer any rebates on JCT and SAGT when it maximises Colombo's total profit. However, SLPA reduces only the price of JCT, which is directly operated by SLPA when it maximises its own profit. This is reasonable because SLPA's profit includes some share from the Hambantota Port profit as well; thus, it is not motivated to reduce concession terminals' prices in Colombo and enhance Colombo port's overall competitiveness when maximising own profit.

Next, the results of pricing decisions made by CMPH are summarised in Table 3 when CMPH maximises its demand together with the different objectives of SLPA.

Table 3: Incentives Given by CMPH when CMPH Maximises Total Demand

Incentives	Both Ports US	CMB Total Demand	CMB Total Profit	CMB Total Profit and SLPA's HBT Profit	CMB Total SS	SLPA Total Profit	CMB Total US
Highest	HBT_1	HBT_2	HBT_1	HBT_1	HBT_1	HBT_2	HBT_2
↓	HBT_2	HBT_1	HBT_2	HBT_2	HBT_2	HBT_1	HBT_1
Least	CICT	CICT	CICT	CICT	CICT	CICT	CICT

Thus, CMPH reduces the prices of HBT_1, HBT_2, and CICT when SLPA maximises both ports' user surplus, Colombo's profit, Colombo's social surplus, and SLPA's total profit. However, since SLPA offers the highest rebates on CICT when it maximises the demand, user surplus, and profit of Colombo Port and SLPA's portion of the profit from Hambantota (Table 2), CMPH reduces the prices of only HBT_1 and HBT_2. Thus, CMPH receives the benefits from the discounted price at CICT made by SLPA while behaving as a free rider rather than making own effort for the price reduction at CICT.

Next, Table 4 summarises the SLPA's objectives which give the least and highest prices of each terminal at the equilibrium when CMPH maximises its total demand.

Table 4: Objectives for the Least and Highest Prices of Terminals when CMPH Maximises the Total Demand

Price	JCT	SAGT	CICT	CMB Average	HBT_1	HBT_2	HBT Average
Least	CMB Total SS	CMB Total US	CMB Total Profit and SLPA's HBT Profit	CMB Total US	CMB Total SS	CMB Total US	CMB Total Profit and SLPA's HBT Profit
↓ Highest	CMB Total Profit and SLPA's HBT Profit	CMB Total Profit and SLPA's HBT Profit	SLPA Total Profit	CMB Total Profit	CMB Total US	CMB Total SS	CMB Total US

When SLPA maximises Colombo's total social surplus and user surplus, respectively, JCT and SAGT have the least prices. However, they have the highest prices when SLPA maximises Colombo's total profit and SLPA's portion of profit from Hambantota port. However, since CICT's price is influenced by the decision of both

SLPA and CMPH, it derives the least and highest prices when SLPA maximises Colombo's total profit and SLPA's portion of profit from Hambantota port and when SLPA maximises own profit, respectively. As the average price of Colombo, the least and highest prices are derived when SLPA maximises Colombo's user surplus and Colombo's profit, respectively. This is because SLPA's profit maximisation objective focuses on its portion of profit from the Hambantota port's operation as well.

When Hambantota port's terminals are considered, HBT_1 and HBT_2 have the lowest prices as well as the highest prices when SLPA maximises Colombo's social surplus and Colombo's user surplus, respectively. This could be explained by CMPH maintaining a trade-off relationship between the prices of HBT_1 and HBT_2 to have a competitive average price for the entire port. Hambantota Port receives the least average price when SLPA maximises Colombo's profit and SLPA's profit from Hambantota port. This is reasonable because the comparatively high prices of JCT and SAGT in this objective encourage CMPH to reduce the average price at Hambantota to obtain a large market share when competing with Colombo. CMPH maintains a high average price at Hambantota port when SLPA maximises Colombo's user surplus, which generates the least average price at Colombo port. Thus, instead of perfectly competing by lowering port charges, CMPH takes advantage of low/high prices at both ports while balancing interests in both, because it has own terminals in both ports. This behaviour is different from that of two independent ports competing in a market because an independent operator would reduce its own price when its competitor reduces the price as they do not have conflicting interests in both ports, unlike a GTO, which operates terminals in both competing ports.

6.2. Decision-making when CMPH Maximises Total Profit

This section discusses the results when CMPH maximises its total profit with SLPA's different objectives. Thus, the results of SLPA's pricing decisions are summarised in Table 5.

Table 5: Rebates/Incentives Given by SLPA when CMPH Maximises Total Profit

<table>
<tr><th>Rebates</th><th>Both Ports US</th><th>CMB Total Demand</th><th>CMB Total Profit</th><th>CMB Total Profit and SLPA's HBT Profit</th><th>CMB Total SS</th><th>SLPA Total Profit</th><th>CMB Total US</th></tr>
<tr><td>Highest</td><td>CICT</td><td>SAGT</td><td>CICT</td><td>CICT</td><td>CICT</td><td>JCT</td><td>SAGT</td></tr>
<tr><td>↓</td><td>SAGT</td><td>JCT</td><td rowspan="2">JCT/SAGT</td><td rowspan="2">JCT/ SAGT</td><td>SAGT</td><td rowspan="2">CICT/SAGT</td><td>JCT</td></tr>
<tr><td>Least</td><td>JCT</td><td>CICT</td><td>JCT</td><td>CICT</td></tr>
</table>

Although SLPA gives the highest rebates on CICT with most of its objectives when CMPH maximises total demand, SLPA gives the highest rebates on SAGT, for some objectives when CMPH maximises its total profit. This is reasonable because CMPH does not reduce prices of HBT_1, HBT_2, and CICT when it maximises profit although it reduces prices of these terminals when it maximises total demand. Thus, SLPA also offers the least rebates on CICT when it maximises Colombo's total demand or user surplus. Since CMPH does not reduce the prices of its terminals when it maximises the profit, the prices of HBT_1 and HBT_2 remain unchanged.

Table 6: Objectives for the Least and Highest Prices of Terminals when CMPH Maximises Total Profit

Price	JCT	SAGT	CICT	CMB Average
Least	SLPA Total Profit	CMB Total Demand	CMB Total Profit	CMB Total US
↓ Highest	CMB Total SS	CMB Total Profit and SLPA's HBT Profit	SLPA Total Profit	CMB Total Profit and SLPA's HBT Profit

Table 6, above, summarises objectives related to the least and highest prices of terminals. Thus, JCT receives the lowest price when SLPA maximises its profit because SLPA reduces only the JCT's price with this objective. However, JCT receives the highest price when SLPA maximises Colombo's total social surplus due to the SLPA's focus on profit and user surplus of all three terminals in Colombo with this objective. Moreover, SAGT and CICT have the highest prices when SLPA maximises Colombo's total profit and SLPA's profit from Hambantota port, and the SLPA's total profit, respectively because giving rebates on terminal fees to reduce these concession terminals' prices significantly decreases the SLPA's own profit. However, the least prices of these two terminals are received when SLPA maximises Colombo's total demand and Colombo's total profit, respectively. The Colombo port receives the lowest average price when SLPA maximises Colombo's total user surplus because the lower charges would reduce shipping lines' generalised cost and increase terminals' demand. The Colombo port receives the highest average price when SLPA maximises Colombo's total profit and SLPA's profit from Hambantota port because the SLPA's interest in balancing revenue from both ports potentially discourages it from reducing the prices of Colombo Port's terminals. Therefore, additional revenue earned by the SLPA from navigation services due to the increased demand at Colombo Port at lower port charges would be insufficient to compensate for the losses earned by SLPA when giving rebates to reduce prices at concession terminals.

6.3. Resulting Profit with Pricing Decisions

Figure 6 illustrates the variation of Colombo and Hambantota ports' profits which are significantly influenced by the terminals' pricing decisions.

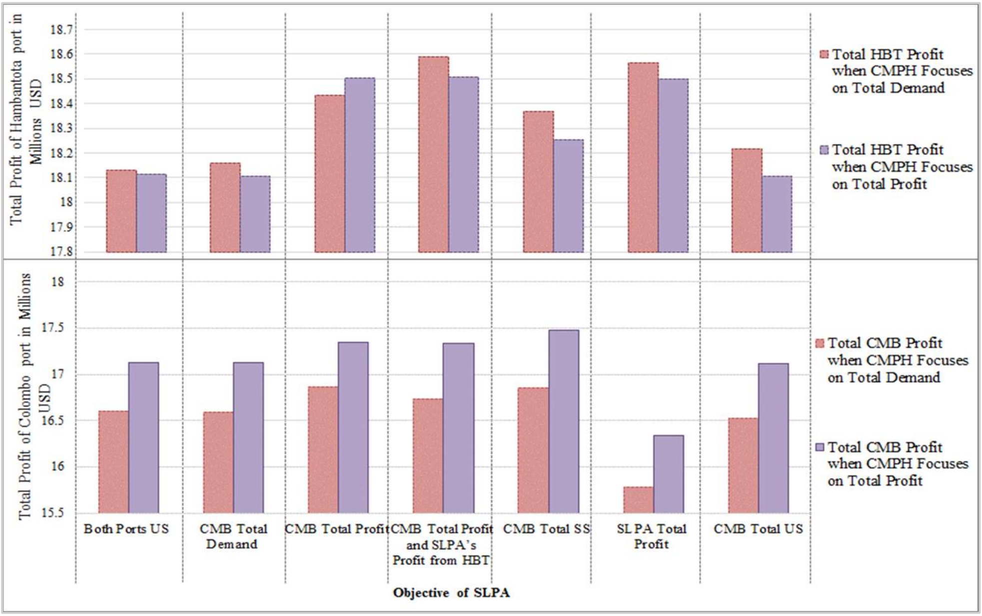

Figure 6: Resulting Profits of Colombo and Hambantota Ports

Thus, Colombo Port receives higher profits when CMPH maximises its total profits than when maximising total demand. However, with both objectives of CMPH, Colombo's profit indicates a similar pattern of variation when changing SLPA's objective. Thus, Colombo receives the least and highest profit when SLPA maximises its total profit and Colombo's total social surplus, respectively. However, Hambantota Port's profit indicates a significantly different variation when changing the objectives of both SLPA and CMPH. Hambantota Port receives the least profit with the profit and demand maximisation objectives of CMPH when SLPA maximises Colombo's total user surplus and both ports' user surplus, respectively. Moreover, Hambantota port receives a higher profit when SLPA maximises Colombo's total profit and SLPA's profit from Hambantota port, and SLPA's own profit because SLPA's profit contains a share from Hambantota port as well. Except for Colombo Port's profit maximisation objective, for all other objectives of SLPA, Hambantota port receives higher profits when CMPH maximises its total demand than maximising total profit.

Next, the profits of SLPA and CMPH are illustrated in Figure 7. When comparing Figures 6 and 7, SLPA's profit maximisation objective generates its highest profit while generating the least profit for the Colombo port.

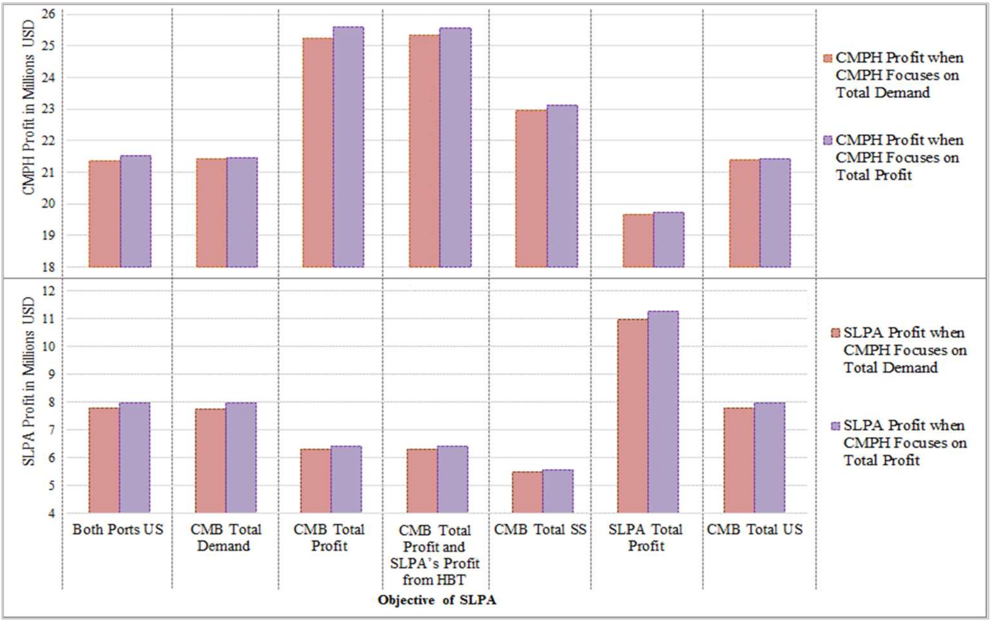

Figure 7: Resulting Profits of SLPA and CMPH

This is because SLPA does not offer any rebates to reduce prices at two concession terminals while balancing its interest in both ports with its profit maximisation objective. Such behaviour of SLPA could reduce the Colombo port's total profit by reducing its demand due to the high average port charges.

6.4. Demand for Ports and Terminals with Pricing Decisions

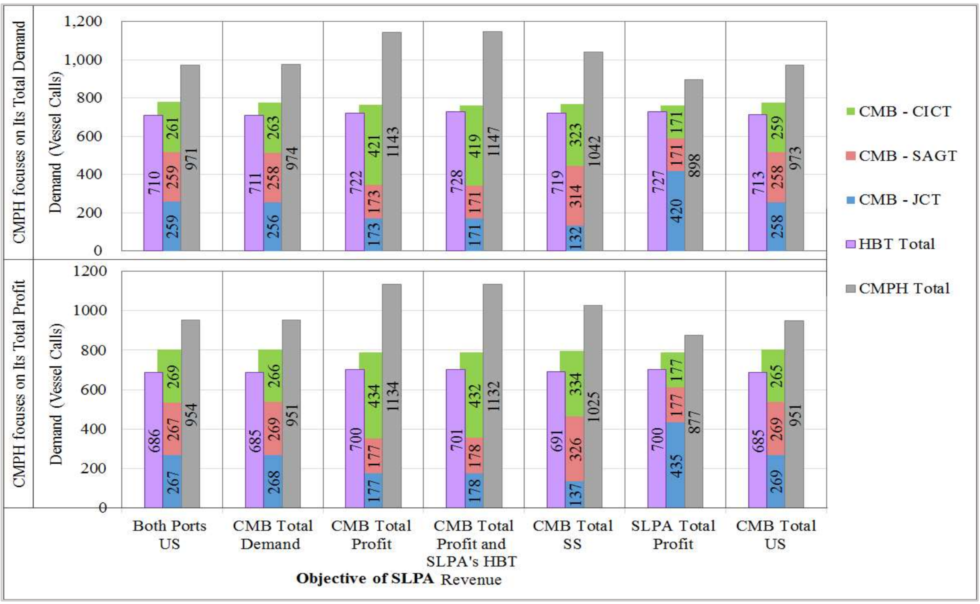

Figure 8: Demands for Ports and Terminals with Pricing Decisions

Figure 8 (above) illustrates the demand for Colombo and Hambantota ports at the equilibrium where terminal prices become stable. Its upper and lower panels provide results for each objective of the SLPA together with the demand and profit maximisation objectives of CMPH. The distributions of Colombo Port's total demand among its three terminals, Hambantota Port's total demand, and CMPH's total demand are represented by different colour codes.

Thus, Colombo Port receives the least demand when SLPA maximises Colombo's total profit and SLPA's profit from Hambantota port with both objectives of CMPH. However, Colombo Port receives high demand when SLPA maximises both ports' user surplus, Colombo Port's total demand, and Colombo Port's user surplus. CMPH receives the highest demand with its demand and profit maximisation objectives when SLPA maximises Colombo's total profit and SLPA's profit from Hambantota port, and the Colombo port's total profit, respectively because CICT receives a higher demand than JCT and SAGT with those objectives of SLPA.

7. CONCLUSIONS

This study analysed the competition at port- and terminal- levels with the involvement of a port authority, SLPA, and a GTO, CMPH, in two competing ports, Colombo and Hambantota, in Sri Lanka considering their conflicts of interests in both ports. SLPA is the main administrator for both ports and operator of the public terminal in Colombo and CMPH operates terminals in both ports. A multi-period decision-making model was applied with an incentive/rebates policy to decide container handling charges/prices at terminals, such that both SLPA and CMPH decide the prices of their related terminals with multiple alternative objectives.

7.1. Summary of Main Findings

When summarising the main findings as to the SLPA's pricing decisions, CICT receives the highest rebates from most objectives of SLPA, excluding SLPA's profit maximisation objective in which SLPA reduces the price of only the public terminal, JCT. When SLPA offers the highest rebates on CICT, CMPH does not reduce CICT's price from its own incentives; thus, CMPH acts as a free rider while receiving benefits from the discounted price at CICT facilitated by the SLPA. Colombo Port receives the highest average price with SLPA's objectives of maximising Colombo's profit. Under both objectives of CMPH, Colombo Port receives the lowest average price when SLPA maximises Colombo Port's total user surplus because a lower price would reduce the shipping line's generalised cost and increase the port's demand. Hambantota Port receives the highest average price when SLPA maximises Colombo's user surplus. Although CMPH does not reduce its terminals' prices with the profit maximisation objective, it reduces terminals' prices with the demand maximisation objective.

7.2. Policy Implications

This study derives significant policy implications as follows. Because the SLPA's profit maximisation objective reduces the Colombo Port's competitiveness, a pure profit maximisation objective may not be feasible for a port authority. When a port authority receives profit from two competing ports, it tries to balance the interests in both ports rather than allowing a price competition between them by lowering port charges. Moreover, as opposed to pure price competition, CMPH also takes advantage of the least or highest prices of Colombo while balancing interests in both ports as it operates terminals in both. This behaviour is different from the perfect competition between two independent port operators with no conflicting interests in both ports [17]. When CMPH does not reduce the prices of own terminals, SLPA is discouraged from reducing the price of CICT. Colombo Port generates a higher profit when CMPH maximises its profit than maximising demand. Thus, although the profit maximisation objective of a decision-maker discourages the reduction of its port charges, it may increase the profit of a competing port. With both objectives of CMPH, Colombo Port receives the least and highest profits when SLPA maximises SLPA's total profit and Colombo's total social surplus, respectively. However, Hambantota Port receives the least profit with the profit and demand maximisation objectives of CMPH when SLPA maximises Colombo's total user surplus and both ports' user surplus, respectively due to higher benefit for port users which is aligned with the findings from Munim et al. [25]. Thus, a port may receive less profit when the port authority of a competing port focuses on user surplus maximisation. The CMPH receives the least profit when SLPA maximises SLPA's own profit because SLPA does not offer any rebates to reduce CICT's price. However, when SLPA focuses on Colombo Port's profits, CMPH receives a high demand mainly due to the higher demand received by CICT. Thus, SLPA should make its terminal pricing decisions appropriately to manage competition between these two ports without promoting extreme price competition. If CMPH focuses on maximising market share of Hambantota Port, as a newly established port, there would be a significant impact on Colombo Port's handling volume. Thus, the port authority should have a significant influence on deciding a competitive average price for Colombo balancing both profit and non-profit objectives.

7.3. Limitations and Future Research Directions

Although this study analyses the competition between two local ports without external competing ports, such external competitors can have a significant influence due to the possible demand shifts among the ports. Moreover, focusing on the theoretical contribution, the initial market condition is assumed to have equal port charges and equal demand at each terminal. Furthermore, as a GTO, CMPH may focus on medium or long-haul network types to attract a strong cargo-base rather than competing with the existing hub status of Colombo, thus further studies can consider different network types. Since this study assumes a pricing scenario with a unilateral decision-making process, further studies may also consider simultaneous decision-making. Moreover, a proper validation could not be done due to the unavailability of actual market shares of these ports and terminals when analysing a futuristic scenario.

Finally, although the pricing decisions with several objectives of the port authority and GTO were analysed in this paper, the equations developed could be adapted to suit different cases, in keeping with various changes in profit components, and port ownership, among other factors.

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APPENDIX

A. Significance Score of individual criteria

Significance Score of Criteria	Score Value
$SS_{(\text{Port charges})}$	4.46
$SS_{(\text{Deviation cost})}$	4.46
$SS_{(\text{Feeder link cost})}$	4.69
$SS_{(\text{Deviation time})}$	4.69
$SS_{(\text{Vessel turnaround time})}$	4.77
$SS_{(\text{Waiting time})}$	4.46
$SS_{(\text{Feeder link time})}$	4.77

Source: [15]

B. Journey distance and time between hub and feeder ports and deviation from main sea routes

Feeder Ports	Distance (nm)		Time (hours)	
	Colombo	Hambantota	Colombo	Hambantota
Chittagong	1318	1184	86.4	79.2
Kolkata	1238	1109	81.6	72
Haldia	1190	1061	79.2	69.6
Visakhapatnam	867	738	57.6	48
Krishnapatnam	670	541	43.2	36
Chennai	600	471	40.8	31.2
Tuticorin	146	279	9.6	19.2
Cochin	313	432	19.2	28.8
New Mangalore	505	624	33.6	40.8
Nava Shiva	896	1015	60	67.2
Pipavav	1016	1136	67.2	74.4
Mundra	1220	1339	81.6	88.8

C. Total transhipment TEUs given by each feeder port to Sri Lanka

Feeder Ports	Transhipment TEUs
Kolkata	599642
Chennai	1191018
Cochin	671265
Haldia	171029
Krishnapatnam	228629
New Mangalore	207429
Mundra	290359
Nava Shiva	398007
Pipavav	73558
Tuticorin	1974285
Visakhapatnam	263082
Chittagong	1665186

Source: Data collected from the SLPA