ISSN 2783-8897
eISSN 2783-8676

Journal of South Asian Logistics and Transport

Volume 2 Issue 2
September 2022

Sri Lanka Society of
Transport and Logistics

JSALT

Journal of South Asian Logistics and Transport

ISSN 2783-8897 eISSN 2783-8676

Volume 2 Issue 2
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Sri Lanka Society of
Transport and Logistics

International Journal of the
SRI LANKA SOCIETY OF TRANSPORT AND LOGISTICS

Moratuwa, Sri Lanka

JOURNAL OF SOUTH ASIAN LOGISTICS AND TRANSPORT
International Journal of the Sri Lanka Society of Transport and Logistics
Bi-annually published

ISSN 2783-8897 eISSN 2783-8676

Volume 2 Issue 2, September 2022

Editor-in-Chief: T Lalithasiri Gunaruwan

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Printed by:

Cybergate Services (Private) Limited

57A, Soratha Mawatha, Gangodawila, Nugegoda 10250, Sri Lanka
Telephone: +94 78 378 3783 Email: info@cybergate.lk

Sri Lanka Society of Transport and Logistics

ISSN 2783-8897 eISSN 2783-8676

JSALT

Journal of South Asian Logistics and Transport

Volume 2	Issue 2	September 2022

BOARD OF EDITORS

Sri Lanka Society of Transport and Logistics

ISSN 2783-8897 eISSN 2783-8676

JSALT

Journal of South Asian Logistics and Transport

Volume 2 | Issue 2 | September 2022

EDITORIAL ADVISORY BOARD

Sri Lanka Society of Transport and Logistics

ISSN 2783-8897 eISSN 2783-8676

Journal of South Asian Logistics and Transport

International Journal of the Sri Lanka Society of Transport and Logistics

AIMS AND SCOPE

South Asia, and Sri Lanka in particular, are currently facing many transitional challenges; transport and logistics being among those most critical and important ones. Rapid economic growth and increasing income levels have radically changed the aspirations of people and thus, their demands, while expanding global markets and international competition have made meeting such demands highly complex and knowledge-intensive. Ever-expanding motorization increasingly generates negative externalities, pushing the transport industry to the limits of being unsustainable in the medium term. These factors make it imperative for transport and logistics professionals, including industrialists and academics, to focus on research and dissemination of results in view of addressing the challenges mankind is facing in meeting mobility needs. The Journal of South Asian Logistics and Transport (JSALT) seeks to fulfil this mandate.

The JSALT is a refereed bi-annual English language journal published by the Sri Lanka Society of Transport and Logistics (SLSTL). It creates a space where findings of original research can be disseminated, and thereby contributes to the knowledge base and thought process in the discipline of Transport and Logistics. Critical evaluation of policies, investment, expansion, service delivery, pricing, equity and social welfare, technological progress and challenges posed to such fundamentals, in regard to transportation and logistics, are the major areas of interest of the journal. Sub-sectoral issues, such as Public Transportation, Railways and Roads, Ports and Shipping, Aviation and Airports, Freight and Passenger Haulage, Logistics and Supply Chain related issues also are addressed through the dissemination of industry-related research, particularly focusing on the South Asian context.

Apart from the research articles the journal carries a special section titled ‘Strategic Perspectives’ which articulates alternative strategic thoughts and policy approaches.

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Sri Lanka Society of Transport and Logistics

ISSN 2783-8897 eISSN 2783-8676

Journal of South Asian Logistics and Transport

International Journal of the Sri Lanka Society of Transport and Logistics

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PANEL OF REVIEWERS (Contd.)

ISSN 2783-8897 eISSN 2783-8676

JOURNAL OF SOUTH ASIAN LOGISTICS AND TRANSPORT

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DOI: http://doi.org/10.4038/jsalt.v2i2.47

MODELLING GAMMA COEFFICIENT IN THE GOMPERTZ CURVE TO DETERMINE THE VARIABILITY OF VEHICLE OWNERSHIP SATURATION

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ABSTRACT

Vehicle ownership forecasting models based on the Gompertz curve generally employ per capita Gross Domestic Product as the primary explanatory variable. The γ coefficients in the curves specify the ultimate vehicle saturation level and α, β the profile of the S-curve shape. The γ coefficient is assumed to be the single universal value that all countries will eventually reach. The present research hypothesised that countries could have variable saturation levels and, as such, the γ coefficient would not be a universal constant. On that premise, it attempted modelling the γ coefficient as a function of several other extraneous factors that significantly influence a country's vehicle ownership and ultimately its saturation level, thus resulting in a country-specific γ; the application of the Gompertz model and the relationship of vehicle ownership would then be influenced by the country-specific characteristics. It was found that, while vehicle ownership is influenced by the GDP as in the case of Gompertz model, the country-specific γ would also be influenced by other identifiable variables such as household size, population density, share of public transport, and percentage of female drivers in each country. The results confirm the globally observable phenomenon that high-income countries do not converge to a universal vehicle ownership saturation level. Singapore and Hong Kong are examples, usually excluded from the Gompertz model, which can now be explained by the new model.

Keywords: *Vehicle Saturation Level, Gompertz Curve, Vehicle Ownership Rate, Gamma Function, Public Transport*

1. INTRODUCTION

Motorisation plays an increasingly critical role in determining the health of our cities and our transportation systems. The growth of the fleet of vehicles is an essential parameter used by any country in planning and providing road infrastructure as well as determining transport policy interventions if, indeed, motorisation should be curtailed [1],[2]. Models to forecast vehicle ownership as a function of Gross Domestic Product (GDP) per capita have emerged in recent literature [3],[4]. The Gompertz curve has been the widely used model for forecasting vehicle ownership, and the fleet of vehicles in a country has even been used as an indication of its prosperity - a popular political indicator of development. However, a careful study of countries that have reached high-income status shows exceptions to this widely held belief.

The Gompertz model captures the saturation level as a pre-defined constant called Gamma (γ) [5],[6]. Accordingly, the Gamma value (the level of maximum vehicle ownership a country will reach as income rises) is established as a global constant of 621.9 [5],[7]. Singapore and Hong Kong, which have achieved high-income status, have not reached this pre-defined value of γ; thus violating the assumptions of the Gompertz model [5].

A country *j* with higher population density has a higher viability for successful public transport delivery, which will lower Vehicle Ownership Rate (γ_j) at a given GDP per capita and eventually reach a lower Vehicle Ownership Saturation Rate (γ_j). Some countries leave vehicle ownership entirely to consumer choice. Others influence it through fiscal policies that severely disincentivise owning a vehicle while improving the quality of public transport [8]. The higher use of public transport in Singapore and Hong Kong reveals the combined impact that population density, the quality of public transport and transport policy can have on γ_j in the Gompertz model.

Moreover, it is observed that several countries in the Middle East, though having reached high income, demonstrate relatively lower vehicle saturation levels. This was found in this research to be due to a lower proportion of female drivers which in turn lowers vehicle ownership.

The use of γ in the Gompertz curve as a near-constant value for vehicle saturation in literature, therefore, cannot be considered appropriate. This use of a universal γ should instead be replaced by a function that represents a country-specific γ_j [7]. This result will provide a more accurate representation of the vehicle ownership in the application of the Gompertz Model allowing for more complex policy variable interactions.

Rota et al. [5] have described vehicle ownership as having both a micro and macro perspective, explaining that household income, in the long run, affects a household's demand for a vehicle at the micro-level, while the national income influences the macro perspectives for the long-run national demand for motor vehicles. In this respect, they have assumed that household characteristics such as age, sex, and employment status are micro-level variables of vehicle ownership. The number of working adults in a household, age and sex of household head has also been found to influence γ_j.

The paper attempts a two-staged model formulation by establishing a mathematical relationship between the vehicle ownership rate of 34 high-income countries and the contextual social and policy variables of the particular country [9]–[12]. The development of a functional form for the model is presented in Section 3, followed by its calibration, statistical analysis and estimates summarised in Section 4, while the findings and their applicability are discussed under Section 5.

2. LITERATURE REVIEW

The Gompertz Model can be used to determine the VOR of a country *j* given in vehicles per 1000 persons [9]. A sigmoidal or S-shaped curve, described as the Gompertz curve, represents a relationship with an upper limit or saturation rate in the growth of a dependent variable [13]. It assumes that growth would be slow, to begin with, and would increase exponentially before eventually slowing down on reaching its saturation rate [1].

Its application in determining the Vehicle Ownership Rate (VOR) is represented in the Gompertz Model illustrated in Equation 1 where Gamma (γ) is to be interpreted as the universal saturation of VOR and also measured in (vehicles owned per 1000 persons) while the other two coefficients α and β, describe the shape of the curve [4],[5],[9].

$$\boldsymbol{VOR_j = \gamma e^{\alpha e^{\beta(GDP_j)}}} \quad \text{..... (1)}$$

Figure 1 illustrates how the shape of the curves varies with the variation of the parameters (α and β) with GDP per capita (in $000's). The Gompertz-style levelling-off in vehicle ownership indicates that all countries will experience similar patterns of GDP growth and reach a universally-established γ_s [3],[6]. The Vehicle Ownership Saturation Rate (VOSR)--defined as the maximum number of vehicles per 1000 persons that may be expected in a given country is generally determined by long-run demand factors, such as the cost of vehicle ownership and the convenience of car travel.

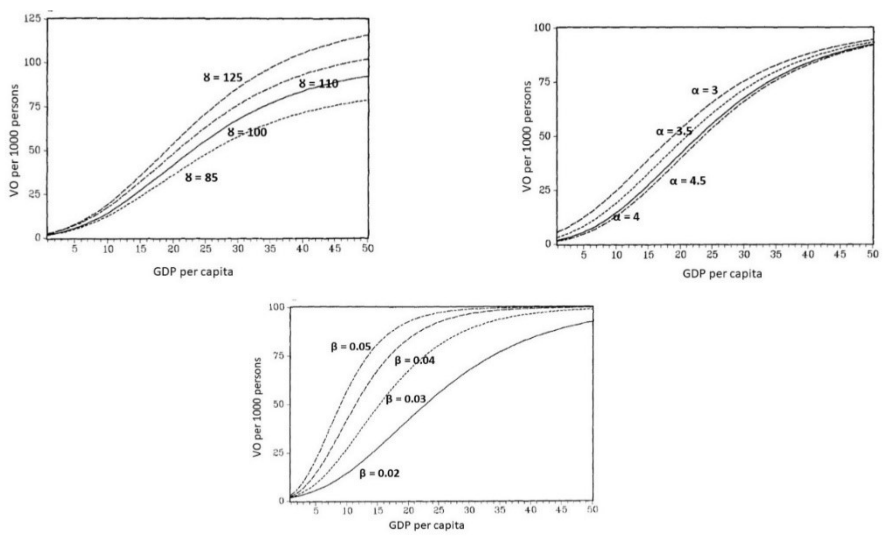

Figure 1: Projections of estimated vehicle Gompertz functions (source: [14])

Dargay [15] assumed that only the coefficient β was country-specific, while γ and α were universal, i.e., same for all countries. The differences between countries were reflected only in the curvature parameters β and not the final VOSR, which was determined as 850 vehicles per 1000 people, of which 620 being cars. It should be noted that this VOSR has not been reached in most developed countries. For instance, though it is 800 for cars and light-duty trucks in the U.S [7], it is only 450–600 in European countries, and 440 in Japan [16].

The authors have taken a more rigorous look at this observed variability of VOSR and have relaxed the assumption of a typical universal level denoted by Gamma (γ) in the Gompertz Model. Instead, they postulate that the VOSR would be country-specific and would depend on its socio-economic characteristics and specific transport policies.

$$\boldsymbol{VOR_j = \gamma_j e^{\alpha e^{\beta(GDP_j)}}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

Where VOR_j would represent the VOR of country j and new γ_j (“country specific asymptote”) in Gompertz form would be it’s VSOR. Thus, a two-stepped model was developed to derive a function for Gamma (γ) in Gompertz curve.

3. METHODOLOGY

3.1. Categorisation of Data

A simple country-based categorical analysis was employed to understand the impact of income on vehicle ownership, as shown in Table 1. The composition of income

level is measured using Gross National Income (GNI) per capita and divided into four income groupings [17],[18], namely, low, lower-middle, upper-middle, and high-income categories.

It was found that, the VOR spread between 77 (Hong Kong) and 797 (United States) for HI countries confirms the hypothesis in the research that VOR would not depend on GDP alone. In fact, Dargay et al. [6], noted that the inclusion of non-OECD countries in the sample's population would introduce a high degree of variation in vehicle ownership. In order to avoid the large variations that could be observed in very small countries, only the 34 HI countries with a population of 4 million were included in the regression.

Table 1: Breakdown of Countries by GNI per capita

Category of GNI per capita	GNI per capita Range USD	# of Countries	Examples
High Income (HI)	12,746 < I	79	UK, USA, UAE, Australia, Hong Kong
Upper Medium Income (UMI)	4,125 < I < 12,746	60	Maldives, Jordan, Brazil, Mexico, China
Lower Medium Income (LMI)	1,045 < I < 4,125	47	Pakistan, Myanmar, Kenya, Nigeria, India, Sri Lanka
Low Income (LI)	1,045 < I	31	Somalia, Ethiopia, Haiti, Uganda, Nepal, North Korea

Source: [19]

3.2. Vehicle Ownership and Population Density

Table 2: Breakdown of the selected countries by population density

Category	Mean VO/1000 HH (VOR)	Std. Dev. of VO/1000 HH	Countries
Low population density: 0-50 persons/ km^2	1488	444	Australia, Canada, Oman, Norway, Saudi Arabia, New Zealand, Finland, Sweden, Chile, United States
Medium population density: 50-6000 persons/ km^2	1272	232	Ireland, Croatia, Greece, Spain, Austria, Hungary, Slovakia, Portugal, France, Poland, United Arab Emirates, Denmark, Czech Republic, Italy, Switzerland, Germany, United Kingdom, Japan, Belgium, Israel, Netherlands, South Korea
High population density: more than 6000 persons/ km^2	366	212	Hong Kong, Singapore

The impact of population density has been investigated in estimating the VOR in HI countries [6]. When divided into three groups by population density, these HI countries were found to have significantly different mean VORs (Table 2). Generally, it is observed that countries with low population densities have a high VOR, while those with medium population densities have moderate VOR, and those with higher population densities have lower VORs.

Figure 2 depicts the GDP and VOR of the countries by the three population density categories. Moreover, Figure 2 shows that most countries in the low population density category have a higher VOR except Chile, Oman, and Saudi Arabia.

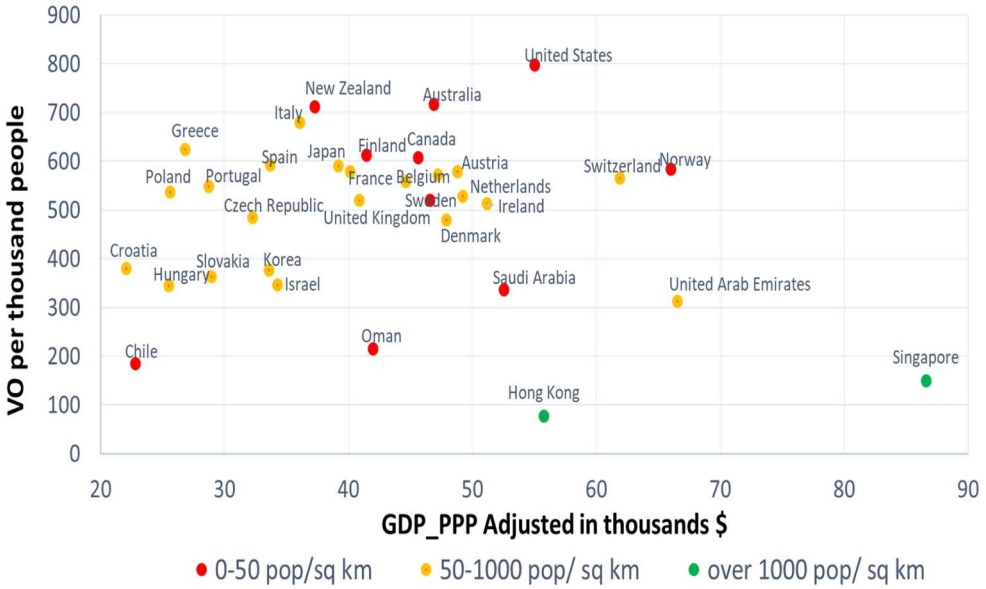

Figure 2: Vehicle ownership vs GDP vs population density

It was observed that the United Arab Emirates deviates from the general pattern of other medium population density countries while the two countries with high population density seem to have maintained relatively lower VORs. These relationships and the exceptions prompted a more detailed study of population density and VOR.

3.3. Vehicle Ownership and Household Size

One of the observations was that vehicle ownership is influenced by household size. Some countries such as Oman, Saudi Arabia, and United Arab Emirates in the HI sample have an average of 6-7 persons per household, significantly higher than around 4 per household in most other countries. Figure 3 depicts the conversion of VO per 1000 persons to VO per 1000 households (VOR), reducing the scatter of the graph and the deviations referred to above.

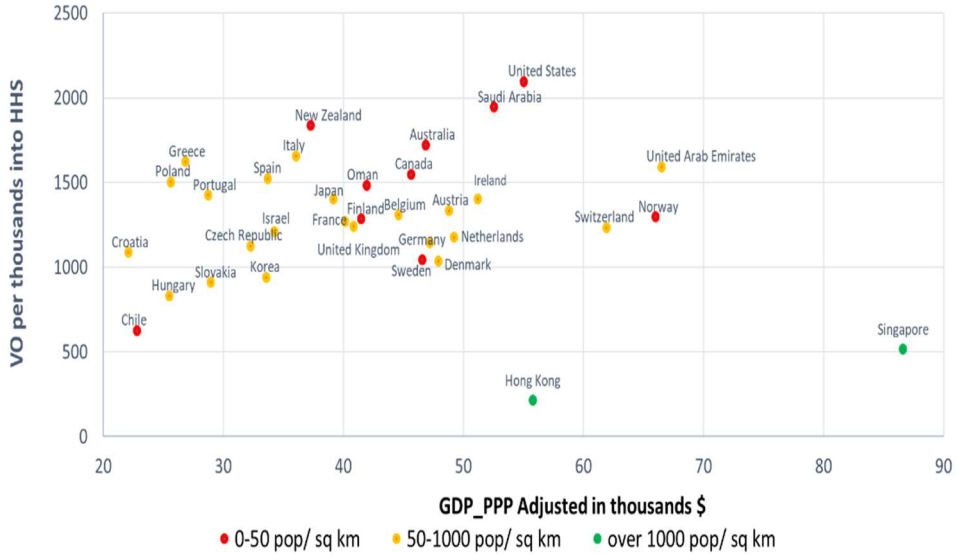

Figure 3: VOR into HHS vs GDP

3.4. Vehicle Ownership and Female Drivers

Another noteworthy observation, as shown in Figure 4, was that not all countries had an equal percentage of female drivers. For example, the three countries referred to above, namely Oman, Saudi Arabia, and the United Arab Emirates, had a significantly lower percentage of female drivers. This is another social factor influencing the country's VOR.

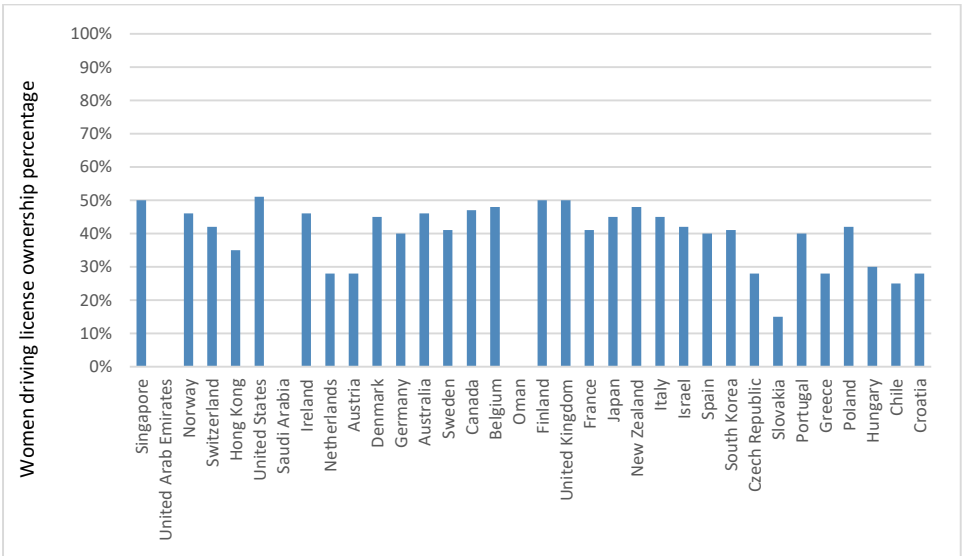

Figure 4: HHS and breakdown of women driving license ownership

3.5. Vehicle Ownership and Public Transport

As was noted earlier, Chile demonstrated a relatively lower VOR compared to other countries with low population density. It was observed that 87.3% of the total population was urban. Chile had harnessed this demographic feature to improve its public transport share to over 50%, while many lower-density countries had not [5]. Figure 5 shows a clear relationship between VO/1000 HHs and the share of public transport for all countries.

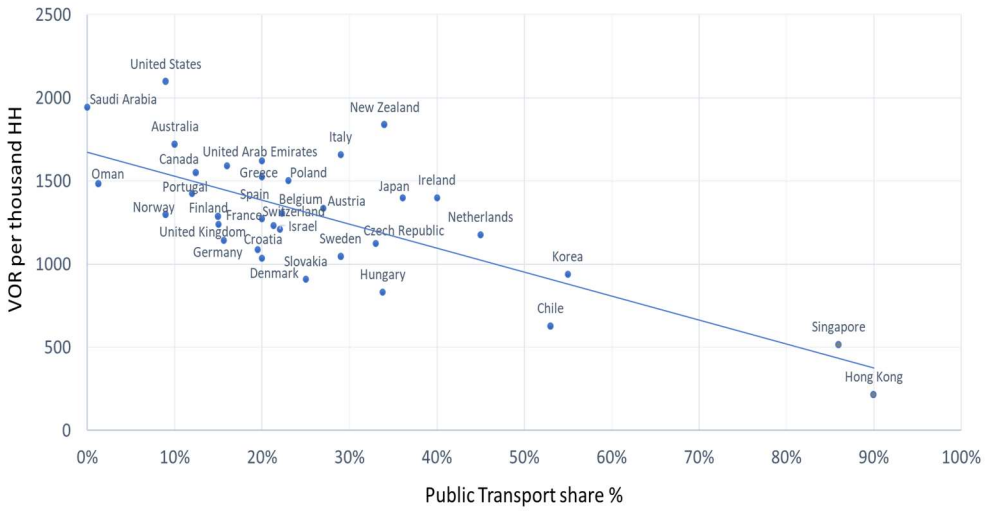

Figure 5: VOR vs Public Transport Share

It also clearly shows that the high population density countries, namely Singapore and Hong Kong, both are city-states, have the highest (more than 80%) public transport share, resulting in a low VOR. Both these countries follow public transport priority policies and have effectively curtailed the rise of VOR by even using measures to control private vehicle ownership and resort to such policies explicitly.

3.6. Study Procedure

The methodology adopted in this research was to (a) progressively study the patterns, trends, and influential factors for vehicle ownership levels in 34 High Income (HI) countries, (b) identify parameters that appeared likely to contribute to the country-specific VOR reached, and thereafter, to (c) calibrate a mathematical model for Gamma (γ) in Gompertz curve based on the identified country-specific variables. Thus, this proposed model formulation consists of two stages; first, modelling VOR using the traditional Gompertz curve mentioned under Equation 1, and thereafter, deriving a function for country-specific Gamma (γ), denoted for the purposes of this research as Gamma γ_j, "country specific asymptote" in Gompertz form would be derived as depicted by the Equation 2.

4. CALIBRATION OF THE VEHICLE OWNERSHIP MODEL

4.1. Stage 01: Estimation of Generalised Gamma for the Model Development

The model described in Equation (1) was estimated using Stata Statistical software for the pooled cross-country data on vehicle ownership for the 34 countries. The resulting estimates are shown in Table 3.

Table 3: Parameter estimates for Equation 1

Parameter	Estimate	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
$\boldsymbol{\gamma}$	505.19	32.44	439.02	571.36
$\boldsymbol{\alpha}$	-13056.93	170737.89	-361279.15	335165.29
$\boldsymbol{\beta}$	-45.24	57.68	-162.88	72.40
Adjusted R^2: 84%				

All coefficients were found statistically significant, and the estimated coefficients were with expected signs: Gamma (γ) being positive and α, β negative. The results of the regression returned a common saturation level of 505.19 vehicles per 1000 people.

On the basis of assumptions mentioned under Gompertz curve, the model (Equation 3) projects Vehicle Ownership Rate (VOR) for each country.

$$\widehat{VOR_J} = \gamma e^{\alpha e^{\beta(GDP_j)}} \quad \text{..... (3)}$$

As the model results indicate (see Appendix A), the estimated country-specific VORs ($\widehat{VOR_J}$) demonstrated a considerable deviation from actual VOR data observed. This fact could be explained by the relevance of unobservable factors in the long run demand of automobiles. These unobservable variables could not be attributed to economic variables, like GDP per capita, since the differences in the estimated VOR were observed among countries with similar levels of economic development.

These patterns observed further substantiated the importance of deriving a country specific Gamma coefficient to be used in the Gompertz curve, including more information at country level. This was attempted in the country-level case study during the second phase of this research.

4.2. Stage 02: Definition of a Country Specific Gamma

In order to derive a function that would replace the common Gamma coefficient (γ) in the Gompertz curve, a residual adjustment mechanism was used as indicated below:

$$\widehat{Y_J} = \ln(VOR_j) - \ln(\widehat{VOR_J}) \quad \text{..... (4)}$$

Here, VOR_j is the actual vehicle ownership and $\widehat{VOR_J}$ is the predicted vehicle ownership rate estimated using the Equation 1. The difference in log form ($\widehat{Y_J}$) therefore could be recognized as reflecting the disparity between actual and predicted values as per Gompertz curve and capturing factors other than the GDP per capita, including public transport mode share; household size; female driver ratio; and population density. The examination in Section 3 revealed the significant relationships between VOR and other determinants, namely, population density (PD), public transport mode share (PTS), household size (HHS) and female driver ratio (FDS) which yielded substantial justification for developing an improved vehicle ownership model. The present study therefore attempted to regress this unexplained variability of the log form of VOR, based on country-specific characteristics in HI countries as indicated in Equation (5).

$$Deviation\ of\ \ln(VOR) = \widehat{Y_j} = f(PD_j, PTS_j, HHS_j, FDS_j) \quad \text{..... (5)}$$

A stepwise regression was employed to determine the significance of each exploratory variable when determining a particular country's VOR. The logarithmic transformations respond to more substantial influences from the large values, mostly from larger countries. The linear and log formulations were tested. The logarithmic transformation became not significant ($p > 0.05$). Table 4 summarises the result of the linear regression.

Table 4: Statistical results of the stepwise regressor

OLS Regressor	Coefficient	Significance Level (1-tailed)
Intercept	0.2909	0.036*
Population density	-0.0001	0.000***
Share of Public Transport	-0.3175	0.024*
Household Size	-0.1393	0.018*
Share of Female Drivers	0.8515	0.039*
Adjusted R^2: 82.7%		

*** p<0.001, ** p<0.01, * p<0.05

The results (Table 4) show that, at a 95% confidence interval, the optimum regression output satisfies all the significant values ($p < 0.05$) and rejects the null hypothesis that there is no significant linear relationship between deviation of ln(VOR) estimated through Gompertz curve as the dependent variable and the four socio-demographic variables tested as independent variables. Furthermore, the adjusted R^2 value of 82.7% is considered significant in explaining the fitted model. The population density (coefficient= -0.0001) and public transport mode share (coefficient= -0.7590) contribute negatively to the VOR difference in log form, indicating that the difference of ln(VOR) estimate would decrease with a higher population density and higher public transport share. In contrast, female drivers (coefficient= 0.8515) appeared to increase the difference of ln(VOR).

Cross-sectional studies often range between very small and large values and, thus, are more likely to have heteroscedasticity effects. The developed OLS assumed that the spread of the residuals would be constant across the plot (null hypothesis). Therefore, the following OLS diagnostic statistics were obtained to check the violation of assumptions, if any. Breusch-Pagan/Cook-Weisberg test for heteroskedasticity had 6.63 Chi-squared value (Prob > Chi-squared = 0.0100). Mean Absolute Deviation (MAD), Mean Absolute Percentage Error (MAPE), and Mean Square Error (MSE) were 1.75E-01, 2.5%, and 4.38E-02, respectively, indicating an acceptable model result (see Appendix B).

The model for $\widehat{\boldsymbol{Y_J}}$ depicted in Equation (6) could thus be derived using the regression output.

$$\boldsymbol{Deviation\ of\ ln(VOR) = \widehat{Y_J} = (0.2909 - 0.0001(PD) - 0.3175(PTS) - 0.1393(HHS) + 0.8515(FDS)} \quad \text{..... (6)}$$

This relationship was fitted into Gompertz formula for $\widehat{\boldsymbol{VOR_J}}$ as described in the following steps, to derive a formula for country-specific Gamma coefficient (γ_j).

Firstly, the Equation (7) could be developed by substituting the equation (6) into equation (4).

$$\boldsymbol{\ln(VOR_j) = 0.2909 - 0.0001(PD) - 0.3175(PTS) - 0.1393(HHS) + 0.8515(FDS) + \ln(\widehat{VOR_J})} \quad \text{..... (7)}$$

Next, the logarithmic transformation of Equation (3) was substituted for $\ln(\widehat{VOR}_J)$ in Equation (7), which yielded the Equation (8):

$$\boldsymbol{\ln(VOR_j) = 0.2909 - 0.0001(PD) - 0.3175(PTS) - 0.1393(HHS) + 0.8515(FDS) + \ln\gamma + \alpha\, e^{\beta(GDP_j)}} \quad \text{..... (8)}$$

Third, Equation (9) could be worked out a indicated below, by taking the Antilog of Equation (8).

$$\boldsymbol{VOR_j = e^{[0.2909-0.0001(PD)-0.3175(PTS)-0.1393(HHS)+0.8515(FDS)]}.\gamma.e^{\alpha e^{\beta(GDP_j)}}} \text{ .. (9)}$$

Finally, the Vehicle Ownership Rate for country *j* ($\boldsymbol{VOR_j}$) could be expressed in the form of the initial Gompertz model, as depicted in the Equation (10).

$$\boldsymbol{VOR_j = \gamma_j e^{\alpha e^{\beta(GDP_j)}}} \quad \text{..... (10)}$$

Such that, $\boldsymbol{\gamma_j = e^{[0.2909-0.0001(PD)-0.3175(PTS)-0.1393(HHS)+0.8515(FDS)]}.\gamma}$]

where "γ_j" represents the country specific asymptote in Gompertz form and γ denotes Gamma coefficient in the initial Gompertz model.

With the introduction of this new parameter, authors were able to determine how the traditional Gompertz model could be used for policy variables. Accordingly, the growth of female drivers, and improvement in public transport share are the vital factors that will change the VOR. The relationship between population increases and VOR was negatively correlated, while denser countries tend to have lower VOR given the viability of public transport. In the proposed study of calibrated vehicle ownership modelling, all coefficients were found statistically significant, and the estimated coefficients were with expected signs which confirms the observation we made. Through this model, significant improvement has been made to the traditional Gompertz curve with the regression-based model justifying the unexplained variability of VOR based on country-specific characteristics in HI countries.

5. CONCLUSIONS AND POLICY IMPLICATIONS

This study was built on numerous previous research efforts to derive a function for γ_j as a country-specific value of Vehicle Ownership Saturation Rate instead of it being considered a universal constant in the Gompertz function. Our two-staged model specification exploited the similarity of response in VORs to per-capita income across countries, while allowing for cross-country variation in the instruments that could be used to direct vehicle ownership and the eventual saturated vehicle ownership.

Our study revealed that this relationship would be significantly affected by the large HHS and low prevalence of driving licenses among women in Middle Eastern countries. High population density in countries would tend to support rapid uptake of public transport. This better explains the observation that countries like Singapore and Hong Kong account for the most extensive public transport ownership. However,

the effects were found to vary across high to low levels of the population density. They were further subject to the urban population percentages. Accordingly, it was observed that the sustainable level of motor vehicles would be determined by the ability of an area to accommodate a given level of vehicle ownership without imposing a burden on available land, the economy, or the environment.

Based on a stepwise regression analysis, the VOR was found to depend on the attributes of household size, population density, percentage of public transport share, percentage of female drivers in a country, in addition to the traditional understanding of its relationship to changes in GDP and per capita income. It indicated that social, demographic, and transport policy variables identified and calibrated with statistical significance would be contributory; providing a much more plausible, robust, and functional model to forecast the desirable vehicle ownership level (VOR_j) for a given country "j" at its given GDP, and its ultimate saturation level (γ_j). The application of the model shows that the household size, the share of female drivers, the population density, and the public transport service level would therefore be the factors that would determine the γ_j of a country, and eventually, its VOR.

The findings of this paper are expected to benefit policymakers, especially in middle and lower-income countries, to manipulate the transport, urban densification and other instruments that could be used to manage vehicle ownership and the eventual saturation level of vehicle ownership. It also looks to encourage future studies that explore the influence of other variables that could possibly further increase the predictability of the model.

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APPENDIX A

Country	VOR_j (Actual)	$\widehat{VOR_j}$ (Estimated)
Singapore	149	505.19
United Arab Emirates	313	505.19
Norway	584	505.19
Switzerland	566	505.19
Hong Kong	77	505.19
United States	797	505.19
Saudi Arabia	336	505.19
Ireland	513	505.19
Netherlands	528	505.19
Austria	578	505.19
Denmark	480	505.19
Germany	572	505.18
Australia	717	505.18
Sweden	520	505.18
Canada	607	505.18
Belgium	559	505.18
Oman	215	505.15
Finland	612	505.14
United Kingdom	519	505.13
France	578	505.1
Japan	591	505.06
New Zealand	712	504.87
Italy	679	504.65
Israel	346	503.97
Spain	593	503.62
South Korea	376	503.53
Czech Republic	485	502.17
Slovakia	364	491.7
Portugal	548	490.56
Greece	624	471.2
Poland	537	447.48
Hungary	345	445.13
Chile	184	326.83
Croatia	380	277.18

APPENDIX B

Country	VOR_j (Actual)	$\lambda_{(s)_j}$ (New ($\gamma_{(s)_j}$))
Singapore	149	106.00
United Arab Emirates	313	288.98
Norway	584	684.02
Switzerland	566	589.80
Hong Kong	77	112.20
United States	797	672.10
Saudi Arabia	336	296.56
Ireland	513	499.56
Netherlands	528	414.87
Austria	578	498.85
Denmark	480	618.01
Germany	572	615.27
Australia	717	663.12
Sweden	520	579.05
Canada	607	645.01
Belgium	559	588.06
Oman	215	256.06
Finland	612	687.14
United Kingdom	519	636.01
France	578	595.06
Japan	591	514.77
New Zealand	712	546.78
Italy	679	548.63
Israel	346	473.62
Spain	593	561.08
South Korea	376	411.11
Czech Republic	485	470.84
Slovakia	364	429.19
Portugal	548	576.56
Greece	624	472.59
Poland	537	477.84
Hungary	345	417.76
Chile	184	224.20
Croatia	380	268.46

Sri Lanka Society of Transport and Logistics

Journal of South Asian Logistics and Transport
Volume 2 Issue 2 September 2022
JSALT 2.2.2: pp. 19-41
DOI: http://doi.org/10.4038/jsalt.v2i2.48

THE ROLE OF SUPPLIER SWITCHING COSTS AND SUPPLY CHAIN RESPONSIVENESS

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ABSTRACT

This study explored the effect of supplier switching costs on supply chain responsiveness in Sri Lankan Small and Medium-scale manufacturing firms. It considered three types of switching costs: procedural, financial, and relational switching costs. Survey data were collected from 188 manufacturing firms and analysed using Structural Equation Modelling. The results revealed that, procedural switching cost was positively related to supply chain responsiveness, while the relational switching cost, the most important predictor, was negatively related. The relationship between financial switching costs and supply chain responsiveness was not significant. No significant relationship was found between supplier switching costs and supply chain responsiveness either, possibly due to a different set of variables influencing this relationship. No significant impact was found on the price and product competition in the context of Sri Lankan manufacturing sector indicating that supplier switching costs do not play a significant role on these variables. Yet, there may be an influence from intervening variables due to internal organisational situation and external factors such as market conditions. Switching suppliers is not an issue for some companies as they already have well-defined supplier networks with multiple providers for the same raw materials. However, this differs based on companies' relationships with suppliers and the availability of resource supplies.

Keywords: *Supplier switching costs, Supply chain responsiveness, Structural equation modelling.*

1. INTRODUCTION

The corporate environment has become more global and competitive in recent years. Modern business is characterised by shorter product life cycles, rapid releases of new products, and clients who are increasingly aware and well informed. These changes require supply networks that preserve and gain competitive advantage, by responding quickly, effectively, and efficiently to market changes. So far, a majority of studies have concentrated on supply chain flexibility or agility. It is also worthwhile to investigate supply chain responsiveness [1]. Evaluating supply chain performance can facilitate a greater understanding of the supply chain, influence performers' behaviour, and enhance its overall performance [2]. In their study of measurements of supply chain efficiency and supply chain responsiveness, Suraweera and Galahitiyawa [3] find that the concepts are interrelated but opposed to one another (duality). Based on this finding, the present study considers supply chain responsiveness as a construct measuring supply chain performance.

Switching cost is an influential business strategy because increasing switching costs will help to retain customers. [4]. This strategy contributes to supply chain performance. Matzler et al. [4] claim that studies on the causes and repercussions of switching costs in a business-to-business (B2B) setting are few. According to McLaren, Head & Yuan [5], many earlier studies attest to the transaction cost savings of existing inter-organisational networks, but fail to account for the costs of moving partners or business processes. Despite the fact that McLaren, Head, and Yuan [5] highlighted switching cost as a contributing component to performance measurement, their findings do not provide any clear information on the various aspects of switching cost. It is clear that their study does not include the three main types of switching costs; procedural, financial, and relational switching costs [6] in measuring supply chain performance.

Sri Lanka's manufacturing sector is a major contributor to the country's economy, with SMEs (small and medium-sized enterprises) playing a critical role [7]. As the nature of SME interactions is interpersonal: their focal enterprises are determined based on the relationship between supply chain managers. As a result, supplier switching cost is of fundamental importance to supply chain performance. The key objective of the study is to investigate how three types of supplier switching costs namely procedural switching costs, financial switching costs, and relational switching costs lead to supply chain responsiveness.

This research contributes to both theory and practice. The study looks at the impact of all three dimensions of supplier switching costs (procedural switching costs, financial switching costs, and relational switching costs) on supply chain

responsiveness. Few prior studies use empirical methods to conduct this type of research. This study also makes recommendations on potential improvements to supply chain performance metrics through lower supplier switching costs based on existing supply chain management methods. These improvements directly affect a firm's competitive advantage.

The theoretical background to this study and underlying theories are described in the next section. Thereafter, the study method and statistical analysis results are presented. Finally, the paper ends with a discussion of the findings, their ramifications, and future research objectives.

2. LITERATURE REVIEW

2.1. Supplier switching cost

Switching costs, which have been identified as a determinant in supply chain performance, result in lower relationship costs and higher revenues [4]. Switching cost is also mentioned by McLaren et al. [5] as a factor contributing to performance measurement. Customers are increasingly trying to cut costs by switching suppliers, according to Matzler et al. [4]; notably in business-to-business (B2B) settings [8]. Switching costs, described as “costs a buyer perceives, anticipates, and/or experiences when switching a connection from one vendor to another” [9], are seen as effective defensive marketing techniques [10]. According to Wu [11], when a business customer switches to a new supplier, they must pay switching costs, which Wu [11], defines as "the one-time charges that customers identify with the process of moving from one provider to another" [6]; [12].

Literature explores many typologies for switching costs [8]; [6]; [12]. Burnham et al. [6] establish a generic understanding of switching costs based on a thorough assessment of this literature and interviews with industry management and consumer focus groups.

Figure 1: A typology of consumer perceptions of switching costs [6]

As illustrated in Figure 1, the typology of switching costs given by Burnham et al. [6] was employed for the purposes of this study. Their cost scale contains eight first-order factors, categorised into three higher-order factors. The eight elements of switching costs are economic risk costs, assessment costs, learning costs, setup costs, benefit loss costs, monetary loss costs, personal relationship loss costs, and brand relationship loss costs. These can be categorised into three higher-order switching costs: procedural switching costs (primarily time and effort), relational switching costs (psychological and emotional discomfort), and financial switching costs (loss of financially quantifiable resources).

2.2. Procedural switching costs

These costs are related to the time and effort spent evaluating alternative offerings and establishing a relationship with a new supplier.

They include:

- Economic risk costs: expenditures incurred as a result of uncertainty regarding the new provider's performance,
- Evaluation costs: costs associated with evaluating other options and making a selection, such as time and effort spent searching for and analysing them [6]
- Learning costs: Costs expended as a result of the time and effort required to learn how to use a new product or service efficiently
- Setup costs: incurred as a result of the time and effort required to initiate a relationship with new customer.

2.3. Financial switching costs

As Burnham et al. [6] explained, these costs are associated with the loss of financially determinable resources as a result of relocation.

Examples include:

- Benefit loss expenses (costs incurred as a result of the loss of discounts or similar benefits provided by the existing provider but not guaranteed by the new supplier),
- Monetary loss costs (one-time costs associated with switching suppliers that are not related to the cost of the new product itself) are two examples of these costs.
- Financial loss cost: the cost of one-time financial expenses, such as asset replacement for specific transactions that are required to begin working with the new supplier.

2.4. Relational switching costs

Relational switching costs are costs associated with the psychological or emotional distress associated with severing ties with the existing supplier.

- Personal relationship loss: expenditures incurred as a result of the emotional losses resulting from the breakdown of bonds with the supplying firm's employees,
- Brand relationship loss: cost incurred as a result of the emotional losses incurred as a result of the provider's brand being broken, are the costs directly impact for the relational switching costs [6].

2.5. Supply chain responsiveness

The ability to respond rapidly and the degree to which the supply network can adjust to changes in consumer demand are both referred to as supply chain responsiveness [13]; [14]; [15]; [16]. Compared with the past, it is essential that organizations and supply chains grow significantly more flexible and responsive to competition [17]. Although studying supply chain responsiveness from the standpoint of supply interference would be interesting, the current study focuses on customer demand using three sub-constructs for supply chain responsiveness: operations system responsiveness (OSR), logistics process responsiveness (LPR), and supplier network responsiveness (SNR). Thatte, [1] has discussed supply chain responsiveness and above mentioned three dimensions in his work. This study further discusses supply chain responsiveness by incorporating supply chain switching costs.

2.6. Operations system responsiveness

The production system's ability to respond to changes in client demand can be introduced as operation system responsiveness. Manufacturing and service operations are both affected by the responsiveness of the operations system. In conceptual research, Duclos et al. [16] and Lummus et al. [15] state that supply chain responsiveness includes operations system responsiveness at each node of the chain. They further highlighted that in order to satisfy the end customer expectation, each business in the supply chain must deliver the output on-time and reliably. The dimensions in this category would be used to assess the responsiveness of a supply chain node (business) [16]; [15]. Further, OSR is directly influenced by the demand fluctuations, switching cost should be a vital factor when setting product pricing [1].

2.7. Logistics process responsiveness

Logistics process responsiveness includes the capacity of outbound transportation, distribution, and warehousing infrastructure to respond to changing client demands.

The responsiveness of logistics procedures is critical to the success of a responsive supply chain strategy [13]. Logistics and distribution management handle the transportation of goods from suppliers to manufacturers and then to the final locations of consumption through distribution hubs [16]; [15]. These logistics activities include warehousing, packing, and shipping, as well as transportation planning and management, inventory management, reverse logistics, and order tracking and delivery. According to Duclos et al. [16], a company's logistics system is critical in giving value to its consumers. This value generation for a company's clients entails maintaining logistics flexibility and speed throughout the supply chain to meet the unique needs of each client [16]; [15].

2.8. Supplier network responsiveness

The ability of a company's key suppliers to respond to changes in demand is referred to as supplier network responsiveness. Upstream and downstream of the focal business, the presence of responsive and flexible partners is crucial to supplier network responsiveness [18]. Businesses' ability to adapt quickly to client demand is dependent on suppliers' ability to adjust the volume quickly. According to Slack [19], the basic building blocks of a flexible system are supplier networks.

According to many interviews with operations managers at Volvo's European automobile assembly plants [13], the company's response was delayed due to a lack of supplier network flexibility. Supply chain responsiveness includes both supplier network flexibility [20] and supplier network responsiveness. According to Holweg [13], the capacity to respond to changes in consumer demand requires supplier network flexibility. As a result, in this study, supplier network responsiveness is considered as a dimension of supply chain responsiveness.

3. HYPOTHESES AND CONCEPTUAL FRAMEWORK

3.1. Supplier switching costs and supply chain responsiveness

With the exception of a few studies [5], little thought has been given to how supplier switching costs affect supply chain performance. Similarly, McLaren, Head, and Yuan [5] found switching cost as a contributing element to a performance measure, despite the fact that their findings provide no clear information on the many aspects or types of switching costs in B2B context. Switching costs have also been linked to higher profits [19], inelastic response to price [21] increased product preannouncements [22], and barriers to market entry and sustainable strategies advantage [23] [24]. According to Burnham, Frels & Mahajan [6], it is sometimes noticed that a client does not discontinue a supplier relationship immediately even where there is a low level of satisfaction. This is primarily due to the cost of

transitioning [25]. Customers may be compelled to stay with suppliers notwithstanding the level of satisfaction established in the relationship if switching obstacles are high [26]. Supplier switching costs, when added together, can cause major supply chain disruptions, limiting a company's ability to continue operations, reliably fulfil customer orders in a timely way, and offer vital services to end customers [25]. Consequently, this study can hypothesize:

Alternative hypothesis H1: Supplier switching costs have an impact on supply chain responsiveness.

3.2. Three types of supplier switching costs and supply chain responsiveness

Although McLaren, Head, and Yuan [5] identify switching cost as a factor contributing to performance measurement, the findings do not provide any clear information on the various aspects of switching cost, and it is clear that it has failed to incorporate the three types of switching cost, namely procedural switching cost, financial switching cost, and relational switching cost [6] in measuring supply chain performance. Previous studies have emphasised that in addition to these switching costs, the buyer's company will also consider competitive reactions and economies of scale of incumbent suppliers [27].

Using three different forms of switching costs, this study aims to fill a theoretical gap by assessing the impact of supplier switching costs on supply chain responsiveness. Past research has theoretically demonstrated that supply chain responsiveness is influenced by supply chain management practices such as strategic supplier partnership, customer relationship, information sharing and modularity-based manufacturing methods [1]. They have emphasised the importance of hypothesizing these relationships.

This study can hypothesize the following to fill this theoretical gap:

- *Alternative hypothesis H2 (a):*
  Procedural switching costs have a significant impact on supply chain responsiveness.
- *Alternative hypothesis H2 (b):*
  Financial switching costs have a significant impact on supply chain responsiveness.
- *Alternative hypothesis H2 (c):*
  Relational switching costs have a significant impact on supply chain responsiveness.

The conceptual framework depicted in the Figure 2 was built based on the above literature.

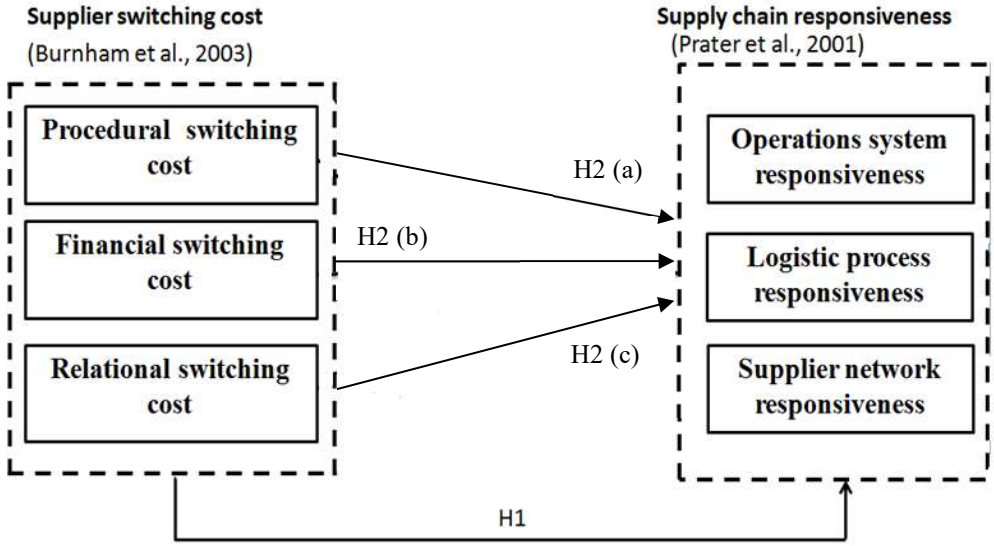

Figure 2: Conceptual framework

4. METHODOLOGY

4.1. Participants and procedure

This study adopts the positivist paradigm, given the nature of its objectives. The study deals with real-life social events, and its outcome can be applied to similar situations [28]. The positivist paradigm allows researchers to develop knowledge objectively and investigate further. The population of this study is made up of all SME manufacturers in operation with the Board of Investment (BOI); there are 360 such SMEs. A sample was drawn from the population using a basic random sampling procedure. The sample unit covered several industries: agro-processing and beverages, high-tech industries, machinery and equipment, pharmaceuticals, garments, and rubber-based products. The unit of analysis was the BOI registered SMEs (business customers) in the manufacturing sector. Senior managers, supply chain managers, executives working in the field of supply management, and owners were the most appropriate respondents for supply chain performance and supplier information, according to previous research [29]; [30]. As a result, the supply chain manager, operations manager, general manager, or the company's owners were the point of contact or respondent in this study. When these managerial positions were not available, the designated persons in charge of dealing with particular suppliers were contacted directly. The survey was administered in person and online. As a result, the researcher individually completed 40 questionnaires. More than 300 online questionnaires were emailed to a random sample of respondents. The in-person technique had an 80 percent response rate, while the online method had a lower

response rate of 54%, where only 162 responses out of 300 were received. The questionnaires were then examined, and incomplete responses were removed from the sample; 188 questionnaires were analysed for this study. Data analysis was conducted using Structural Equation Modelling (SEM) by SPSS AMOS 23.0 software.

4.2. Measures

The questionnaire consists of 48 questions, and they were used to evaluate six components: procedural switching costs, financial switching costs, relational switching costs, operations system responsiveness, logistic process responsiveness and supplier network responsiveness. The experience in terms of switching cost and responsiveness were questioned and respondents were asked to react using a rating scale depending on the type of purchase (raw materials, accessories, or capital items) and the type of industry. The survey was divided into two parts. The component (A) contains questions designed to gain a general understanding of the participants, such as their title, location of employment, type of the company's product, suppliers' names, and previous switching experience. The section (B) contains information on switching costs, such as procedural switching costs (18 elements), pecuniary switching costs (5 elements), and relational switching costs (7 elements). All three forms of switching costs were measured using a seven-point Likert scale. The following section contains information on supply chain responsiveness, including operations system responsiveness (7 elements), logistic process responsiveness (5 items), and supplier network responsiveness (6 items). All three characteristics of supply chain responsiveness were evaluated using a five-point Likert scale. Every question in the study was generated from questions that had previously been assessed.

5. DATA ANALYSIS AND RESULTS

A pilot survey of 30 people was undertaken to identify and remove possible flaws in the survey instrument design as well as to test the validity and reliability of measurements. In the pilot survey, Cronbach's alpha coefficient was more than 0.7 for all constructs [26], as summarised in Table 1.

Table 1: Reliability statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardised Items	N of Items
.883	.868	55

Cronbach’s Alpha test is used to see if multiple-question Likert scale surveys are reliable and have internal consistency. It will tell that the test has designed is

accurately measuring the variable of interest. If the alpha value of 0.9 will indicate a perfectly reliable test. However, having 0.7 as the alpha value is an acceptable signal to go ahead with the analysis [25].

The data for this study was first entered into the IBM Statistical Package for Social Science (SPSS) software version 23.0 after the pilot survey. All data were winsorised at a 95 percent level to exclude outliers, and the 188 occurrences were transmitted for missing value analysis. A winsorisation is an initial replacement of the smallest and largest values with the observations that are nearest to them in an average, which is a statistical measure of central tendency.

In any of the 188 surveys included in this study, there were no missing values. After missing value data analysis and outlier detection, the data was checked for multivariate assumptions such as normality, linearity, homoscedasticity, and multicollinearity. The results required to be within +2.0 and were checked for normality using skewness and kurtosis. Popović, [26] measured linearity and .homoscedasticity using normal probability plots (p-plots) and scatter plots, and found no deviations. Finally, multicollinearity was measured using a correlation matrix, and all inter-correlation values were less than 0.9. According to the results of multivariate assumptions, all variables were guaranteed to be normal, linear, homoscedastic, and multicollinear. The Kaiser-Meyer-Olkin (KMO) test was used to determine the appropriateness of the study's sample. According to the KMO statistics, the sample adequacy of all constructs is more than 0.5, indicating that the sample is adequate. To ensure that all structures were uni-dimensional, exploratory factor analysis (EFA) was used. EFA and confirmatory factor analysis (CFA) are similar techniques. Since we can specify the factors used in the survey, it can move ahead with CFA. However, in this study, EFA was done prior to CFA to ensure the measured variables are related to every latent variable. The data was then sent for multivariate analysis, having confirmed the reliability of all constructs through Cronbach’s alpha.

5.1. The measurement model

The measuring model “specifies the indicators for each concept and allows construct validity to be assessed” [24]. Procedural switching costs (PSC), financial switching costs (FSC), relational switching costs (RSC), operations system responsiveness (OSR), logistics process responsiveness (LPR), and supplier network responsiveness (SNR) are the six latent variables identified by the conceptual model. Because the initial measurement model had a poor match, modification indices were used to improve the model. To improve the baseline model, stepwise deletion of items with a loading of less than 0.5 factors was used. Six items were deleted during the revision

process due to low standardised regression weights. To develop the latent variables, impact of all the supply chain cost types to supply chain responsiveness and impact of supply chain flexibility to responsiveness were observed separately. Covariances were also constructed between the error terms of numerous items with the goal of improving them. The final measurement model was found to be a good fit.

Table 2: Model-fit statistics of measurement model

Absolute					Incremental		Parsimony
CMIN/DF	GFI	AGFI	RMSEA	IFI	TLI	CFI	PRATIO
1.012	.811	.779	.054	.876	.871	.824	.821

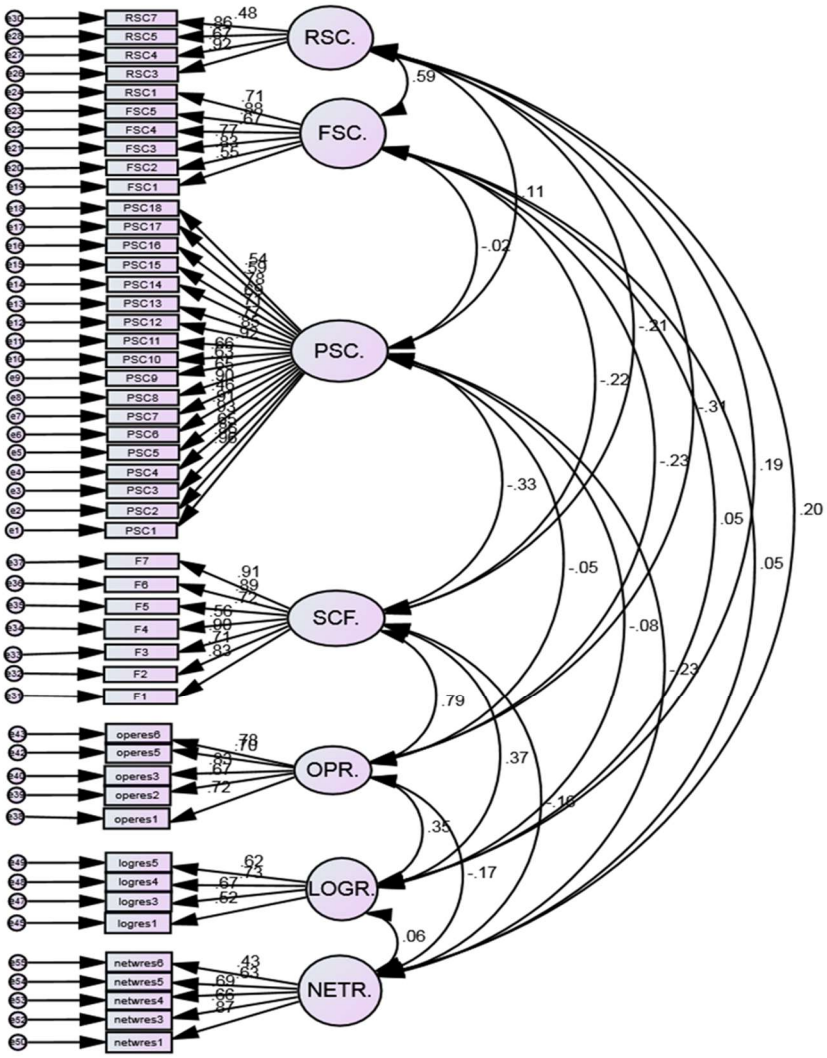

Figure 3: Modified measurement model

According to Popović, [26] a satisfactory model fit is indicated by a CMIN/DF (X2/df) value around one and not exceeding 3, a Comparative Fit Index (CFI) value near one, a Tucker-Lewis Index (TLI) value near one, and a Root Mean Square Error of Approximation (RMSEA) value of roughly 0.08 or less. According to Popović, 2015 [26] the .stated GOF (goodness of fit) suggests that at least one absolute measure (X2/df/p value/GFI/RMSR/.RMSEA), one incremental measure (NFI/.CFI/TLI/RNI), and one parsimony (PRATIO/PCFI/PNFI) fit measure must be included. The measurement model's CIMIN/DF is close to 0.1 and below 0.3, and the RMSEA is 0.054, as reported in Table 2, indicating absolute model fit. In addition, the incremental and parsimony indices in Table 2 are near to 1, indicating a good model fit.

Table 3: Convergent and discriminant validity

	AVE	CR	MSV	ASV	PSC	FSC	RSC	OSR	LPR	SNR
PSC	.808	.987	.623	.332	**.899**					
FSC	.692	.918	.546	.279	.212	**.832**				
RSC	.755	.955	.589	.296	.236	.641	**.868**			
OSR	.623	.918	.518	.263	.044	.026	.687	**.789**		
LPR	.622	.888	.518	.252	.343	.407	.456	.354	**.788**	
SNR	.748	.918	.588	.293	.562	.035	.357	.235	.437	**.865**

Note: Diagonal 5 entries (in bold) are the square root of AVE for all constructs; sub-diagonal entries are the correlation coefficients estimates between each construct

Confirmatory Factor Analysis (CFA) was performed to further test the components' convergent and discriminant validity. According to Malhotra & Dash [31], acceptable convergent validity requires 0.5 or higher factor loading and 0.5 or more Average Variance Extracted (AVE). Furthermore, Composite Reliability (CR) must be at least 0.7. If the square root of the VAE is greater than the correlation coefficients, discriminant validity is generally guaranteed [32]. Furthermore, the Maximum Shared Variance (MSV) and Average Shared Variance (ASV) must be less than AVE to ensure discriminant validity [26]. Furthermore, the study constructs' correlation coefficients do not exceed 0.85. As a result, each of the constructions in the study represents a distinct concept. The convergent and discriminant validities are satisfactory because all of the aforesaid requirements are met, as shown in Table 2.

5.2. The structural model

The structural model investigates the direct links between constructs. The first structural model was created to see if there was a direct link between supplier switching costs (SSC) and supply chain responsiveness (SCR). Figure 4 depicts the

output path diagram of structural model 1. The structural model 2 was created to investigate the link between three forms of supplier switching costs (procedural switching costs (PSC), financial switching costs (FSC), and relational switching costs (RSC)) and supply chain responsiveness (SCR). The output path diagram of the structural model 2 is shown in Figure 5. At a 95% confidence level, all hypotheses were examined.

Table 4: Model-fit statistics of structural model 1

	Absolute				Incremental		Parsimony
CIMIN/DF	GFI	AGFI	RMSEA	IFI	TLI	CFI	PRATIO
1.166	.804	.874	.029	.901	.858	.825	.931

The model fit data for structural model 1 are summarised in Table 4. As a result, the structural model 1 model fit statistics results show that the model is well-fit. The CIMIN/DF ratio is less than three (CIMIN/DF = 1.166, GFI =0.804, RMSEA =0.029, IFI =0.901, TLI =0.858, CFI =0.825). The GFI is greater than 0.8, and the RMSEA suggests good absolute model fit. Incremental metrics (IFI, TLI, CFI) also show that the model is well-fit. Furthermore, Parsimony indices show that model fit is satisfactory.

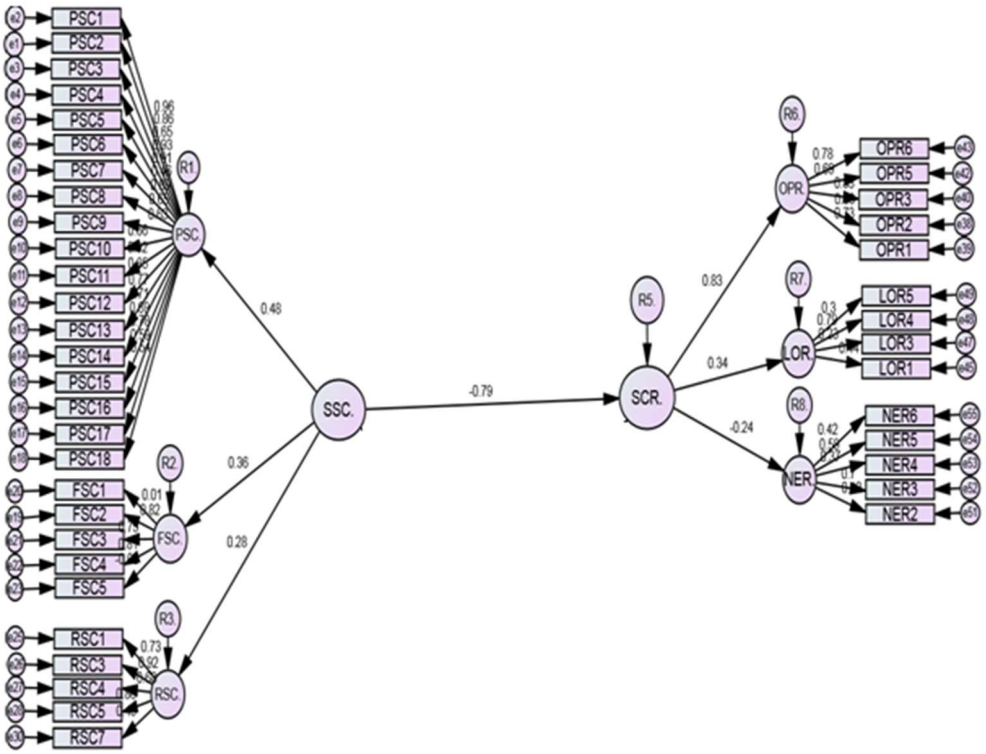

Figure 4: The structural model 1

Figure 4 shows the direct path hypothesis testing (H1) outcome. As depicted, it was hypothesised that supplier switching costs (SSC) has an impact on supply chain responsiveness (SCR). The result of hypothesis 1 shows that SSC has an insignificant negative impact on SCR. (β = *-0.79, p = 0.121) at* the 95% confidence level.

Table 5: Model-fit statistics of structural model 2

	Absolute				Incremental		Parsimony
CIMIN/DF	GFI	AGFI	RMSEA	IFI	TLI	CFI	PRATIO
2.331	.712	.701	.044	.821	.801	.728	.802

Table 5 summarises the model fit statistics for structural model 2. Only the GFI and other absolute indices indicate a moderate model fit, but CIMIN/DF and other fit indices (e.g., RMSEA, .RMR) imply a high incremental model fit. In addition, Parsimony indices show that the model is well-fit. Figure 5 shows the results of hypothesis testing (H2a, H2b, and H2c) for direct pathways.

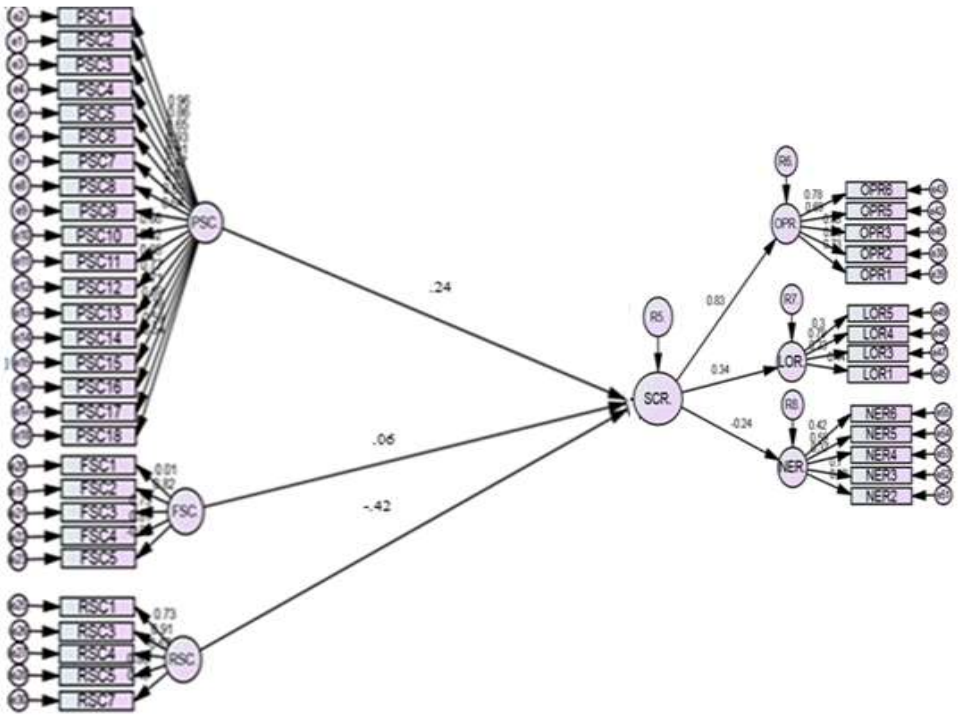

Figure 5: The structural model 2

As depicted in Figure 5, hypothesis 2a investigates the relationship between procedural switching cost (PSC) and supply chain responsiveness (SCR). It was hypothesised that there would be a relationship between PSC and SCR. The result demonstrates positive and significant paths from PSC and SCR ($\beta = 0.24$, $p = 0.002$).

Thus, hypothesis 2a is supported. Hypothesis 2b tested the relationship between financial switching cost (FSC) and supply chain responsiveness (SCR). It was hypothesised that there would be a relationship between FSC and SCR. The finding reveals a positive but statistically insignificant connection between FSC and SCR (= 0.61, p = 0.113). As a result, hypothesis 2b is unsupported. Hypothesis 2c investigated the relationship between relational switching cost (RSC) and supply chain responsiveness (SCR). It was hypothesised that RSC and SCR would have some sort of link. The results demonstrated a negative and statistically significant connection between RSC and SCR (= -0.42, p = 0.000). As a result, hypothesis 2c is confirmed.

6. DISCUSSION

The first objective of this research is to identify the impact of supplier switching costs on supply chain responsiveness. Empirical evidence indicates that supplier switching costs are associated with decreased supply chain responsiveness. Previous studies investigated the effect of supplier switching cost to customer loyalty, based on the preference level, satisfaction and price indifference of alternative products [33]. Supplier switching costs insignificantly limit a firm's ability to respond to changes in customer demand. It also affects the ability of its outbound transportation, distribution, and warehousing systems and its key suppliers to respond to changes in demand. Thus, for SME manufacturers in Sri Lanka, supplier switching costs have negative insignificant effects on supply chain responsiveness at a 95% confidence level. Accordingly, this relationship might be influenced by different intervening variables. Even though past literature has not measured the relationship strength between switching costs and supply chain responsiveness, it has indicated that impact of switching costs can be mitigated within firms without shifting them downstream [34]. Large-scale firms maintain stocks that allow them to grow more responsive to sudden changes in demand; making their switching costs negligible. The findings of this study are in line with earlier studies conducted in both public and private sector enterprises.

The second goal is to investigate the impact of three different types of supplier switching fees on supply chain responsiveness. Supplier switching costs are divided into three categories: procedural switching costs, financial switching costs, and relational switching costs. Although McLaren, Head, and Yuan [5] identify switching cost as a component contributing to performance measurement, the findings do not provide any clear information on the many aspects of switching cost, and it is clear that the three categories of switching costs are not included, namely, procedural switching costs, financial switching costs and relational switching costs [6] in measuring supply chain performance.

For the purpose of this study, a more inclusive typology consisting of the three main types of switching costs proposed by Burnham, Frels & Mahajan [6] has been used. The findings of the present study reveal that, procedural switching cost has a significant positive impact on supply chain responsiveness at 95% confidence level. As a result of the costs associated with the time and effort required to evaluate alternative offerings and establish a relationship with a new supplier, the ability to adjust to changes in customer demand with the least amount of time penalties increases [6]. The outcomes of this study also show that, at a 95% confidence level, financial switching costs have a negligible positive impact on supply chain responsiveness. As a result, SME manufacturers neglect the costs that can be defined as financial loss caused when they took the switching decision. The results of this study also show that, relational switching costs are associated with decreasing supply chain responsiveness. Especially, relational switching costs are the costs related to the psychological or emotional discomfort related to the breaking of the established bonds with the current suppliers. It encompasses the expenses of severing personal relationships as well as the costs of severing brand relationships [6]. As a result, when switching costs are substantial, the focal firm prefers to stick with its long-term suppliers. However, having high relational switching costs might put a company at risk of becoming too reliant on a single supplier, reducing its competitive advantage. Therefore, the negative relationship between relational switching cost and supply chain responsiveness could be explained logically.

7. THEORETICAL CONTRIBUTIONS

This study uses conclusions from an instrument that is valid and trustworthy given its setting to measure the impact of supplier switching cost and supply chain responsiveness. Furthermore, the study identifies substantial correlations between supplier switching costs and supply chain responsiveness, as well as a research framework. This structure (Figure 2) provides a basis and insight for future supply chain performance researchers. Although some earlier studies have looked at the influence of supplier switching costs on supply chain performance, none have looked at the impact of three types of switching costs: procedural switching costs, financial switching costs, and relational switching costs.

As a result, three significant characteristics of supplier switching costs are captured by the instrument created in this study. The new tool will serve as a better guideline for supply chain performance studies and may thus be classified as a strategic management tool. The study also looks at supply chain responsiveness at the firm level, evaluating a firm's ability to respond to changes in consumer demand in a variety of ways. The degree to which demand changes are addressed at various nodes

of a company (upstream, within the company, and downstream) can be used as a proxy for supply chain responsiveness. Researchers interested in gauging supply chain responsiveness will find this measure useful.

8. MANAGERIAL IMPLICATIONS

The outcomes of this study show that measuring supply chain performance using supplier switching costs is critical because it drives supply chain excellence and helps the firm accomplish its business objectives. Depending on the firm's specific ability of manufacturing system and logistic system to respond changes in consumer demand, the influence of procedural, financial, and relational switching costs on the intention to stay with the existing supplier will be different. The firm's aim in keeping a strong capacity to adjust changes in the market stems from its expectation of high switching costs. Because of the expected high switching costs, capacity preservation is seen as a priority, resulting in a commitment to the changes. Most companies have good relationships with their existing suppliers, based on mutual trust, joint problem solving, and delivery of pre-specified promises, and are better able to adapt to unforeseen changes, identify and produce tailored solutions to organisational problems, and reduce monitoring costs, all of which help improve supply chain performance.

The study provides enterprises with a set of accurate and reliable measurements for evaluating, benchmarking, and comparing supply chain responsiveness at the point where raw materials are supplied. The measurements developed in this study capture several aspects of supply chain responsiveness, allowing practitioners to not only recognise immediate outcomes, but also to comprehend their effects on organisational performance. Based on the outcome of the study, it can be assured that investigated relationships have both practical and statistical significance. It is important when providing implications [1].

Organisations need to be more responsive in today's fast-paced global competition in order to address client expectations quickly. Furthermore, whole firm responsiveness necessitates responses on all dimensions, including supply, internal, and downstream. The term "supply chain responsiveness" is loosely defined, and people's perceptions of what it means vary greatly. The findings show practitioners what makes responsiveness so important, as well as how to achieve it.

The knowledge gathered from the visiting the small and medium scaled firms revealed that manufacturing firms organised in networks had a higher chance of survival than those with arm’s length market contacts but to avoid the risks associated by being tied to particular suppliers the firms maintain a well evaluated supplier base

with a significant number of suppliers for each of the raw materials. The findings also exposed that unlike switching costs, the ability to adjust to sudden changes in customer demand does not always play the frequently mentioned role against price and product competition in the context of manufacturing sector companies [13]. Since most firms as of now have an altogether assessed supplier base with numerous suppliers for the same raw material, exchanging suppliers isn't a major problem as they can be effortlessly replaced.

This study empirically verifies that SMEs compete based on their supply chains and that those with more responsive supply chains enjoy a substantial competitive advantage.

9. LIMITATIONS

Although this study makes substantial contributions from both a theoretical and a practical standpoint, it does have several drawbacks. Because of the limited number of investigations, the data collected may be confined to the area covered by the survey instrument. To increase response rates, new email lists and research approaches can be deployed. Because this cross-sectional study was conducted for such a short period of time, the long-term impact of supplier switching costs was not recorded. This survey asked individual respondents (high-level executives from procurement, operations, .materials, and logistics functions) to respond to supply chain responsiveness practices. However, no single person in an organisation is in charge of the entire supply chain: purchasing managers, for example, are primarily responsible for purchasing and supply; they may not be qualified to reply to supply chain responsiveness questions. As a result, relying on a single respondent may lead to measurement errors.

10. DIRECTIONS FOR FUTURE RESEARCH

The use of a single respondent to represent intra/inter-organisational factors may result in some inaccuracy, in addition to the usual degree of random error. In order to improve the dependability of research findings, future studies should aim to include several responders from each participating organisation. Other significant parameters that were not examined in this study should be considered in future research. In this regard, other elements of supply chain responsiveness, such as assembly responsiveness and inbound logistics responsiveness, would be examined. Adding more performance measures for the supply chain responsiveness would further enhance the future outcomes. Also include more detailed conceptualisations of switching costs to gain a deeper knowledge of potential links and improve the diagnostic value of the mechanisms that drive supplier retention. Future research

should also examine the impact of other variables that can mediate the relationship between supplier switching cost and supply chain responsiveness in this model.

11. CONCLUSION

The findings reveal that the direct relationship between supplier switching costs and supply chain responsiveness is not significant. Thus, this relationship might be influenced by a different intervening variable. Furthermore, the impact of procedural, financial, and relational switching costs on the desire to stay with the current supplier will vary based on the specific relationship attaching the focal firm to the supplier. The findings also exposed that supplier switching costs do not play a significant role in the price and product competition in the manufacturing sector in Sri Lanka.

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ANNEXURE

Variable wise statistics

Item Statistics				Item Statistics			
	Mean	Std. Deviation	N		Mean	Std. Deviation	N
PSC1	4.29	1.738	168	flexibility1	4.55	1.670	168
PSC2	4.43	1.756	168	flexibility2	4.96	1.697	168
PSC3	4.65	1.533	168	flexibility3	4.26	1.689	168
PSC4	4.37	1.708	168	flexibility4	4.87	1.302	168
PSC5	4.35	1.748	168	flexibility5	4.80	1.664	168
PSC6	3.95	1.517	168	flexibility6	4.46	1.677	168
PSC7	4.42	1.725	168	flexibility7	4.32	1.749	168
PSC8	4.39	1.758	168	operes1	3.97	0.815	168
PSC9	4.90	1.731	168	operes2	3.96	0.803	168
PSC10	4.88	1.242	168	operes3	3.83	0.933	168
PSC11	4.36	1.745	168	operes4	3.83	0.838	168
PSC12	4.38	1.750	168	operes5	4.02	0.811	168
PSC13	4.48	1.551	168	operes6	3.81	0.966	168
PSC14	4.53	1.555	168	operes7	3.81	0.840	168
PSC15	4.64	1.522	168	logres1	3.26	0.758	168
PSC16	4.15	1.603	168	logres2	3.32	0.898	168
PSC17	4.25	1.519	168	logres3	3.19	0.875	168
PSC18	4.19	1.532	168	logres4	3.43	0.747	168
FSC1	4.60	1.477	168	logres5	3.58	0.696	168
FSC2	4.83	1.588	168	netwres1	3.39	0.675	168
FSC3	4.96	1.675	168	netwres2	3.26	0.728	168
FSC4	4.55	1.413	168	netwres3	3.78	0.746	168
FSC5	4.13	1.707	168	netwres4	3.66	0.733	168
RSC1	4.26	1.583	168	netwres5	3.79	0.874	168
RSC2	4.88	1.164	168	netwres6	3.72	0.804	168
RSC3	4.45	1.555	168				
RSC4	4.88	1.229	168				
RSC5	4.55	1.488	168				
RSC6	4.32	1.583	168				
RSC7	5.36	1.752	168				

Procedural. Switching Costs (PSC)

Financial. Switching Costs (FSC)

Relational Switching Costs (RSC)

Operations System Responsiveness (OSR)

Logistics Process Responsiveness (LPR)

Supplier Network Responsiveness (SNR)

Sri Lanka Society of Transport and Logistics

Journal of South Asian Logistics and Transport
Volume 2 Issue 2 September 2022
JSALT 2.2.3: pp. 43-77
DOI: http://doi.org/10.4038/jsalt.v2i2.49

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.

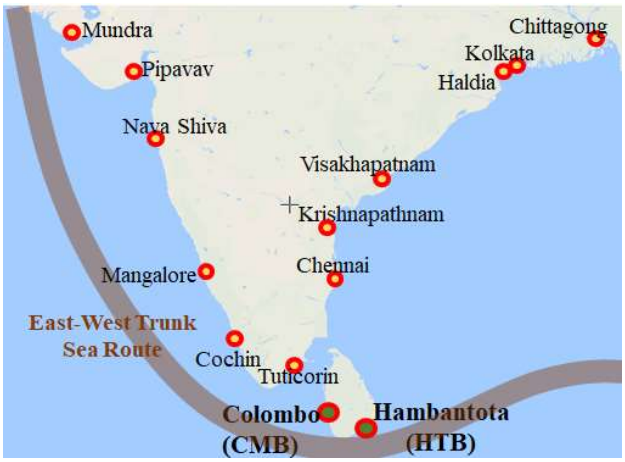

Figure 1: Study Area

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.

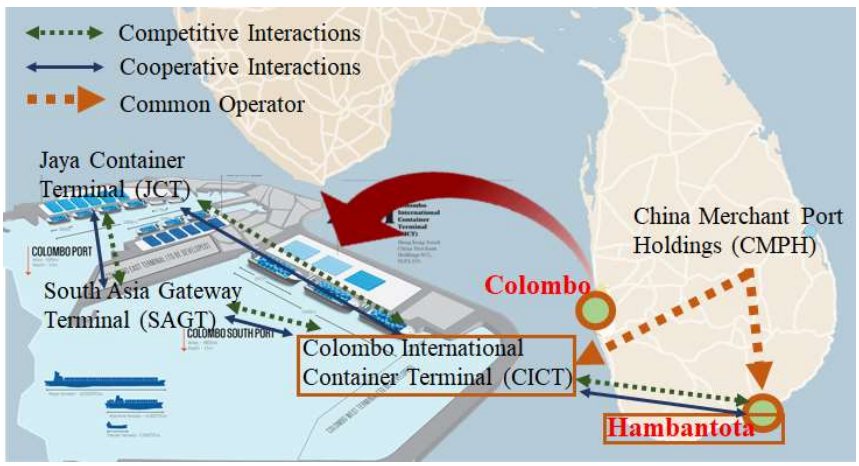

Figure 2: Terminal Ownership and Interactions

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).

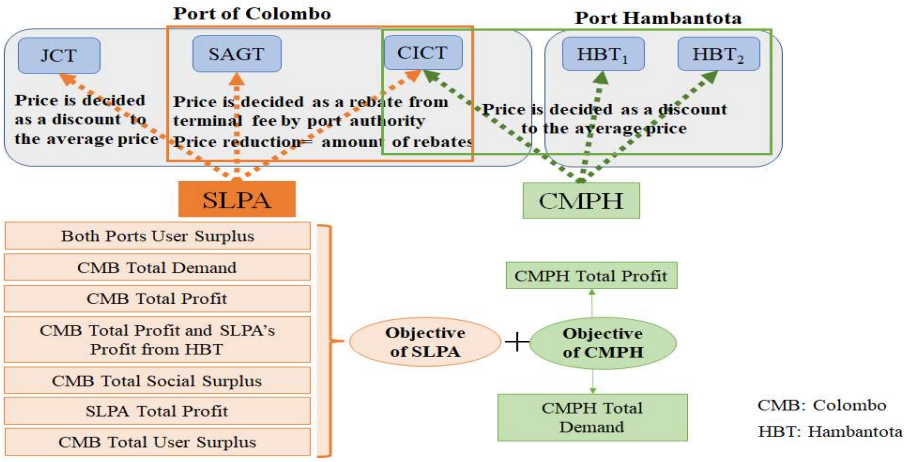

Figure 3: Objectives for Decision-making of SLPA and CMPH

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 ($JC_t^{f,h}$), time cost ($TC_t^{f,h}$) 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 ($JC_t^{f,h}$), 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, $UDC_t^{(j,f,h)}$. Equation (4) calculates the $UDC_t^{(j,f,h)}$ incorporating the average port charge, MPC_t^h in that period. Similarly, Equation (5) estimates the time cost ($TC_t^{f,h}$) 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 $VOT_t^{(w,f,h)}$, which reflects the value of time. Equation (6) estimates the $VOT_t^{(w,f,h)}$ 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).

$$GC_t^{f,h} = MPC_t^h + JC_t^{f,h} + TC_t^{f,h} - VNQC_t^h \quad (1)$$

$$MPC_t^h = \sum_{i=1}^{i=m^h} (Share_t^i * MPC_t^i) \quad (2)$$

$$JC_t^{f,h} = \sum_{j=1}^{j=2} \left[D^{(j,f,h)} * UDC_t^{(j,f,h)} \right] \quad (3)$$

$$UDC_t^{j,f,h} = \frac{\left(\frac{MPC_t^h}{SS_{(Port\ Charges)}} \right) * SS_{(j)}}{(\sum_{h=1}^{h=2} D^{(j,f,h)}/2)} \quad (4)$$

$$TC_t^{f,h} = \sum_{w=1}^{w=4} \left[T^{(w,f,h)} * VOT_t^{(w,f,h)} \right] \quad (5)$$

$$VOT_t^{(w,f,h)} = \frac{\left(\frac{MPC_t^h}{SS_{(Port\ Charges)}} \right) * SS_{(w)}}{(\sum_{h=1}^{h=2} T^{(w,f,h)}/2)} \quad (6)$$

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.

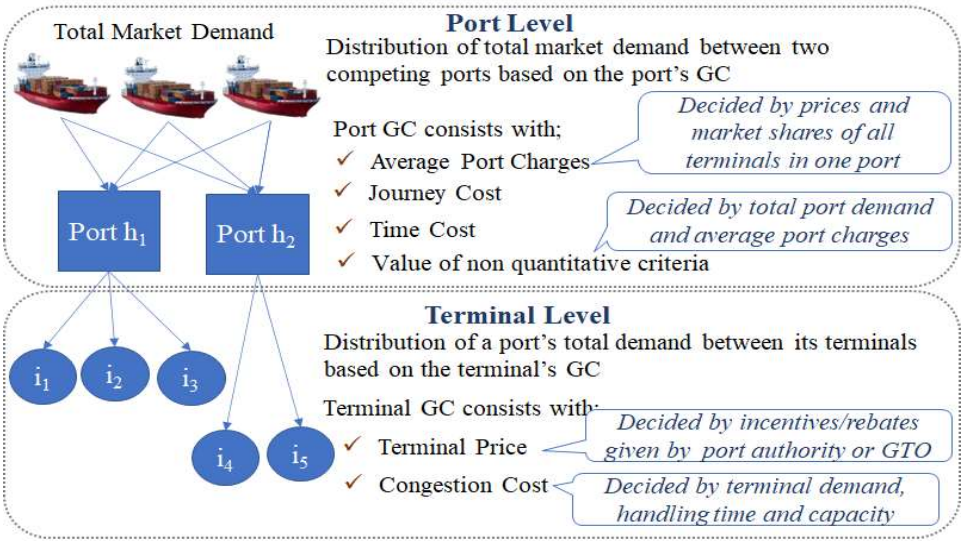

Figure 4: Port-level and Terminal-level Analysis

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.

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

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

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

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).

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

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

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

$$\text{Max; } \mathrm{SS_t^{CMB}} = \sum_{i=1}^{i=3} \left[\mathrm{US_t^i} + \pi_t^i\right] \qquad i = \mathrm{JCT, SAGT, CICT} \tag{21}$$

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

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

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

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

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

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

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

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.

$$\mathrm{MPC}_t^i = \mathrm{MPC}_{\mathrm{avg}}^i - \gamma * \ln(x_t^i) \qquad i = \mathrm{HBT}_1, \mathrm{HBT}_2, \mathrm{CICT} \tag{29}$$

$$\begin{aligned}\text{Max; } \pi_t^{\mathrm{CMPG}} = \Bigg[V * \Big[(1-\rho) \Big[\big[Q_t^{\mathrm{HBT}_1} * \big(\mathrm{MPC}_t^{\mathrm{HBT}_1} - C^{\mathrm{HBT}_1} \big) \big] + \big[Q_t^{\mathrm{HBT}_2} * \big(\mathrm{MPC}_t^{\mathrm{HBT}_2} - C^{\mathrm{HBT}_2} \big) \big] \Big] \\ + \big[Q_t^{\mathrm{CICT}} * (\mathrm{MPC}_t^{\mathrm{CICT}} - \mathrm{TF}_t^{\mathrm{CICT}} - C^{\mathrm{CICT}}) \big] \Big] \\ + (1-\omega) \big[(Q_t^{\mathrm{HBT}_1} + Q_t^{\mathrm{HBT}_2}) * (N^{\mathrm{HBT}} - N_{\mathrm{cost}}^{\mathrm{HBT}}) \big]\end{aligned} \tag{30}$$

$$\text{Max; } Q_t^{\mathrm{CMPG}} = \big[Q_t^{\mathrm{HBT}_1} + Q_t^{\mathrm{HBT}_2} + Q_t^{\mathrm{CICT}} \big] \tag{31}$$

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 $\left|\frac{(x^i_{n+2}-x^i_n)}{x^i_n}\right|$ 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.

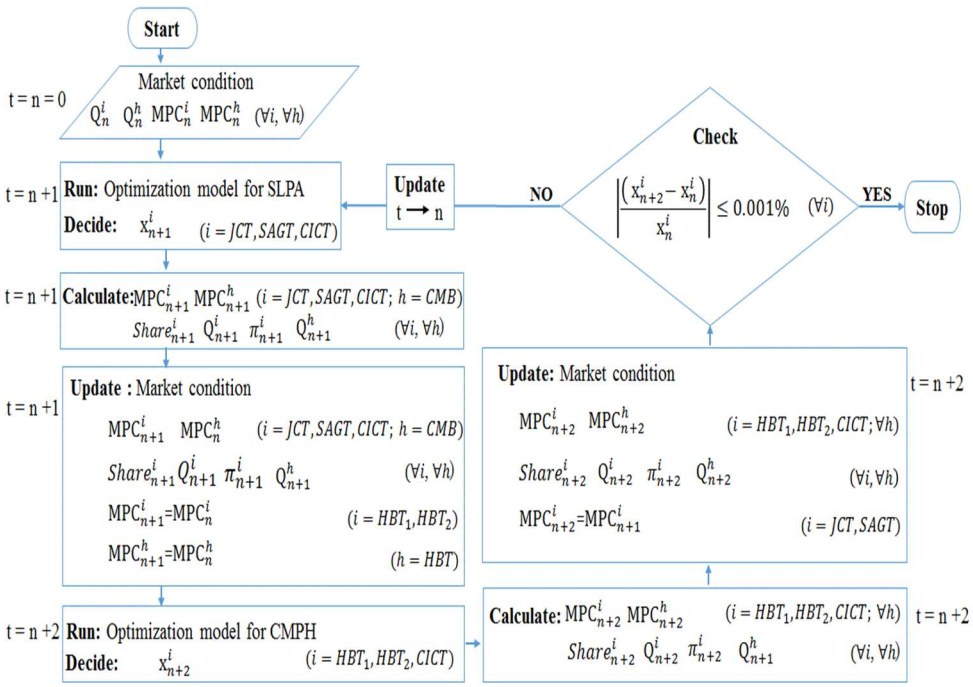

Figure 5: Terminals' Pricing Decisions with Multiple Periods

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]
$\mathbf{no\ of\ berths^i}$	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; $SS_{(Port\ charges)}$,$SS_{(j)}$ 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 rowspan="2">↓</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

Rebates	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	CICT	SAGT	CICT	CICT	CICT	JCT	SAGT
↓	SAGT	JCT	JCT/SAGT	JCT/ SAGT	SAGT	CICT/SAGT	JCT
Least	JCT	CICT			JCT		CICT

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.

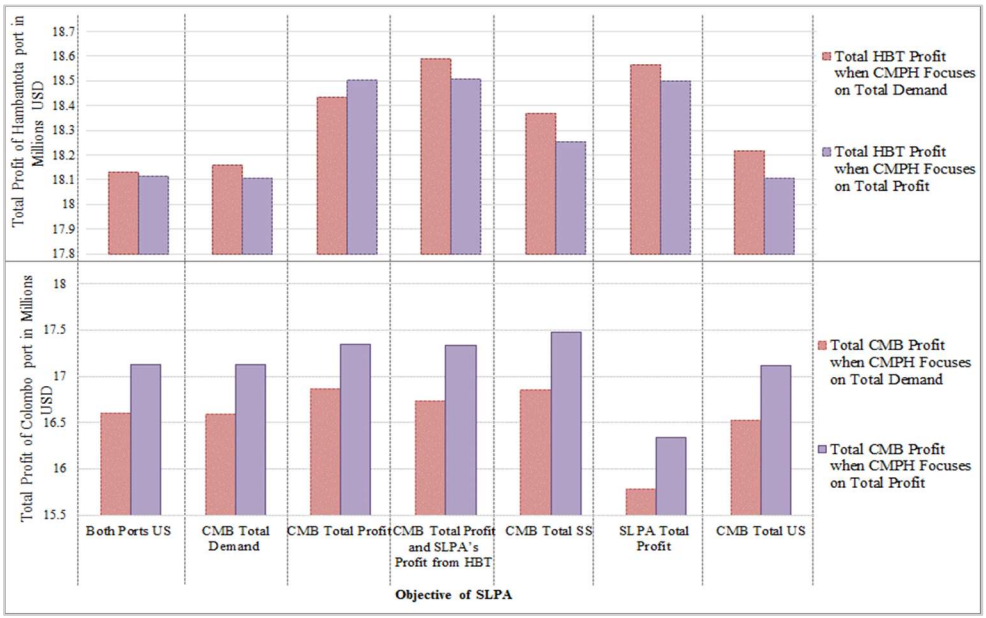

Figure 6: Resulting Profits of Colombo and Hambantota Ports

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.

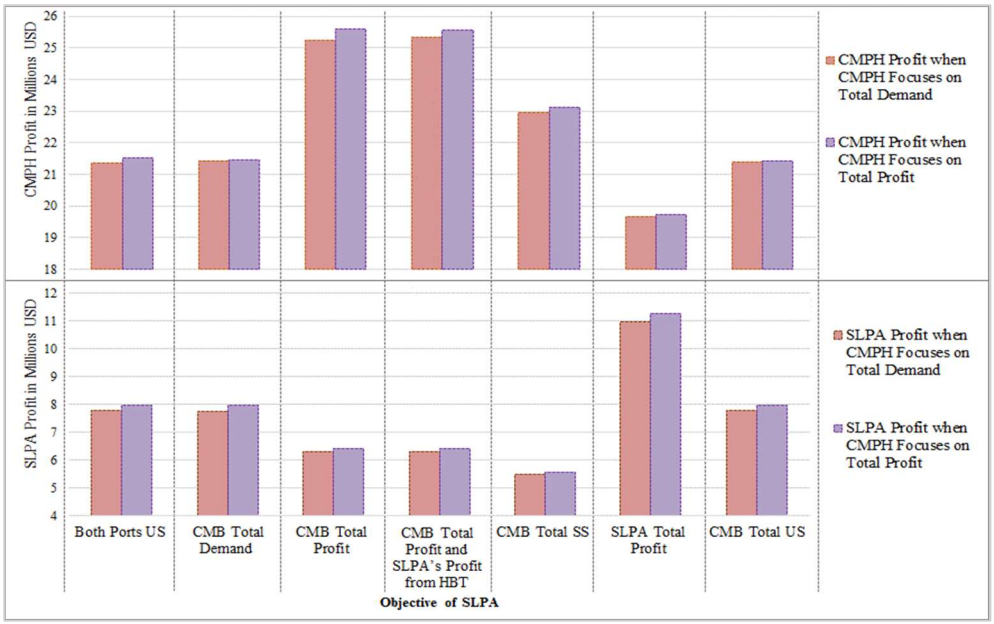

Figure 7: Resulting Profits of SLPA and CMPH

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

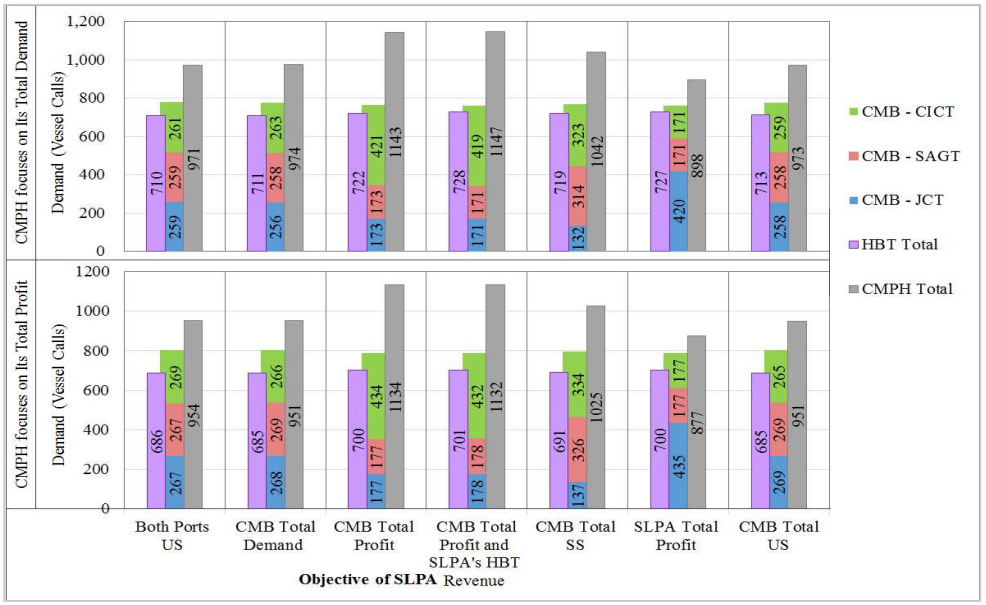

Figure 8: Demands for Ports and Terminals with Pricing Decisions

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
$SS_{(Port\ charges)}$	4.46
$SS_{(Deviation\ cost)}$	4.46
$SS_{(Feeder\ link\ cost)}$	4.69
$SS_{(Deviation\ time)}$	4.69
$SS_{(Vessel\ turnaround\ time)}$	4.77
$SS_{(Waiting\ time)}$	4.46
$SS_{(Feeder\ link\ time)}$	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

Sri Lanka Society of Transport and Logistics

Journal of South Asian Logistics and Transport
Volume 2 Issue 2 September 2022
JSALT 2.2.4: pp. 79-98
DOI: http://doi.org/10.4038/jsalt.v2i2.50

REPORTING BEHAVIOUR OF PEDESTRIAN INVOLVED ACCIDENTS IN SRI LANKA

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ABSTRACT

According to the World Health Organisation, the majority of victims of road traffic accidents are vulnerable road users, including pedestrians. However, under-reporting of such accidents leads to inadequate availability of reliable data in this area of research.

The present study was an attempt to investigate the severity of this problem of under-reporting of accidents involving pedestrians. Primary data were collected for the purpose, and statistical techniques such as univariate and bivariate analyses, Chi-square testing, and Binary Logistic Regression were used to examine the association of several diverse factors including demographic features, severity of injury, lost productivity, and receipt of compensation, with accident reporting behaviour.

The results revealed that the most common accidents, nearly 30% of all, involved motorcycles, while accidents due to slipping on roads or pavements and roadside structures together accounted for 33% of all reported accidents. These, according to this study, appeared to largely go under-reported, precluding further action.

The study found the presence of a strong relationship between reporting behaviour and the nature and severity of injuries sustained in the accidents. The lowest chance of reporting an accident was found in regard to slipping on a pavement while the injuries treated without visiting a hospital had the lowest likelihood of being reported to the Police.

Keywords: *Reporting behaviour, Accident underreporting, Vulnerable users of roads, Pedestrians, Accident severity*

1. INTRODUCTION

According to the Global Status Report on road safety (2018) by the World Health Organisation (WHO) [1], approximately 1.35 million people die every year due to road traffic accidents and nearly 50% of traffic accident-related deaths impact the vulnerable road user group comprising of pedestrians, cyclists and motorcyclists. Further, it also reports that males are more likely to be victims of road traffic crashes than females. As walking is an important activity in maintaining the physical fitness of individuals, as well as to complete the first and the last miles of a trip, more attention of responsible infrastructure development agencies is required to the safety of pedestrians.

A comprehensive study on safety of pedestrians on roads is not possible due to various issues pertaining to records on pedestrian involved accidents. This subject, though was addressed by many research groups in other countries, not many studies could be found in the Sri Lankan context. Therefore, the current research was undertaken to examine the nature of pedestrian involved accidents and accuracy of reporting to police in Sri Lanka and to propose appropriate methods to improve the situation.

As pedestrian crashes have been identified as a serious issue, many researchers have conducted pedestrian crash analyses in detail [2], [3], [4], [5], [6], [7]. There were a number of studies on the characteristics of pedestrian involved accidents. According to a study carried out on multi-level hot zone identification for pedestrian safety in Florida, United States of America (USA) [8], nearly 90% of accidents involving pedestrians had happened within 14 miles of the residence of the victim and approximately 50% of pedestrian involved accidents had occurred within residential zones. One of the major challenges faced in carrying out scientific research related to road traffic accidents is the non-availability of a comprehensive databases. Under-reporting of traffic accidents is a well-known issue in this regard in many countries. In late 1980s, the average level of error in the reporting of minor injury accidents among countries was 50% [9], which increased to 75% by late 1990s [10]. In Australia, the level of error was reported to be 69% [11]. Errors in reporting traffic accidents were found to be caused by lack of motivation, knowledge, and benefit, and due to others' influence too [12].

Furthermore, the severity of an injury has been found to have a direct relationship with under-reporting [13], and under-reporting varied within 93% - 98% for slight injuries, 32.5% - 96% for non-fatal injuries, and 0.5% - 89.5% for fatal injuries in middle income countries. Reluctance to summon the police [14] especially by the pedestrians [15] and younger road users [6] contribute heavily to under-reporting.

Lack of awareness and the fear of being caught by the parents are reasons for the teenagers to keep away from reporting accidents [16]. According to a model developed using a Poisson process for the under-reporting problem in underprivileged areas with low income and minority populations in Illinois, USA, it was found that pedestrian crashes were contributed by the absence of separate paths for walking and vehicular traffic, income disparities, and the presence of children [4]. A study conducted in Denmark revealed that under-reporting level of fatally injured accident data for pedestrian, cyclists, moped, motorcyclist, car, bus and other victims of road crashes in Denmark was 16.42% [12]. According to that study, the pedestrian injury rates were associated with population density, age composition of the local population, their level of unemployment, gender composition and level of education.

According to a study conducted by Mako and Szakonyi, the knowledge and attitude of pedestrians have a direct relationship with accidents [17]. That study further revealed that 44% of pedestrian engaged accidents were mainly due to the fault of the pedestrians and 27% occurred due to the speeding of drivers. In retrospect, the common causes behind errors in accident data reporting were cited as weaknesses in the policing system, distance to the nearest police station, victims not following the "within 30 days" rule to report, their ignorance of the law, limited legal requirements for reporting an accident, intentional non-compliance by road users, reluctance of people to summon the police and file a report, settlement (agreement between the parties), absence of serious injuries, hit and run cases, and political vs. militia conflicts [13]. Though there are a number of studies/ research on pedestrian accidents, there is a need for new knowledge in relation to under-reporting accidents in which only pedestrians are involved such as slipping on roads or on pedestrian walkways as they cause untold hardships to the pedestrians.

In Sri Lanka, the percentage of deaths of vulnerable road users who met with road traffic accidents was as high as 78% in the years 2017, 2018 and 2019. Even though there has not been any systematic study to estimate the severity of accident under-reporting in Sri Lanka, there is evidence to perceive increased incidence of traffic accident under-reporting from the year 2003 onwards. The ratio of fatal accidents to property-damage-only accidents dropped from 20.2 to 5.3 and the ratio of fatal accidents to minor injury accidents dropped from 7.1 to 5.1 during the period from 2003 to 2008. As there was no significant change in the annual increment of fatal accidents and grievous accidents, it could be observed that accident under-reporting has become increasingly common since the year 2003.

There could be numerous reasons for accident under-reporting in Sri Lanka. One such cause behind could be the new insurance schemes introduced by various parties facilitating claims without a police report, even though, according to the law of the

country, all traffic accidents should be reported to police [17]. Lack of knowledge among accident victims is another major reason for accident under-reporting. If an accident does not involve another party, many pedestrians tend not to report such incidents assuming that the fault is with the pedestrians themselves. It is noteworthy that without such vital information, organisations responsible for road maintenance become unable to take corrective measures to minimise future incidence of accidents.

In the light of the above, this study was carried out to investigate the rate of accident under-reporting with respect to pedestrian involved accidents in Sri Lanka, and the significance of associated factors, namely, gender, employment, severity, days lost, and the nature of the accident, on such under-reporting. The study was designed based on primary data collected by students of the Faculty of Engineering, University of Peradeniya, in an island-wide structured questionnaire survey.

In Section 2, the nature of data and the criteria behind filtering data for the study, coding, and the variables are described in detail because comprehensive primary data were collected following a time-consuming process. Further, the statistical techniques used for data analysis, namely, the univariate and bivariate analyses, Pearson's Chi-square test, and Binary Logistic Regression, are also presented in this section. Section 3 elaborates the results obtained from the above statistical methods and highlighting the reasons for under-reporting of pedestrian involved accidents with possible follow-up action in the discussion. The conclusions are summarised in Section 4.

2. METHODOLOGY

2.1. Data Collection

Primary data were collected through a comprehensive survey using the Convenience Sampling Method covering the whole country and gathering information from 1242 respondents, which included four demographic characteristics of the population: age, gender, highest educational qualification, and profession. Questionnaire for the study was developed using the knowledge and information gathered from similar preceding studies [12], [16]. The survey was administered using a google form; however, the respondents were interviewed in person by a large group of students of the Faculty of Engineering at the University of Peradeniya, Sri Lanka who came from all over the country. Of these respondents, only those who had met with at least one accident were filtered out to make a preliminary sample of size 422. As some of the respondents had experienced more than one accident and as separate questionnaires were administered to them, this sample comprised of 804 different accidents to carry out the statistical analyses. In addition to the demographic details, the questionnaire sought elaborative information on the nature of the accident, its seriousness, lost

productivity, compensation received, complaint made as well as whether the accident was reported or not. Accordingly, all those aspects were represented by the variable names of Gender, Age, Profession, Education, Nature, Severity, Loss, Compensation, Complaint and Report.

2.2. Missing Values

Dealing with missing values is an important preliminary step in statistical analysis based on raw data. Some data may not be available, either due to the refusal of a respondent to answer or the irrelevance of a particular question to the person. The percentage of missing values was examined in terms of the number (and the percentage) of variables, cases (respondents), and the values. All ten variables (100%) had some missing values, 106 (13.18%) cases had at least one missing value, and 214 (2.66%) of the values were missing. The questionnaire included the nine independent variables listed in Table 1, which provided all the mean variables having at least 0.01% of missing values arranged according to their descending order. The tenth variable, Report, (dependent and binary) was introduced to identify whether the accident was reported or not for the purpose of statistical analysis.

Table 1: Variable Summary

	Missing		Valid N	Mean	Standard. Deviation
	N	Percent			
Loss	44	5.5%	760		
Age	30	3.7%	774	30.74	12.294
Complaint	29	3.6%	775		
Compensation	26	3.2%	778		
Education	17	2.1%	787		
Profession	13	1.6%	791		
Severity	9	1.1%	795		
Gender	9	1.1%	795		
Nature	8	1.0%	796		

As the overall percentage of missing values (2.66%) was below the cut off mark (5%) adopted for removing the missing values in a statistical analysis, the examination was extended to check whether the missing values were randomly distributed. The distribution of missing values for the ten variables indicated no particular pattern among the missing values of different variables to create any bias in them, which confirmed their random occurrence. Further, it was equally important to understand the most frequent patterns of missing values, for which the percentages of cases

(respondents) against the decreasing order of the ten most frequent patterns were examined. This revealed that over 80% of the cases had no missing values and the missing values on Loss was less than 5%. As the overall percentage of missing values was under 5% and distributed randomly, listwise deletion method [18] could be used to remove them and to make a revised representative sample of 698 cases, used for all analyses of this study. The distribution of *reporting behaviour* in the modified sample is shown in Table 2, which indicates that 80.5% of the respondents had not reported accidents.

Table 2: Distribution of *reporting behaviour* in the modified sample

		Frequency	Percentage	Valid percentage	Cumulative percentage
Valid	No	562	80.5	80.5	80.5
	Yes	136	19.5	19.5	100.0
	Total	698	100.0	100.0	

2.3. Method of Analysis

As the main objective of the study was to describe the accident reporting behaviour, the information on reporting an accident was treated as the dependent variable while all the others were considered as independent variables. A univariate analysis was carried out for the categorical variables of Nature, Severity, and the Complaint itself while bivariate analyses were conducted to study the reporting behaviour with each of Gender, Profession, Age, Educational qualifications, Nature of the accident, Severity of the accident, Loss of productivity, and the Compensation received. Further, the reporting behaviour was considered with the nature of the accident, its severity, and the lost productivity. Also, the same was studied with the nature of the accident and the profession involved.

The Pearson's Chi-square Test was used to identify whether there is any significant association between the dependent variable of reporting behaviour and the categorical independent variables at 5% level of significance using the following hypothesis:

H_0: There is no association between the independent variable considered and the reporting behaviour.

H_1: There is an association between them.

The null hypothesis would be rejected if the p-value was found to be less than 0.05 [19]. Further, the Cramer's V Test was used to identify the level of association as weak [< 0.2], moderate [0.2, 0.3], or strong [> 0.3]. The Pearson's correlation coefficient was used instead of the Chi-square test in assessing the relation between the continuous variable of age and the reporting behaviour.

Although bivariate analysis (Chi-square test and correlation) is useful in identifying the association of independent variables with the accident reporting behaviour, there is a possibility that variables found as insignificant in the bivariate analysis could emerge non-negligible in an advanced complex multivariate analysis. In order to explore this situation statistically, all independent variables were used to fit the binary logistic model.

Binary Logistic Regression (BLR) is a versatile analysis tool of regression that can extract relationship between a categorical dependent variable and a set of independent variables. It is used when the dependent variable is of Bernoulli type, i.e., assuming only two values such as 0 and 1 or success and failure. Also, the BLR can deal with qualitatively different values that cannot be tested by other widely used statistical models like Multiple Linear Regression for binary response data [20].

The simple binary logistic model has the form,

$$\text{logit } P(x) = ln\frac{P(x)}{1-P(x)} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n \quad (1)$$

where $X_1, X_2, \ldots, X_n$ are the explanatory (independent) variables, $P(x)$ is the probability of the outcome of interest (success), and β_0 is the intercept term.

Further, the odds ratio was calculated as follows, to measure the impact of a sub-category of an independent variable on the accident reporting behaviour, relative to that of the reference category of the same variable.

$$\text{Odds, the ratio of probability of success to the probability of failure} = \frac{P(x)}{1-P(x)} \quad (2)$$

where $P(x)$ is the probability of success (reporting an accident).

Accordingly,

$$\text{if Odds1} = \frac{P_1(x)}{1-P_1(x)} \text{ and } \text{Odds2} = \frac{P_2(x)}{1-P_2(x)}, \text{ then,}$$

$$\text{Odds Ratio} = \frac{P_1(x)/1-P_1(x)}{P_2(x)/1-P_2(x)} \quad (3)$$

where Odds1 is the Odds of the sub-category and Odds2 is that of the reference category.

All possible answers to each question posed to the respondents were separated into one reference category while retaining the others as the dummy variables for the analysis in the SPSS package. Accordingly, female (Gender), government (Profession), postgraduate (Education), accident with a vehicle (Nature), full-cost/ adequate amount (Compensation), admitted to hospital (Severity), and one or two days (Loss) were chosen as the reference category of each categorical variable indicated within parenthesis while considering the other responses as its dummy variables.

The final model was decided after a few steps by carrying out the BLR analysis with forward conditional method within the SPSS package and the Hosmer – Lemeshow Test was used to find the goodness of fit of the model with the following hypothesis [19].

H_0: Model is a good fit for data

vs.

H_1: Model is not a good fit for data

The Hosmer- Lemeshow Test produces a Chi–square value and the p–value, which is compared at 5% level of significance to determine the goodness of fit. Further, the Cox & Snell R square and Nagelkerke R Square values generated by the SPSS explain the percentage range of variation in the dependent variable (accident reporting behaviour) explained by the fitted model.

Having considered all the variables at the outset, the final model (regression equation) retained only the most significant variables whose significance was quantified in terms of the p-values associated with each predictor while indicating the Odds Ratio for each sub-category, which was the probability of reporting an accident relative to the reference category.

Finally, hypothesis testing was conducted to check the significance of each predictor in the regression equation. The results obtained through this process are explained in the next section.

3. RESULTS AND DISCUSSION

Univariate analysis was carried out for the categorical variables of Nature, Severity, and Complaint and the continuous variable of age, depicted in Figure 1.

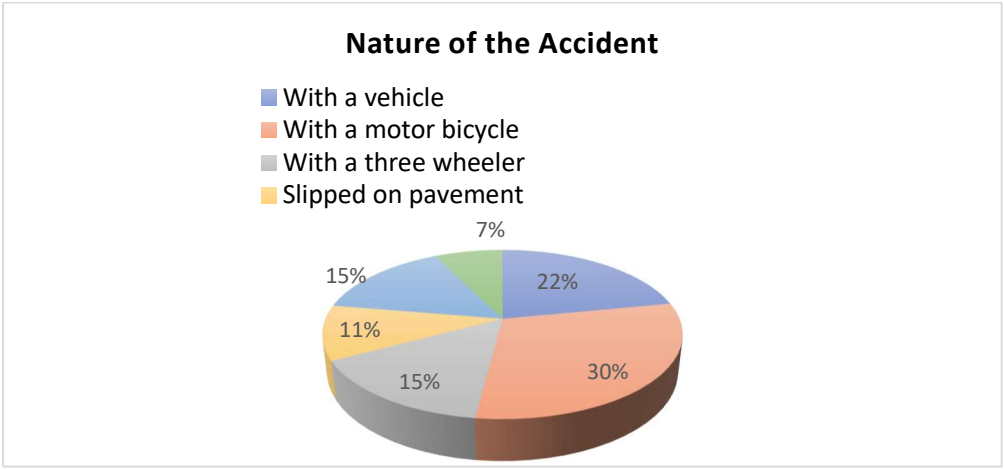

Figure 1(a): Percentage Shares of the Accidents by Nature

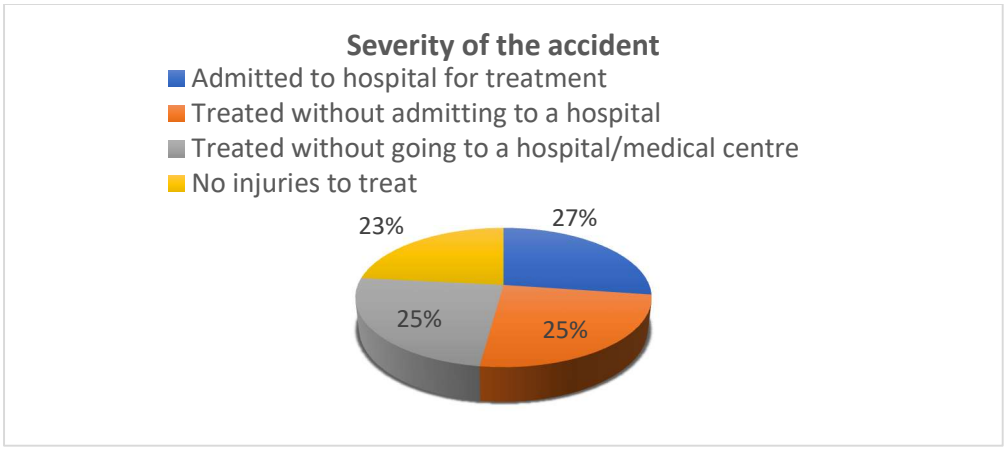

Figure 1(b): Percentage Shares of recorded Accidents by Severity

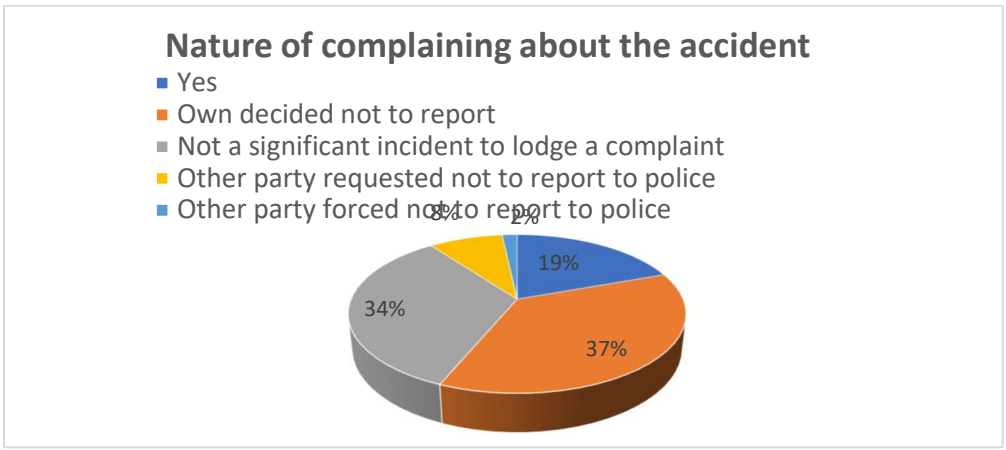

Figure 1(c): Percentage shares of Accidents by the Status of Complaining

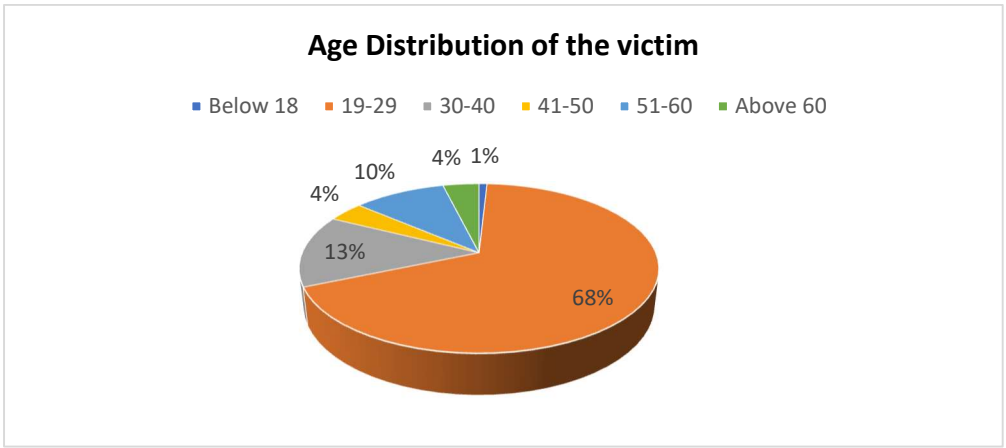

Figure 1(d): Percentage Share of Recorded Accidents by the Age of the Victims

According to Figure 1(a), it could be noticed that the highest percentage of accidents, recorded in the survey, occurred with a motor bicycle while the least was with a roadside structure/tree/pole. Accidents with a three-wheeler and due to slipping on the road occurred in equal ratios. Figure 1(b) shows that 27% of those facing accidents were admitted to a hospital for treatment while 25% were treated without being admitted to a hospital. One quarter of them was treated without visiting a hospital/ medical centre and nearly one quarter had escaped without injuries. In Figure 1(c), it can be seen that the percentage of complaints lodged was below 20% and more than one-third of the cases were underreported due to the respondents' own decision while another one-third decided not to lodge a complaint due to the insignificance of the incident. Figure1(d) makes it clear that most respondents were in the age group of 19-29 years followed by those in the age groups 30-40 and 51-60.

Bivariate analysis was performed on the independent variables of Gender, Profession, Age, Educational qualifications, Nature of the accident, its Severity, Loss of productivity, and Compensation, with the dependent variable of reporting behaviour. This analysis revealed the following major characteristics of the data. The highest percentage of females (39.6%) did not report accidents due to their insignificance followed by a similar percentage (37.10%) voluntarily deciding against reporting. Comparatively, the highest percentage of males (36.7%) stayed away from reporting on their own and 30.3% due to the insignificance of the incident. Higher percentage of females treated the injuries without being admitted to a hospital, but that of males got admitted to a hospital for treatment. In each employment category, the majority of underreporting of accidents were due to own decision and insignificance of the incident. In each complaint group, students were the highest percentage, which may be due to them belonging to the largest category among all respondents. They also accounted for the highest underreported cases.

Half of those in the age group below 18 years did not report accidents due to their insignificance while a majority of those in 30 - 40 year age group did so voluntarily. However, 51 - 60 age group was found more likely to report accidents compared to the other age groups, which could be due to their experience and concerns on the consequences of not reporting. If the accident involved a four-wheeled vehicle, a motor cycle, or a three-wheeler, a large proportion of respondents decided on their own not to lodge a complaint while the accidents due to slipping on the pavement / road or with a roadside structure / tree / pole were underreported due to their lower significance caused without involvement of another person.

Figure 2 depicts the distribution of the reporting behaviour within each category of accident. Accordingly, the largest proportion of reported cases was accidents with a four-wheeled vehicle and the least was slipping on the pavement. The largest share

of respondents had faced accidents with a motor cycle, which were largely underreported.

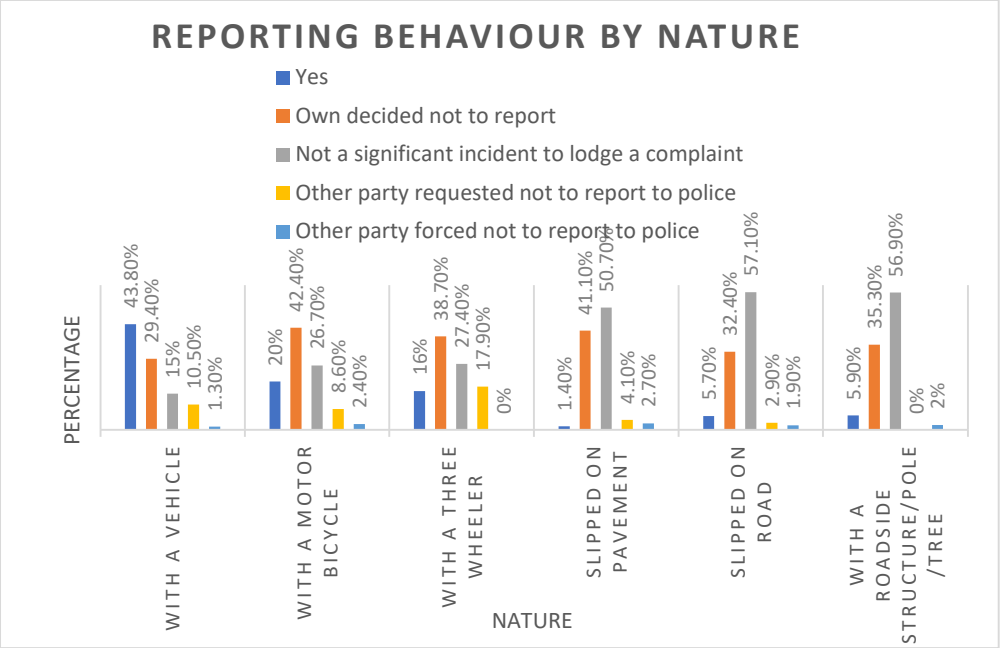

Figure 2: Reporting Behaviour by Nature

Furthermore, the following results could be obtained from the descriptive analysis.

A majority of those who got admitted to a hospital (51.1%) for treatment had lodged a complaint and vice versa, i.e., a majority of those who had reported the accident (71.3%) were admitted to a hospital.

Of the respondents who had lost one or two days due to an accident, a vast majority (80.8%) decided not to lodge a complaint voluntarily or due to insignificant impact of the accident. Moreover, even if the lost productivity was a few months, only 37.1% of them complained about it. These statistics clearly indicate the reluctance of the majority of people to report accidents, which may be due to their lack of confidence in getting any compensation or the hassle to be experienced in the reporting process.

More than half of those who received full cost/ adequate amount as compensation had lodged a complaint. A higher percentage of respondents who had reported the accident had received full/ adequate amount of compensation, whereas a large majority (72.4%) of those underreported voluntarily had not received any compensation.

A vast majority (82.1%) of those admitted to a hospital for treatment had lost two days to two weeks of productivity and a majority (54.8%) of the respondents, who

experienced accidents causing a few months of productivity loss, were admitted to a hospital for treatment. In each accident category, one or two days of productivity loss was more frequent than other durations of loss of productivity, wherein the accidents due to slipping on pavements had the highest percentage (72.6%). The longest productivity loss (a few months) was higher among accidents with a four-wheeled vehicle than those with other vehicle categories considered.

Of all kinds of accidents, the highest percentage was encountered by the students. Among the government employees and retired persons, accidents with a four-wheeled vehicle were higher compared to other categories under the Nature of involvement, whereas among the private sector employees, self–employed persons, and students, accidents with a motor bicycle were higher. The largest representing group of all the respondents (46.8%) were students and they mostly had accidents with a motor cycle. Among all employment groups, retried people were much less likely to meet with accidents compared to government or private sector employees, self–employed persons and students.

3.1. Chi-square Tests for Variables

Having observed the above salient features of data through the bivariate analysis, the next step was to carry out Chi-square tests of independence to test the association between the reporting tendency and each independent variable summarised in Table 3 with the following hypotheses:

Null hypothesis [H_0]: No significant association between the two variables

Alternative hypothesis [H_1]: There is an association between the two variables.

Further, Cramer's V value was also calculated with the Chi-square and p-values to find the strength of the associations.

Table 3: Chi-square Value, p-value and Cramer's V Value between the Reporting Tendency and the Categorical Independent Variables.

	Gender	Profession	Education	Nature	Severity	Loss	Compensation
Chi-square	6.593	3.515	3.334	92.433	166.389	31.132	145.515
P-Value	0.010	0.621	0.649	0.000	0.000	0.000	0.000
Cramer's V	0.097	0.071	0.069	0.364	0.488	0.211	0.457

The Pearson's correlation was calculated between the reporting tendency and the continuous variable, age, which was 0.081 with the p-value of 0.032.

According to the statistics in Table 3, null hypothesis could not be rejected for the variables of profession and education as the p-values for each of them was greater than 0.05 at 5% level of significance. As the other p-values were less than 0.05, it could be concluded that each of the variables, Gender, Nature, Severity, Loss, Compensation and Age was associated with the reporting tendency. Based on the Cramer's V value, it could be further determined that the variables, namely, nature, severity, and compensation had strong pairwise relationships with the reporting behaviour while the variables of gender and age had weak pairwise relationship with the reporting behaviour. The pairwise associations between the lost productivity and the dependent variables of severity and nature were also examined; the results are summarised in Table 4.

Table 4: Chi-square value, p-value, and Cramer's V value between the Loss and the Independent Variables of Severity and Nature

	Severity	**Nature**
Chi-square	197.291	62.417
P Value	0.000	0.000
Cramer's V	0.307	0.173

Applying the same criteria, it could be concluded that both severity and nature were associated with loss of productivity such that the severity showing a strong relationship while nature having a weak relationship with the loss.

3.2. **Binary Logistic Regression to Fit the Model**

Although six factors were found to be associated with the accident reporting behaviour using the Chi-square test and correlation in the bivariate analysis, it was possible that one or more of the other variables could be significant in a complex multivariate analysis. A binary logistic model [21] was fitted to investigate all factors affecting the accident reporting behaviour considering all independent variables. The dummy variables and the reference category in respect of each categorical variable were coded by the SPSS package to carry out the binary logistic regression with the forward conditional method.

Table 5 presents the odd ratios, Exp(B), p-values, and the coefficients in respect of the dummy variables for each predictor retained in the following regression equation:

$$logit\ P(x) = \ln\frac{P(x)}{1-P(x)} = 1.553 - .507 * \text{Nature}(1) - .878 * \text{Nature}(2) - 2.320 * \text{Nature}(3) - 1.265 * \text{Nature}(4) - 1.632 * \text{Nature}(5) - 2.153 * \text{Severity}(1) - 1.849 * \text{Severity}(2) - 1.845 * \text{Severity}(3) - .536 * \text{Compensation}(1) - 1.397 * \text{Compensation}(2) - 2.037 * \text{Compensation}(3) \quad (4)$$

It could be noticed that only the variables Nature, Severity and Compensation have made their presence in the BLR model.

The following hypothesis was used to check the significance of each predictor in the regression equation based on the p-values in Table 5, produced by the SPSS software.

H_0: The variable did not make a significant contribution to the prediction

vs

H_1: The variable made a significant contribution to the prediction.

As the null hypothesis is rejected for the variables with p–values less than 0.05, the nature, severity and compensation could be highlighted as the factors making the most significant contribution to the reporting tendency.

Table 5: Odd ratios, Exp(B), p-values, and Coefficients for Each Predictor in the BLR Equation

Predictor	Label	Coefficient (B)	p-value	Exp(B)
Nature:			.006	
Nature(1)	With a motor bicycle	-.507	.084	.602
Nature(2)	With a three-wheeler	-.878	.018	.415
Nature(3)	Slipped on pavement	-2.320	.029	.098
Nature(4)	Slipped on road	-1.265	.011	.282
Nature(5)	With a roadside structure/pole/tree	-1.632	.013	.196
Severity:			.000	
Severity(1)	Treated without admitting to a hospital	-2.153	.000	.116
Severity(2)	Treated without going to a hospital/medical centre	-1.849	.000	.157
Severity(3)	No injuries to treat	-1.845	.000	.158
Compensation:			.000	
Compensation(1)	Partial cost	-.536	.120	.585
Compensation(2)	Pending	-1.397	.007	.247
Compensation(3)	Not at all	-2.037	.000	.130
Constant		1.553	.000	4.725

According to the statistics presented in Table 5, except for the coefficient for Nature(l), i.e., accidents involving a motor bicycle, all the other coefficients of Nature

(2-5) were significant (p – value < 0.05) and hence they were associated with the tendency of reporting. Odds ratios in respect of accidents involving a motor bicycle, a three-wheeler, slipping on pavement/ road, a roadside structure/pole /tree were less than 1, which means all such accidents were less likely to be reported compared to accidents with a vehicle. More specifically, the odds of reporting accidents with each of the above modes declined by 39.8%, 58.5%, 90.2%, 71.8%, and 80.4% respectively compared to reporting accidents with a vehicle. It could be noted that among all accident types, slipping on pavement was much less likely to be reported compared to the rest.

Looking at the results for severity in the Table 5, it could be noticed that the coefficients for all Severity (1-3) were significant and negative. The odds ratio of the accidents treated without being admitted to a hospital means that they were 0.116 times (or 88.4%) less likely to be reported than those admitted to a hospital for treatment (reference category). Further, the accident-caused injuries treated without visiting a hospital/ medical centre and the accidents without any injuries were equally likely to be reported but their reporting tendencies were 0.157 (84.3%) and 0.158 (84.2%) times respectively lower than reporting accidents that caused admission to the hospital (reference category).

The coefficients for all Compensation (1-3) categories were negative but only (2) and (3) showed a significant association with the reporting behaviour. Compensation (1), which distinguished 'Partial Cost' from 'Full Cost/ Adequate Amount', had an odd ratio of 0.585, which meant that an accident partially compensated was 0.585 (41.5%) times less likely to be reported than an accident that received full cost/ adequate amount of compensation. Moreover, when the compensation was either pending or not eligible, i.e., Compensation (2) or (3), the odds of reporting those were 75.3% and 87% lower with reference to those receiving full cost/ adequate amount.

Since the knowledge of victims about the options available for claiming compensation was not tested, a further study on the knowledge of accident victims on procedures would be needed to clarify the degree of independence of the variable, compensation received.

To assess the goodness of fit of the model, the Hosmer and Lemeshow Test was conducted with the following hypotheses:

H_0: model was a good fit for data

vs.

H_1: model was not a good fit for data.

The resultant test statistics are summarised in Table 6.

Table 6: Hosmer and Lemeshow Test for Goodness of Fit of the Model

Step	Chi-square	p-value
3	13.653	.091

The p-value of 0.091 implies that there is a probability of greater than 0.05 for incorrectly rejecting the null hypothesis when it is actually true. Thus, at 5% level of significance, the H_0 cannot be confidently rejected, which indicates the model's possible good fit for data. However, the resultant low p-value (less than 0.1) is noteworthy, and hence, further research, preferably with more data, may be required to confirm the suggestive evidence pertaining to the goodness of fit of the model yielded from this study.

Analogous to the R^2 (coefficient of determination) in Multiple Linear Regression, the Cox and Snell R Square value and Nagelkerke R Square value in Table 7 confirmed that 29.1% to 46.4% of the accident reporting behaviour was explained by the binary logistic regression model.

Table 7: Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
3	448.477	.291	.464

3.3. Discussion

Pedestrian involved accidents as well as under-reporting of road traffic collisions are two focus areas among research related to road traffic accidents. While reinforcing the findings of such research on the degree of under-reporting and underlying reasons for it, this study focused on the severity of under-reporting accidents involving pedestrians such as slipping on pedestrian walkways (pavements) and roads. The loss of productivity due to different types of traffic accidents is a major setback to the economy of a country unless it is minimised. Authorities could act if there is a proper database of accidents taking place on roads and related infrastructure facilities, since the pedestrians, who account for a significant portion of traffic accidents, play an important role in controlling traffic. The database and the results reported in this article could be used as an initiative for the development of a regularly updated databank as incomplete data cause a serious problem in introducing viable mechanisms to control the number of accidents on roads.

According to the findings of this study, the severity, parties involved, and the nature of the second party influenced the under-reporting. Creating awareness on the rights

and responsibility of pedestrians and bringing the authorities responsible for road safety to limelight would be effective in overcoming this problem. Though 33% of accidents of pedestrians appeared happening due to slipping on road or pavement or due to roadside structures it was shown that the percentages of reporting such accidents were at dismal 1.4% (slipped on pavement), 5.7% (slipped on the road), and 5.9% (with a roadside structure/pole/tree). If there was a proper mechanism for road safety audit on regular basis, some of these issues could have been prevented. As most of the road infrastructure facilities are designed considering the safety and convenience of vehicle occupants, this study has provided compelling evidence to demand basic facilities required for the safety of pedestrians.

The above findings call for more attention paid on providing safe and appropriate facilities for the pedestrians when road reconstruction and rehabilitation projects are planned in the future. Specially, unsafe fixings on pedestrian paths and improper materials used on foot walks should be avoided as a considerable number of unreported accidents are related to such obstacles.

In order to make a comparison with studies relevant to the present research, the following findings could be traced from limited information in the literature [13]. In low-income countries, the under-reporting of fatal and non-fatal accidents varied within the ranges of 0% - 61% and 69% - 80% respectively while that in middle-income countries for slight, severe, non-fatal, and fatally injured accidents was reported to lie within 93% - 98%, 32.5% - 96%, 34% - 99%, and 0.5% - 89.5% respectively.

A limitation of this study would be that accident reporting percentages by pedestrians may vary depending on the nature of the locality; that is, whether they are metropolitan, suburban, and rural areas. In particular, reporting pattern may change closer to urban areas considering the variation in pedestrian categories. This may be an aspect that could be explored through further research.

4. CONCLUSIONS

The present study was conducted to find out the issues pertaining to the reporting behaviour of road accidents occurred in Sri Lanka based on a primary data collection covering the entire island. The data were collected during the period from January to July, 2020 through a detailed questionnaire administered to 1242 respondents. After considering the multiple accidents experienced by the same respondent as separate cases and removing the missing values, a sample of 698 cases was carried forward to the study by means of univariate and bivariate analyses; Chi-square testing for the association of eight independent variables with the reporting behaviour, and fitting a

Binary Logistic Regression Model to identify the most significant factors affecting the reporting tendency.

Findings of the analysis revealed that 34% of respondents experienced at least one accident and the most significant group causing pedestrian accidents was motor bicycles. This inference aligns with the revelations reflected from accident records maintained by the Police. Therefore, it could be recommended that strict regulations should be introduced to control reckless motor cyclists and to safeguard pedestrians.

The considerably high incidence of accident under-reporting, revealed through this research, is also a major concern. In order to address this issue, hospitals and all other injury treatment organisations could be directed to collect relevant data and to share those with relevant regulatory bodies, including the Police, so that the reliability of data available could be improved and made available for making appropriate policy decisions as well as conducting further research on the subject.

When the severity of accidents is considered, accidents causing injuries and requiring treatment without visiting a hospital/ medical centre, and those that did not inflict any injuries, had approximately the same effect on the reporting tendency. Further, the accidents with compensation pending or ineligible for compensation were nearly twice as unlikely to be reported compared to partially compensated accidents.

Though not investigated in the present research, it may be worth if relevant authorities could closely monitor and scrutinise the procedures involved in the payment of compensation through motor insurance in respect of third-party involvement of accidents. This is because the majority of victims appeared to be not receiving any compensation, possibly owing to complex procedures involved in claiming third-party insurance. Victims are either unaware of the procedures involved, or reluctant to apply because of the perception that the procedures are not properly implemented. Introducing less complicated and transparent procedures and creating public awareness in that regard might help victims of accidents in claiming their compensation from third-party insurance policies.

It could also be recommended that the relevant authorities pay attention to the regulations pertaining to maintenance of accident-free and safe facilities. The legislations should be strong enough to bring those authorities neglecting the safety of road users before courts of law, which will be conducive towards improving the safety of all road user categories.

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STRATEGIC PERSPECTIVE

Sri Lanka Society of Transport and Logistics

Journal of South Asian Logistics and Transport
Volume 2 Issue 2 September 2022
JSALT 2.2.SP: pp. 99-120
DOI: http://doi.org/10.4038/jsalt.v2i2.51

GUIDELINES FOR IMPROVING TRANSPORT POLICY EFFECTIVENESS IN DEVELOPING COUNTRIES: A CASE STUDY OF SRI LANKA

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ABSTRACT

Efficient and effective policies pertaining to transportation is an important pre-requisite for satisfactory provision of mobility of people and goods; an essential attribute of an economy to ensure productivity, societal welfare and environmental sustainability. Explicit transport policies formulated in Sri Lanka for that purpose have been mainly ignored by the relevant authorities, even though approved by the government. Implicit policies represented by approvals for investments and recurrent expenditures have continued without critical analysis, in most cases becoming ineffective and obsolete. The blunting of these policy instruments has resulted in the transport sector operating for decades without an effective policy-based direction. The failure of the bureaucracy that is responsible for policy implementation has also been identified as a primary reason for this situation.

This paper provides guidelines based on established global best practices in policy formulation, implementation, monitoring, and review to improve the content of a transport policy and its potential for application towards meeting the country's mobility needs, as opposed to continuing the status quo in transport supply.

The paper also uses examples from the current practice of transport policy in Sri Lanka, typical of many developing countries, and identifying pre-requisites and laying down guidelines for efficient policy making as well as for improving processes and practices to be improved.

Keywords: *Transport Policy, Sri Lanka, Mobility needs, Policy formulation, Implementation, Policy Review, and Monitoring*

1. INTRODUCTION

A policy is generally defined as "*a course or principle of action adopted or proposed by an organisation or individual*"'. Policies can be implicit: not written down, but adopted as practices over time. In most instances, allocating funds for State programs will imply the continuity of an implicit policy. Policies can also be explicit with enforceable legal provisions. Public policy can, therefore, be defined as laws, regulatory measures, courses of action, and funding priorities promulgated by a government or its representative agencies. All countries have a mix of these instruments for policy intervention in different areas of governance. Policy interventions, therefore, have become required only if there is a need for a change, a revision, or at least an improvement.

In the transport sector, these interventions would generally constitute legal access for investment and operation of transport services, their safety and security, fees, and fares and to cover matters of competition and regulation in the provision of these services. By nature of scope and impact, public policy is always complex as it is dynamic, evolving and subject to cognitive bias and reactivity. They are, therefore, complex systems and found, by Mueller [1], to be vulnerable to five pathologies (a) non-linear, (b) dynamic, (c) evolves and coevolved with other domains, (d) subject to cognitive bias, and (e) reactivity, also known as the *Lucas Critique* [2].

This paper focuses on land transportation, and discusses implicit and explicit transport policies, their implementation successes and failures, and it provides guidelines based on established global best practices in policy formulation, implementation, monitoring, and review to improve the content of a transport policy and its potential for application towards meeting the country's mobility needs, as opposed to continuing the status quo in transport supply.

2. LAND TRANSPORT POLICY IN SRI LANKA

Sri Lanka, as a middle-income developing country, has many mobility needs which have remained unfulfilled over decades. There have been several attempts at policy intervention in land transport using both explicit and implicit instruments. These have been introduced with changing political ideologies.

2.1. Explicit and Implicit Transport Policies

Transport policies adopted both explicitly and implicitly are briefly summarised in Table 1. It should, however, be noted that within the periods indicated, different governments have followed somewhat different policies, with some policies introduced and then withdrawn by subsequent governments. It is, therefore, an

assessment of the prevailing condition during the period and not a detailed narrative of all interventions.

Table 1: Political Ideologies and Associated Explicit and Implicit Transport Policy Interventions in Sri Lanka

Period	Prevailing Political Ideology	Explicit Instruments Introduced	Implicit Instruments Introduced
Up to 1948: Pre Independence	Colonial Rule: Transport positioned for economic advantage and administrative needs	Infrastructure: State-provided, self-regulated (Railway Ordinance, Thoroughfares Ordinance) Services: Bus transport, private regulated; Trucking unregulated; Hiring vehicles, regulated.	No subsidies are offered for any passenger services. Encouraged goods transport by rail
1948-1977: Post Independence	Welfare Oriented: Transport for improved mobility and a better quality of life	Nationalisation of Bus Industry; heavy taxes and restrictions on the import of private vehicles,	Targeted subsidies for government employees, students, and remote communities; Low fares and acceptance of general subsidies; political intervention in management, high taxes for petrol, less for diesel
1978- to date: Open Economy	Mixed: Neo-Liberal/Welfare	Opened bus service provision to small-scale private operators followed by increased regulation [3], deregulation of hiring vehicles; devolution of transport regulation and provincial roads administration to provincial councils; attempted Peoplisation of state bus services and re-nationalisation [4].	Transport services expected to make a profit; political interventions in management increase; general operating subsidies discouraged; private vehicle taxes reduced; motorisation encouraged together with intensive road building; neglect of investment for public transport.

(i) Explicit Transport Policies

Explicit policy statements for transport in Sri Lanka available for review are the following:

- Draft National Land Transport Policy, 2020 (unpublished, the version made available for comment)
- Sustainable Sri Lanka Vision 2030 & Strategic Path, 2018 [5].
- National Policy on Transport in Sri Lanka, 2009 -which is the current policy in force [6].
- Transport Policy, Sri Lanka, 1992 (replaced by the 2009 policy) [7].

A fresh initiative to formulate a national land transport policy in 2020 has seen two drafts, but no adoption.

(ii) Implicit Transport Policies

Different administrative processes have led to the approval of numerous implicit policies that have come into operation. Table 2 shows a selection of existing Implicit Policies on Transport being practised in Sri Lanka, with reasons for introduction, how they have been kept current, and how long they have been operational.

Table 2: Analysis of Implicit Transport Policies in Sri Lanka

Implicit Policy	Description of Service, Benefits, and any Issues	Established Justification or Review
Subsidised Student Travel through the issuance of a monthly season ticket	Introduced in the 1950s, offered to all students. The poorest mostly walk to school; being only usable on the state-operated buses makes their use limited and unreliable for school attendance.	No known review. It is continued through annual Treasury allocation.
State employees are provided significant subsidies on home-to-work travel through a monthly season ticket.	Introduced in the 1950s, offered to all government employees as a perk. Results in longer travel distances and significant uptake of rail capacity during peak periods and denying rail as an option for other passengers.	No known review. It is continued through annual Treasury allocation to Sri Lanka Railways to absorb this loss.
Subsidy offered to state buses operating on rural routes	Introduced in the late 1980s, based to offset routes with low revenue per km. There is, however, no quality criterion; typically, all unremunerative routes receive this subsidy acting as a general subsidy.	No known review. A performance-based program, ‘Gami Saeriya', was introduced in 2005, but was abandoned by the state bus operator due to reluctance to achieve stipulated standards.

Implicit Policy	Description of Service, Benefits, and any Issues	Established Justification or Review
Private Buses are not subsidised:	This is a policy practised since the latter 1970s and means that private operators serve only routes and trips that are profitable.	The policy changed in 2005 to negative concessions for school, rural, and night-time services.
Cabinet of Ministers approves Railway and Bus Fares.	Since the 1960s, fares have been used as political tools and kept lower than costs, disabling organisational growth, modernisation, and quality improvements in public transport.	Deregulation of the bus sector ended this in 1978. It was further revised by a Fares Formula and Policy in 2001. However, it continues unchanged for the railways leading to heavy financial loss
Petrol and diesel have different tax rates.	From the 1960s, diesel was sold at a concession to trucks and buses which used diesel at that time. Petrol, used by private vehicles, was taxed as a luxury item.	This gap has gradually closed nearly three decades after the entry of private diesel vehicles.
Cars and four-wheeled passenger vehicles are heavily taxed	After the liberalisation of vehicle imports in 1978, this tax curbed rapid motorisation but has been ineffective since vehicles are now seen as an investment. However, this has led to 65% of the fleet comprising 2 and 3-wheelers.	Vehicle taxes are seen only as a source of revenue and not reviewed as a measure of managing transport efficiency or fuel imports.
Duty-Free or Duty-Concession vehicle permits	Initially offered as a reward to state officers who chose to work in Sri Lanka instead of overseas in the 1970s. Progressively expanded by successive governments to cover most professionals, administrators, politicians, dignitaries, etc.	No known review. The foregone annual cost to the Treasury in 2019 has been estimated at LKR 94 billion [8]

Once set in motion to fulfil a policy objective of a government, these implicit policies remain in effect for decades without rigorous analysis by any branch of government. These unsustainable policies have significantly contributed to the overall deterioration in the quality of public transport and led to rapid motorisation, a high energy import bill, and road safety issues. There is no process yet to review any of these implicit policies or improve them.

2.2. Transport Policy Performance

Sri Lanka's most recent explicit land transport policy paper is from 2009 [6]. An analysis of its performance relative to the one hundred most significant policy

recommendations made therein and their degree of implementation, rated as [X] – No progress, [L] – Low Progress, [M] -Moderate Progress, and [F] – Fulfilled, over the last 13 years, is presented in the Annexure.

2.3. Transport Policy Failure in Sri Lanka

A policy may be deemed a failure, even if it is successful in some minimal respects, if it does not fundamentally achieve the goals that proponents set out to achieve. Opposition is excellent, and/or support is virtually non-existent [9].

However, in the case of the Transport Policy in Sri Lanka, only 3% of recommendations have been fulfilled [F]. Most of these are also initiatives that were already ongoing in 2009. The partially fulfilled [M] and [L] add up to a further 11%, making 86% indicating no progress [X]. Therefore, we can conclude that explicit transport policy implementation has been abysmal, indicating that Sri Lanka does not have an environment of policy-based interventions in its transport sector.

(a) Consistency of Explicit Policies

The most recent national transport policy draft, which includes a review of the different explicit transport policies, covered 33 major policy features. They were found to be well aligned with each other; covering 70-80% of these features in any one document, even though there were three new governments since 2009. Thus, the failure of the 2009 policy has been in its implementation and not in change of policy.

(b) Inconsistency of Implicit Policies

However, each of these elections saw different transport interventions proposed through election manifestos and subsequent cabinet approvals by the new government. None of these indicated any consultation with existing Transport Policy and was, in all cases, primarily proposals for projects and programs without an overall strategic plan or as a policy intervention. They mostly appear to be a long list of ad-hoc projects and programs seen as attractive for different stakeholders.

(c) Policy Blunders

An interesting parallel study would be to analyse the performance of such projects and programs introduced through a political process. Such implicit policies represented by these projects and programs at first sight also have not gone on to completion due to (a) deficiencies in technical, economic and financial feasibility or, in other words, design failure and (b) frequent changes in policy drivers such as ministers and secretaries of ministries.

As such, not only has there been a case of not pursuing explicit policy but also a parallel error of pursuing politically oriented policies on an ad-hoc basis.

King and Ivor [10] defined a policy blunder, as being different to a simple policy mistake, as "a case of a government initiative to achieve one or more stated objectives. According to Flyvbjerg [11], such measures fail to achieve those objectives, may waste substantial amounts of public money, and cause widespread human distress, which was eventually abandoned or reversed, and was foreseeable." The primary causes of such policy failures have been identified by him as:

- Corruption
- Incompetence
- Excess optimism
- Political incentives
- Nationalism

This forms the need for further research to determine policy consistency in political manifestos and what validity a previous explicit policy holds in such a scenario. The 2009 land transport policy appears to have been abandoned soon after the incumbent minister was changed in 2010. Though the same government came back into power, it has gone off on new projects and programs instead of aligning the new election manifesto to the transport policy developed the year before.

Hudson [12] noted that policy success is due not just to the policies per se but the entire process from policy formulation to policy implementation, monitoring, and review. Therefore, the present paper sets out a process and framework, as listed below, for future transport policy practice aimed at improved adherence of investments and interventions to an explicit transport policy in Sri Lanka and other developing countries facing similar structural problems.

- Policy Formulation (Design)
- Policy Implementation
- Policy Monitoring or Tracking
- Policy Review

3. GUIDELINES FOR POLICY FORMULATION

Reviewing policy failure in the transport sector leads to the following guidelines for improving policy formulation.

3.1. A policy should be outcome-based instead of only output-based

Most transport policies, both explicit and implicit focus on tangible transport infrastructure and service outputs as objectives. While the public may have an appetite for such output (which lends them greater political appeal) these are inappropriate policy objectives for sector development. The best policy objectives should be fulfilling user needs over the long term. In the case of a transport policy,

these needs are invariably mobility needs. Mobility is what is demanded. This is what the public requires in the form of personal mobility and mobility for goods. A successful transport policy should essentially become a successful "mobility policy". Too often, transport policies focus on the supply side interventions without duly focusing on the demand side requirements that should be the objective. Mobility-based objectives would typically constitute:

- Solving urban traffic congestion and reducing lost hours
- Reducing road traffic fatalities and injuries
- Improving the options for using public transport by improving quality
- Improving access to rural communities
- Making transfers work seamlessly between different transport modes and operators
- Improving the efficiency of domestic freight transport through improved logistics networks and hubs
- Enabling roads to be used safely for walking and cycling and reducing non-motorised accidents
- Enabling the use of a single portal, mobile applications for transport service procurement and information

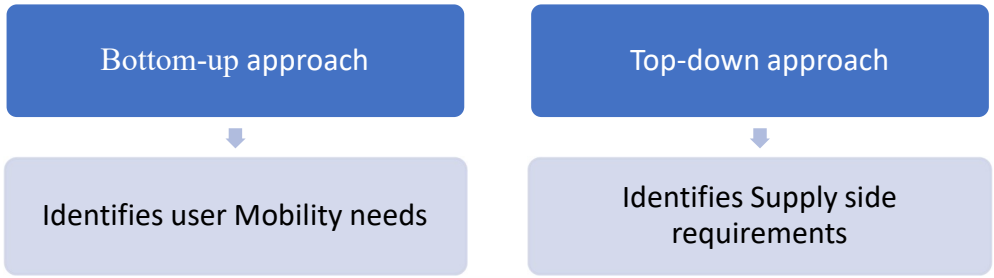
Policy interventions should improve the transport supply infrastructure and services to impact mobility outcomes positively. A transport policy must begin with a well-formulated *mobility policy* as a first step. A transport policy that only has projects delivering outputs and does not consider the user mobility requirements will invariably fail to satisfy the users.

3.2. A policy should be Bottom-Up and Top-Down

When policies are formed by those responsible for the transport supply, it generally becomes top-down, as it is developed by officials whose approach is to improve the infrastructure and services that provide for the mobility needs. Such policy formulation generally does lip service to any bottom-up user need inputs by allowing public comment for a period, a process most often seen as a legal or political obligation rather than a valued input to policy formulation. This is signified by scheduling such public inputs at the end of a policy formulation process rather than at the beginning. Most officials believe that the public is ill-informed; thus, the professionals and experts are the most capable of formulating solutions to problems

the public encounters. This concept, that 'the generals know best', is ill-suited for transport policy formulation, as officials and administrators may have little first-hand knowledge or experience as users of all the different forms of transport.

However, Araral et al. [13] observed that bureaucrats can greatly influence policy-making and are best placed to participate formally and informally in the policy-making process. They can even be the sole actor or leaders in the policy-making process and, therefore, pivotal in shaping the discourse of public policies. Different government styles and traditions allow different levels of influence from bureaucrats in policy making.



Bottom-up policy knowledge would be formed by reading newspaper articles on transport deficiencies and being familiar with the results of user surveys, research, and attending public seminars on transport.

Thus, policy formulation should be an integrated process that includes both the user needs perspective and the provider perspective. The consulted users should include individuals using different modes for different mobility requirements across the country. It should also include the corporate sector, which requires the mobility of personnel and goods. Researchers of mobility needs and civil-based organisations can provide good user perspectives. Transport suppliers, unions, regulators, and administrators are among those who can provide supply-side perspectives. In a country like Sri Lanka, the user representation is undeveloped and thus poorly represented. By default, the supply side perspective dominates policy formulation, often missing real mobility goals.

3.3. A policy should be strategic and not tactical

Policies should not focus on immediate problems that can be solved using existing provisions but on strategic changes required to address issues that cannot be solved in this manner. Too often, transport policy recommendations only include actions that can be implemented within the existing institutional, investment, and legal provisions. The following table captures the strategic and tactical interventions required to provide for the mobility requirements in Sri Lanka listed earlier.

Table 3: Strategic and Tactical approaches to Solving Mobility Issues

Mobility Requirement	Tactical Measures	Strategic Interventions
Solving urban traffic congestion and lost hours	• Improve Quality of Public Transport • Improve Traffic Management	• Introduce Road Pricing • Introduce Car Restraint Measures in City Centers
Reducing road traffic fatalities and injuries	• Purchase high-tech equipment for Police • Provide a new curriculum for driver training/ testing	• Legislate usage of camera detected violations as court-admissible evidence to enforce traffic laws
Improving the options for public transport use by improving quality	• Improve the routing and schedules for buses • Commence Park & Ride	• Regulate quality standards and enforceability • Reform bus sector supply
Improving access to rural communities	• Ensure a minimum level of motorability on rural roads	• Allow civil-based organisations to maintain rural roads
Making transfers seamlessly between different transport modes and operators	• Provide schedule information of different transport modes to a single IT portal	• Legal provision for integrated ticketing and for sharing revenue between operators
Improving the efficiency of domestic freight transport through improved logistics networks and hubs	• Railway to enter into multimodal freight agreements with freight forwarders allowing warehouse facilities	• Legal provision for open access for freight transport by railway • Set up a rail freight regulator
Enabling roads to be used safely for walking and cycling	• Implement a cycle path network in every city	• Open bids for private investment for a micro-mobility cycle project

The Table 3 above separates under tactical, what can be achieved without new policy or policy interventions and could be carried out by redirecting available capital funds or as self-financed projects. These are tactical interventions where existing resources, institutions, procedures and opportunities can be used differently to meet needs and challenges. On the other hand, strategic interventions will be more policy-driven since they require changes to existing investments, organisational structures, or legal provisions, as illustrated above.

Most policy recommendations in Sri Lanka are found to be primarily tactical and technically should not have been included. They may instead be dealt with in strategic and annual plans.

3.4. A policy should identify existing measures that should continue and those that should be renewed or replaced

Table 4 summarises new policy requirements to address policy gaps, identified after a policy analysis, taking Sri Lanka's current context into account.

Table 4: Transport Policies to Continue Vs Policies for Change – Sri Lanka

Mobility Requirement	Policies to Retain	Policy Change
Solving urban traffic congestion and lost hours	• Continue subsidy for suburban rail transport • Continue subsidy for school transport services	• Legislation for Road Pricing • Legislation for Car Restraint Measures in City Centers
Reducing road traffic fatalities and injuries	• Motor Traffic Act	• Legislation for Road Safety Audits
Improving the options for using public transport by improving quality	• National Transport Commission Act • SLTB Act	• Setup Bus Modernisation and Reform Project
Improving access to rural communities	• Rural Roads Act	• Cabinet decision to allow civil-based organisations to maintain rural roads and allocate required finances
Making transfers seamlessly between different transport modes and operators	• Central Bank Regulations on the issue of prepaid travel cards	• Amend NTC Act to regulate integrated ticketing and sharing of revenue
Improving the efficiency of domestic freight transport through improved logistics networks and hubs	• Railway Ordinance for passenger transport	• Railway Ordinance to be replaced by Railway Regulatory Act to provide for open access for freight transport on the rail and to set up a regulator
Enabling roads to be used safely for walking and cycling	• Road Development Authority Act • Motor Traffic Act	• Central government cabinet decision on priority for non-motorised transport • Local Government Ordinance to allow user privileges on bicycle lanes

The above table shows the adequacy of existing policy instruments while identifying gaps that must be filled by revising existing policies or introducing new ones. A new transport policy is only required if existing measures are inadequate to meet current and future mobility needs or service provisions.

Policy renewals may be triggered by changing user requirements, changing economic conditions, new technologies, changing social or environmental conditions, new political ideology, or governing policy. Such revisions should also include implicit policies instituted through cabinet approvals, budget allocations, and other forms of good administrative decisions.

4. GUIDELINES FOR POLICY IMPLEMENTATION

Policy implementation is intended to achieve a set of desired outputs, goals, and outcomes. Ministries, regulatory agencies, and planning agencies are often in a position to influence sector policy-making and set the policy direction for a country.

A sector policy can be in the hands of a powerful ministry such as in charge of finance or planning or be placed under a President or Prime Minister who may have greater control over policy formulation. Such offices may have tremendous success in policy formulation, mainly if it is top-down. But they may fail in policy implementation, which the line ministries must essentially perform with bottom-up inputs.

While policy formulation is ultimately in the hands of elected political leaders, its implementation is in the hands of the bureaucracy, also called public administration. The bureaucracy is, however, a legitimate actor of the state overseeing policy implementation.

Therefore, understanding a policy is critical in undertaking responsibility for its implementation. Mueller [2] notes that poor policy performance could be set straight with more effort, resources, and goodwill. The following recommendations are made for improvement in Policy Implementation in Sri Lanka.

4.1. Commitment to policy-led decision-making

Policy, be it at a corporate or government level, is meaningful only if those that formulate policy commit to being guided by it. It is a form of self-regulation. However, if there is no such discipline, the policy becomes a document consulted only to justify actions aligned to it and conveniently ignored at other times. It is clear from the 2009 Land Transport Policy analysis that, in Sri Lanka there has been an overall disengagement between transport sector administration, planning, and investment with the stated policy.

This is not confined to the transport sector and represents a general departure from policy-led governance. Formulating policy for implementation in an environment where the establishment has no commitment or even a legal obligation to be policy-led is futile. Therefore, an explicit transport policy can only be implemented in an environment that has commitment or accountability for its implementation.

Such a framework for successful policy implementation should essentially include the following features:

- Legal accountability for subscription to policy:
  A citizen should be able to seek legal intervention in any public project or program that is inconsistent with public policy.
- Administrative Processes that safeguard subscription to policy.:
  There is a process that approves investments, projects, and programs and includes checks for policy subscription in all the steps from planning to implementation.

4.2. Competency of the Bureaucracy

The primary function of the bureaucracy or the public administration is to implement public policies, programs, and projects in order of priority. However, unlike projects and programs, which are less complex and often tangible, policies tend to be broad and vague, thus open to bureaucratic interpretation. Bureaucracy is generally not pre-disposed to take ownership of complex problems that may be fraught with challenges.

According to Araral et al. [13], different bureaucracies interpret policies to fit their views and simplify them to fit practicality during the implementation stage. The bureaucracy also adjusts rules and instructions that embody a policy to suit local contexts. Thus, a policy's original intent, as set by policymakers, is often altered due to the bureaucrats' interpretation of the policy [14].

Moreover, as policies are being further defined and designed during the implementation stage, bureaucracy can devise standard operating procedures or process-oriented policies. These can also affect the policy objectives as more attention may be given to the success of outputs as opposed to their outcomes.

Albrow [15] notes that bureaucracy needs to have a strong capacity and competence to be effective in policy implementation. Still, at the same time, it needs to be balanced in responsiveness to the public and higher authorities. This requires intense training, especially for senior bureaucrats, who should be charged with policy compliance and be held accountable through administrative procedures and legal obligations.

While a commitment to policy-led governance will significantly assist in developing the required competencies within its bureaucracy, the absence of commitment will be a significant demotivator.

4.3. Creative Models for Policy Reform

One of the key features of policy implementation is the revision of transport supply business models from time to time. Changes in political ideology, technology,

economic status, and social expectations require the transport supply to be revised from time to time to meet these changing expectations.

Many developing countries have State sector domination in transport infrastructure and service delivery. Trade unions often aggressively protect the status-quo and tend to be bureaucratic and inefficient. On the other hand, de-regulated transport services can also make them inaccessible for low-income users or compromise service quality and standards. Developing countries are likely to have a conventional transport supply, that has come down the years, as opposed to policy-driven models based on efficiency and equitability of delivery. Moreover, the state and the private sector provide mobility requirements in many shades of a dualistic supply environment. Their respective features could be compared as summarised in Table 5.

Table 5: Models of Ownership & Regulation in Transport Service Delivery

Service Feature	State-Sector Monopoly	Regulated Private Sector	De regulated
Motivation for Service Delivery	Service and Employ Centred	Service Centred	Profit Centred
Response to Capacity Enhancement	Very Slow	Slow	Fast
Quality Improvement	Self-enforced	Enforced by regulation	High with quality competition. Low otherwise
Efficiency in Resource Use	Poor	Constrained	High
Willingness to Take Risk and Innovate	Low	Modulated	High
Delivery of Public Service Obligations	High	Incentivised	Low
Basis of Costing Services	Affordable	Regulated	Market-Based
User Rights	Low	Moderate to High	Low to Moderate

There are, however, several constraints that prevent the entry of private investment in transport infrastructure and services. These can be identified as;

- High sunk costs and long pay-back periods involved in transport infrastructure increase the risk and uncertainty for private investors

- Lack of transparency in the process of investing may discourage reputed investors.
- The State may be reluctant to lose its political control over the vital infrastructure.
- Could pose issues for national security
- Service quality is not easily measurable, and quality regulation is complicated.

It is generally more successful when

- The product or production process is well established and observable
- Adequate competition can be ensured, and collusion avoided.
- The government bureaucracy is competent, and transparent government processes are available.

Table 6: Existing and Potential Transport Delivery Models for Sri Lanka

Transport Supply	Current Model	Models to be considered		
		Arrange Service	Supplier	Payment
Passenger Railway	State-owned Monopoly	State	State	User + State on PSO + cross-subsidise passenger with freight
Freight Railway	State-Owned Monopoly	Franchised by State	Private or JV	User
Bus Transport	Dual Unequal Supply	Contracted by State	Consolidated Private and State	User + PSO on delivery
Para Transit	Deregulated	Quality Regulation	Private	User
Road Freight	Deregulated	Consolidate Supply	Private	User

Table 6 above shows existing ownership and regulation models for the different transport sub-sectors in Sri Lanka and the means of reforming them. Policy Implementation requires creative business models to be developed through studying global best practices, insight into the local industry, and discussion with the key stakeholders. Reform models, therefore, become the tools that should be carefully developed by the respective bureaucrats using the respective technical expertise instead of relying on administrative experience alone.

5. POLICY MONITORING & REVIEW

There should be monitoring of policy adherence in all stages of public administration. This is a top-down function in a policy-led government, where there should be an office of policy monitoring under the Executive or the Legislature. Apex ministries such as those in charge of the subjects of finance, investment, and planning should be made accountable to enforce policy adherence by all line ministries at different stages of policy intervention. However, it could be the bureaucracy itself that may be the biggest stumbling block to policy adherence. Hall [16] observes that bureaucrats often prefer fine-tuning or improving existing policy rather than formulating and implementing a new policy. They may even oppose the latter as they cannot assimilate the new knowledge or competencies required. This common weakness leads to the continued use of sub-optimal or obsolete procedures [17].

Literature provides many policy evaluation models, such as goal attainment, side-effects, relevance, client-oriented, stakeholder, collegial, peer-review, and self-evaluation [13]. When a policy is ineffective in reaching its intended goals, a policy review process may need to be set up. Policy review is the process of regular resetting to ensure policy alignment to needs. In the case of a Transport Policy, a dedicated team will be required to do this as a continuing function rather than an ad-hoc intermittent process, as has been the case in Sri Lanka.

Policy revision can be separated into proactive and reactive revisions depending on what triggers a policy revision. The *proactive revisions* shown below are formulated before the problem appears. In comparison, *reactive revisions* are triggered by a crisis, usually created due to delayed policy revision or lack of policy monitoring.

(i) Proactive Revisions

- When a new government has made its policy statement in Parliament after reviewing policies that may have changed
- Periodically, at least every five years, after reviewing the effectiveness of current policies and review of global policies that arise due to changes in technology, economy, and other parameters.
- When a critical review of a strategic plan reveals a need for policy intervention

(ii) Reactive Revisions

- When there is an economic crisis and policy changes are enforced from above.
- When there is user, supplier, or regulator representation suggesting a revision of policy from below

Commissions are often set up to encourage policy learning and may also be used to educate the public about controversial policy issues or debunk beliefs and advertise recent research in the policy area under study [18]. In Australia, the Department of the Prime Minister and Cabinet has issued guidelines for policy proposals with significant implementation risks or challenges. In such cases, a complete implementation plan has to be developed during the drafting process covering seven domains: planning, governance, stakeholder engagement, risks, monitoring, review and evaluation, resource management, and management strategy. Each of these is further broken down and made available as implementation 'toolkits' [12].

Following such best practices, the transport policy implementation in Sri Lanka would require monitoring mechanisms at different stages, as illustrated in Table 7.

Table 7: Transport Policy Monitoring Responsibility Framework for Sri Lanka

Activity in Process	Responsible Stakeholder	Mechanism
Transport Strategic Plan	Transport Ministry	A Policy must be followed by a Strategic Plan, renewed every five years, even if the policy does not change. Strategic plan should ensure its complete alignment with existing policy. This should cover all sub-sectors of transport.
Development Plan for Agency/Sub Sector (may also be called Strategic Plan)	Agency	Must ensure alignment with both the transport policy and the transport strategy.
Request for Assistance from Foreign agencies	Department of External Resources	Must ensure alignment to the Transport Sector Policy and other national policies
Request for Proposals (RFP) for private investments	Ministry of Transport	Ensure alignment to the Transport Sector Policy as well as other national policies
Budget Proposals	National Budget Department	Ensure alignment to the Transport Sector Policy, Sub Sector of Agency Plans

6. CONCLUSION

The paper identifies the broader socio-political ideologies that have shaped the current transport policy environment in Sri Lanka. It has identified the key areas of failure of the Land Transport Policy 2009. The lack of attention to explicit policy

changes and over-reliance on tactical changes has been a key contributor to poor performance.

The paper provides critical guidelines to improve policy performance at each stage of policy intervention. The policy formulation or design stage requirements in a developing country context require focusing on outcomes instead of outputs, sufficient inputs that represent bottom-up representation, and avoidance of tactical interventions that can be carried out under existing policies and identifying new strategic interventions. In policy implementation, which is the area most vulnerable to policy failure, an overall commitment to policy-led governance is a prerequisite for policy interventions. The competency of the bureaucracy which is responsible for policy implementation is critical in ensuring the translation of concepts to projects and programs without losing intended goals and outcomes. Complex policy proposals may be vulnerable to being simplified for ease of implementation.

In developing countries, conventional supply models have long lived beyond usefulness and have not been revised. Innovative models are required for improved policy impact to solve critical mobility issues. The process of policy intervention is completed only when there is systematic monitoring and review, preferably of a proactive nature. The public administration processes should include checks and balances at each project approval stage to ensure subscription to explicit policy.

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ANNEXURE

Evaluation of Transport Policy Recommendations - 2009, Sri Lanka

Transport Feature	Significant Policy Interventions Recommended	Assessment of Policy Implementation			
		[X]	[L]	[M]	[F]
Railway Transport	Investment in suburban and long-distance train operations to improve physical capacity and ICT capability [L] to increase railway passenger share from 6% to 10% [X] and freight share from 2% to 5% [X] within 7 years supplemented by new rail links [X] was recommended to modernise [X] and expand the network [X]. Improve level of comfort and service [M], value-added services [X]. Fare rationalisation [X] is proposed to reduce the Treasury burden [X] together with a Railway Development Fund [X]and the creation of subsidiaries for non-core commercial ventures [X]. Develop non-fare box revenue [X]	11	1	1	
Omnibus Transport	To be restructured by consolidating small operators [X], strengthening regulation of standards [X], improving routing and scheduling [X], cost-based fare regimes [X], and providing employment security for bus employees [X]. Investment, including private investment [X] to be sought for developing and modernising bus terminals [L]. Regulators to be more transparent in the award of permits [X]. No general subsidies are to be provided [L]. Improve competency of regulators [X]. SLTB to operate routes in consultation with regulators [X]. Consolidate private bus industry owners [X] with Qualified Companies [X] and Omnibus Service Contracts [X]. De-incentivise crew earnings based on fare box [X]. Improve social standing and security for private bus employees [X]. Create a national database [X]. Reorganise route network [X].	16	2		

Transport Feature	Significant Policy Interventions Recommended	Assessment of Policy Implementation			
		[X]	[L]	[M]	[F]
Hiring Vehicles	Regulation of standards [X], publication of standard fare structures [X], and introduction of a public complaint inquiry process [X]. Adequate insurance cover for passengers [X]. Issue Hiring Vehicle Certificate of conformity [X]	5			
Vehicle Administration	Pricing policy for vehicles [X] and fuel [X], energy efficiency plan [X], encourage measures for reducing urban congestion [L]. Recover total public cost from private vehicles [X]. Use parking fees to develop off-street parking [X]. Encourage high occupancy vehicles [X].	6	1		
Non-Motorised Transport (NMT)	Encourage the use of bicycles [X], implement through financing schemes [X]; include cycle lanes on urban roads [X] and set up cycle park-and-ride facilities [X]. New road infrastructure to incorporate minimum NMT facilities [X]. Attention to improving safety [X].	6			
Goods Transport & Logistics	Invest in rail-based logistics centres [X] ICDs [X] and develop a sea-air hub for freight [X]; imposition of industry standards on safety [X]. Issue of Goods Vehicle Conformity Certificate [X]. Tax incentives to modernise fleet [X]. JVs with the railway for intermodal [X]. Improve enforcement of axle loads [X]. Develop rail-based logistics centres [X].	9			
Urban Transport	Develop a strategic plan for urban traffic management [X], specifically including providing more significant road space for high occupancy vehicles [X], increasing railway operations [X]; improving bus routing and services [X]; introducing road pricing [X], and rationalising parking fees [X]. Urban goods movement strategy [X]. Transit Oriented Development around terminals [X]. President's Committee on Urban Transport [X].	9			

Transport Feature	Significant Policy Interventions Recommended	Assessment of Policy Implementation			
		[X]	[L]	[M]	[F]
Subsidies for Transport	Improve service delivery of school transport services [L] and rural transport services [X] through community-based service monitoring programs [X].	2	1		
Transport Administration	Set up a transparent process for transport policy implementation [X], planning [X] and monitoring [X], regulation [X], and provision of infrastructure [X] and services [X], as well as encouraging public feedback [X]. Also, to streamline sector planning [X], Research & Development [X], and Human Resource Development [X]. Improve appointments to Boards of Management [X], and encourage professional qualification of senior staff [X].	12			
Energy Efficiency	Rationalise the pricing of fossil fuels [X], introduce incentives for hybrid [M] and electric vehicles [L], electrification of suburban railways [M] and road-based public transport [X], and fix pricing to reduce wasteful or avoidable consumption [X], and create a database for energy use [X].	4	1	2	
Safety and Security in Transport	Revise motor vehicle insurance legislation [X], establish a road safety secretariat [F], introduce safety improvement measures [X] such as road safety audits [X], and expand the Road Safety Fund for more comprehensive coverage [X]. Introduce modern technology and databases for reducing accidents [X] and reduce accidents at road-rail crossings [L]	5	1		1
Transport & the Environment	Introduce vehicle emissions testing program [F], revise vehicle tax structure to encourage less polluting vehicles [X], encourage less polluting fuels [F], move away from 2-stroke technology [M]	1		1	2
Total		**86**	**7**	**4**	**3**
Total (%)		**86**	**7**	**4**	**3**
Key: [X] - No progress [L] - Low Progress [M] - Moderate Progress [F] - Fulfilled					

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JOURNAL OF
SOUTH ASIAN LOGISTICS AND TRANSPORT

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GUIDELINES FOR MANUSCRIPT SUBMISSION

JSALT

Journal of South Asian Logistics and Transport (JSALT) is a peer-reviewed bi-annual English language journal published by the Sri Lanka Society of Transport and Logistics (SLSTL). It provides a space in which findings of original research, particularly focusing on the South Asian context, including those presented at the annual conference on Research for Transport and Logistics Industry (R4TLI), organised by the SLSTL. In addition to research articles, the Journal accepts manuscripts of policy and strategic perspectives.

MANUSCRIPT SUBMISSION

Articles are accepted in English (UK) language.

All submissions should be made electronically as Microsoft Word documents to the Email address: submission-jsalt@slstl.lk. The Editorial Office will duly acknowledge authors on receipt of a duly submitted manuscript.

Manuscripts submitted will be subject to a rigorous and independent double-blind expert review process administered by the Journal's Editorial Board, and the authors will be contacted after the review process is complete. The process generally takes from two to three months. The Editorial Board's decision regarding the publication of an article will be final.

SUBMISSION GUIDELINES

Abstract

An abstract can be used as a basic template in structuring the prospective article. A representative abstract of not more than 200 words should be submitted by the deadline.

Key Words

Authors should submit a maximum of six unique and informative keywords relating to the manuscript. Undefined abbreviations or acronyms should be avoided in the keywords. Editorial Board reserves the right to replace keywords if necessary.

Format

- Submit all manuscript files as Word .doc or .docx file format.
- Use B5 Page format
- No specific word count limitation.
- Font type used for general text should be "Times New Roman" with 11pt size.

Main headings and sub-heading also shall be in the same format but with bold letters. Moreover, the main headings and sub-headings should be numbered in the same format adopted in this paper. The paper margins should be 1" for the top margin, 1" for left and right margins, and 0.8" for the bottom margin.

Equations

Equations should be indented and separated from the text. All equations should be sequentially numbered within brackets and placed on the far-right side of the line.

Tables

Tables should be fitted into the body area in 10 pt portrait orientation. Each Table should be sequentially numbered, and the caption should be located on top of the Table. The font size of the caption should be not less than 11 pt.

Figures

Figures and photographs should be fitted into the body area in portrait orientation. Photographs should be preferably scanned with a resolution of 100 dpi in .jpg or .tiff format and sized before placement in the manuscript. Each figure should be sequentially numbered, and the caption should be located below the Figure. The font size of the caption should be not less than 11 pt. All figures should be in sharply contrasting colours so that they can easily be legible even in black and white prints.

References

This comprises a list of all sources used in the paper located at the end of the paper using the IEEE referencing style. They should contain full bibliographical details in numerical order at the end of the manuscript. In the reference list, all authors should be included. (Times New Roman, 11pt, full aligned).

Appendices

Sometimes appendices help readers to further study the issue presented. Submit appendices separately after attaching tables and figures. If more than one appendix is featured, use capital letters to refer to them in the text: Appendix A, Appendix B, etc. Follow guidelines for tables or figures, as appropriate, when formatting appendices.

Queries

For clarifications, Editor-in-Chief may be consulted via e-mail: editor-jsalt@slstl.lk.

ISSN 2783-8897