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# FEASIBILITY OF ESTABLISHING AN INTEGRATED RAILWAY-BASED CONTAINERISED CARGO TRANSPORT NETWORK BETWEEN THE PORT OF COLOMBO AND FREE TRADE ZONES IN SRI LANKA

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***ABSTRACT***

*A large percentage of Sri Lanka's exports and imports are generated by the manufacturing sector and originate from facilities dispersed throughout Export Processing Zones (EPZs) around the country. An efficient hinterland transport network is required between the Port of Colombo and these EPZs. However, road trucks are the dominant transport mode for moving containerised cargo to/from Colombo Port. This study proposes a dry port-based containerised import/export cargo transportation method using a railway network to connect the Port of Colombo and the EPZs under several alternative network configurations. This study conducts a questionnaire survey with 40 experts to identify issues with the current road-based container transport network and ascertain the benefits of proposed railway-based networks in Sri Lanka. A majority of respondents highlight the benefits of the proposed network from multiple perspectives, along with several drawbacks of the current road-based network. Initially, the feasibility of two alternative dry port locations in Orugodawatta and Kerawalapitiya are analysed. A mathematical model is developed to analyse the feasibility of the proposed alternative networks. Finally, the optimum dry port location is selected as Aluthwaththa using a simulation-based Greenfield analysis approach. Results highlight the advantages of proposed networks under several scenarios. The study demonstrates a systematic approach to decision-making by optimising the local cargo handling process, where Sri Lankan inland logistic operations will become more efficient, with total transport costs, environmental pollution, and transportation time decreasing significantly.*

**Keywords:** *Dry Port, Railway-Based Imports/Exports, Containerized Cargo Transport, Port of Colombo, Export Processing Zone, Economic Feasibility*

## 1. INTRODUCTION

The Port of Colombo is strategically located near the world's busiest shipping routes. Due to the port's natural geographic location, it has earned the status as a hub port in the South Asian region, which connects South Asia to the East-West shipping route. According to the World Shipping Council, the Port of Colombo has been ranked among the top 25 container ports in the world. The Finance Ministry reports the Port of Colombo had a revenue of 20.3 billion rupees in 2020. Moreover, if the container throughput is increased to 10 million, the port will generate 40% of the government's income [1]. Thus, the Port of Colombo significantly contributes to the Sri Lankan economy. The annual cargo tonnage of the port is 30.9 million tons. In 2021, the port handled 7.25 million TEUs, and the majority (about 75% equals 5.85 million TEUs) was transhipment cargo, mainly from the Indian feeder market. Hence, the local imports and exports were only about 1.4 million TEUs in 2021. Therefore, Colombo Port's main business target should be to attract more transhipment cargo and win the hub port competition, which has intensified with the competition with the Southeast Asian hub ports such as Singapore, Klang, and Tanjung Pelepas in the transhipment market [2]. At present, there are over 30,000 vessels that use the East-West shipping route, and the objective of the port authority is to attract these ships to the Colombo Port. But today, Singapore port has a dominant market share from most feeder ports in the hub and spoke networks mainly due to its high performance and competencies. According to the Logistics Performance Index (LPI) in 2018, published by the World Bank, Sri Lanka holds the $94^{th}$ rank with an LPI score of 2.60. Emphasising the strategic location and the intention of the government to improve the country as the leading logistics hub in the region, a continuous improvement process is necessary not only from the port side but also from the hinterland side.

Road trucks have always been the dominant transport mode in Sri Lanka for moving containerised import and export cargo to/from Colombo Port. According to the Association of Container Transporters, over 90 major container transport companies are in the country. Also, 23 licensed inland container depots are in operation within the 20 km radius of the Port of Colombo. Hinterland container transportation requires efficient coordination and interaction among port terminals, container freight stations, exporters, consignees, clearing agents, freight forwarders, and primarily container transport companies to facilitate island-wise containerised cargo transportation to/from the Port of Colombo. Also, this transportation service should have a sufficient scale of operation to facilitate future import/export demand. Therefore, the availability of efficient transportation infrastructure is necessary to enhance the performance of hinterland containerised cargo transportation.

In the history of Sri Lanka, the majority of freight - mainly coffee, tea, and coconut - were transported to the country's seaports via railway freight services. At present, rail freight transportation is mainly used for moving some packages, selected cargo types such as *Thriposha* and mail. However, when considering containerised cargo transportation, the use of railway systems is comparably low, although some companies use railway transportation to move some industrial bulk cargo. For example, railway transportation is used to transport wheat flour from Trincomalee China Bay harbour to Galle and Seeduwa, where the railway department supplies 15 units of railway container carrier wagons for this purpose. Moreover, some cement companies have locomotives, railway yards, wagons, and railway staff for transporting bulk materials by train. Thus, cement raw materials are carried from China Bay to Mahawa, and clinker loads are carried from Aruwaakalu to Puttalam factories. Further, Sri Lanka Railways plans to recommence rail transport of coal for the Norocholai power plant in the future.

Despite the limited usage of railways for freight transportation in Sri Lanka, this mode has many advantages. Railway mode helps to minimise environmental problems resulting from the extensive use of road-based vehicles. Although road trucks can carry only one 40FT container, a single locomotive can transport 10-15 40FT containers by railway. Due to excessive congestion and traffic on motorways, tons of greenhouse gases, including CO2, are emitted into the environment. Transportation is also a primary source of NOx, SO2, and PM (particulate matter or fine dust) emissions. In road transportation, the CO2 Emission per 40FT container (Kg CO2/KM) is 1.79, although the same figure in railway transportation is 0.45 [3]. Besides, the fuel consumption of a laden 40FT container truck is 0.67(litres/KM), and the same for railway transportation is comparatively 0.2(litres/KM) [3]. Moreover, railway transportation is the most cost-efficient inland cargo transport method for freight because it has the minimum charge for wagon reservation, journey, and insurance charge. The other advantages of using railway-based cargo transportation are time efficient, less risky, high capacity, safety, less manpower requirement, etc.

The efficiency of the port is also measured by the time taken for a truck to enter the port, process loading/unloading, and then leave the port, generally known as the Truck Turnaround Time (TTT) [4]. A recent survey highlighted a lower performance of the Colombo Port than other leading ports, and some stakeholders complained about over 8 hours of TTT of the port due to the congestion on some days. High TTT results in unnecessary delays and detention charges and reduces the overall performance of the country's logistics system. This can be considered an alarming situation that may cause low performance and waste of resources, thus; necessary actions should be taken to address these problems.

Although Hambantota and Trincomalee ports may support the reduction of congestion related to the Colombo Port, moving local containerised cargo handling to these alternative ports is not the best solution. Since most free trade zones are located around Colombo, this will eventually increase the cost borne by local importers and exporters. The hinterland transport infrastructure can be developed as another alternative, resulting in lower costs, emissions, and congestion, although it requires high investments. According to the previous financial reports of the country, between 2014-2019, an amount equal to 22% of imports value is spent on building transport infrastructure. Therefore, adding more road infrastructure will not be an attractive solution for the country. Considering all these issues as well as best practices from other countries, a more viable alternative could be the development of a high-capacity dedicated railway-based cargo transportation network operated via a dry port.

The main purpose of this study is to analyse the feasibility of a railway-integrated containerised cargo transport network between EPZs and Colombo Port operated via a dry port. Figure 1 illustrates the current road-based network and proposed railway-based network with one of the five network configurations which this study conducts feasibility analyses for.

This study consists of four sequential steps. First, it identifies the issues related to current container transportation networks and, second, identifies the advantages of the proposed network over the current system. Third, it analyses the feasibility of a railway-based integrated cargo transportation network operated via two alternative dry port locations by comparing total transportation cost and CO2 emission, using five different network configurations with current and future cargo volumes forecasted for 2050. At the final stage, the study identifies an optimum location for the dry port using greenfield analysis with a simulation approach and analyses the feasibility of optimum dry port locations compared to the previous alternatives.

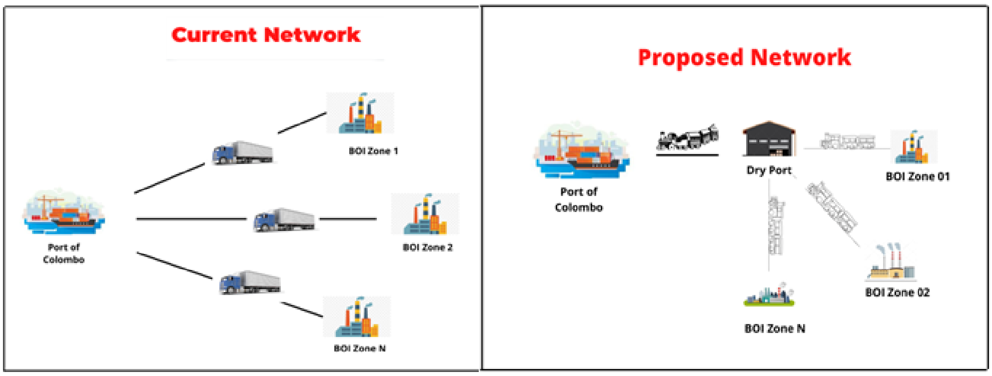


**Figure 1: Current and Proposed Transportation Networks**

## 2. LITERATURE REVIEW

Road freight transportation grows in step with the rapid growth of economic activities and results in increased greenhouse gas emissions and carbon-based fuel consumption. This sector has been responsible for 35% of the world's transport energy use, and diesel vehicles are the major fuel consumer in Asia. Transportation is also the main source of NOx, SO2, and PM (particulate matter or fine dust) emissions [5]. Optimising and adapting intermodal transportation through railway networks will be one of the best options to minimise these adverse impacts. Therefore, without entirely depending on road transportation, the industry may focus on other alternatives which reduce the environmental impact. The level of integration among transportation networks and modes determines environmental performance because greater supply chain integration leads to better environmental performance [6].

Railway transportation is a sustainable solution for increased fossil fuel consumption and climate change. From a logistics company's point of view, these reductions in emissions and congestion can make the supply chain leaner. The use of railway-based container transportation in greening supply chains in Sri Lanka was analysed in a case study [3] with selected EPZs. The feasibility was analysed with estimated emissions and cost. Accordingly, when comparing emissions generated from trains and 10-wheeler trucks, more than 50% of overall emissions can be reduced by shifting freight transportation from 10-wheeler trucks to the railway system. Considering best practices in the global context, the International Transport Forum expects global rail freight volumes to grow 2.7% per year between 2015 and 2030, with some countries having significantly higher growth rates (e.g., in 2017, growth rates were 13.3%, 6.4%, 5.5%, and 5.2% for China, Russia, India, and the USA, respectively) [12]. Moreover, multimodal networks are currently operating in the world's largest ports. The world's top-performing ports, such as Antwerp and Sydney, have a considerable percentage of rail mode share to increase the efficiency of port operations. As highlighted by the use of rail transport as part of the supply chain in an urban logistics context [13], rail transportation can solve current road transport problems in Europe, although the mode share of rail transport in Europe declined in the last decades to less than 15%.

Since this research focuses on dry-port integrated railway-based containerised cargo transportation systems, several previous studies related to dry port networks are summarised here. The dry port concept is based on a seaport directly connected with inland intermodal terminals by rail or a dedicated corridor where containers can be handled in the same way as if they were in a seaport. Connecting container seaports with the hinterland [14] has general benefits to the ecological environment and quality of life by shifting flows from road to rail. The dry port concept also offers seaports the possibility of securing a market in the hinterland, increasing the throughput without physical port expansion as well as better services to shippers and transport operators. Therefore, all port stakeholders, including the general public in seaport cities, can benefit from less road congestion and/or less need for infrastructure investments. A recent study, Optimizing Inland Container Logistics and Dry Port Location-Allocation from an Environmental Perspective, identified the use of intermodal rail transportation through the dry port as a way to reduce environmental impacts resulting from road transportation of port-hinterland freight [15]. However, in the Sri Lankan context, although the National Port Master Plan in 2020 emphasised the significance of the dry port concept and its implementation, no initiatives were taken to fully implement a dry port-based hinterland containerised cargo transport system. However, following the cargo village concept, 450 ha located northeast of the port and south of the Kelani River was designed under North Port development, and several warehousing and handling of cargo operations were due to shift there.

Various network configurations can be considered for a dry port-based transportation network and railway-based containerised cargo transportation. However, none of the previous studies analysed the feasibility of these configurations from both economic and environmental perspectives simultaneously. Besides, there is a shortage of local studies on the issues with the current road-based network and the benefits of proposed railway-based networks. However, with the proposed system, we can shift most of the import/export containerised cargo handling operations, such as customs clearance, inspection, value-adding activities, etc., from the port of Colombo to the proposed dry port, which also would reduce the congestions and inefficiencies related to port operations. Besides, no previous studies focused on optimising dry port locations with a simulation-based approach in the Sri Lankan context, and no studies focused on analysing the feasibility of multiple alternative dry port locations. Therefore, this study is designed to address those research gaps while providing meaningful policy implications to practitioners and policymakers in the transport and logistics sector in Sri Lanka.

## 3. METHODOLOGY

As one of its objectives, this study aims to identify issues related to current road-based container transportation between the Colombo Port and EPZs and introduce a dry port-based containerised railway cargo transport system. Therefore, the issues of the current system were identified from the past literature. A systematic review of the literature was done on studies focused on Port of Colombo logistics operations, railway-based cargo transportation networks of other countries, dry port networks, and the congestion problem with cargo transportation, among others.

A questionnaire survey was designed to identify the issues related to the current road-based container transportation network in economic and environmental aspects (section A) and to identify the advantages of having a dry port-based containerised railway cargo transportation network (section B). The targeted responders of the questionnaire survey were BOI companies, import/export companies, transporters, 3PL companies, port authorities, and Sri Lankan railways. Responses to the survey were descriptively analysed and categorised based on the significance level.

Then, a mathematical model was developed to analyse and compare the current and proposed system's cost and environmental emissions. Initially, the feasibility of the proposed network was analysed with two alternative dry port locations; Orugodawatta and Kerawalapitiya. Analysis was done with both current (cargo volume in 2020) and future (forecasted cargo volume for 2050).

Then, a simulation-based approach was developed to identify an optimised dry port location for the cargo transportation network simulation optimisation software became much more popular because the constraints decide how practical experimental solutions are. In this study, the optimum location for the proposed dry port and the location compatibility for the proposed system is analysed using a simulation-based approach. A simulation model was developed using Supply Chain Guru.

The research design can be drafted in Figure 2.

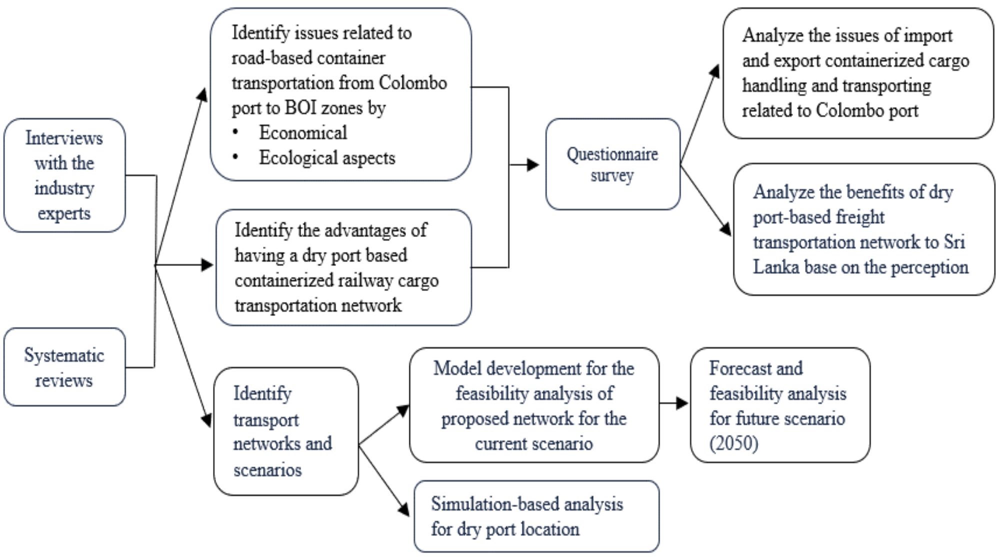


**Figure 2: Study Design**

### 3.1. Mathematical Model Development

A mathematical model was developed to estimate the transportation cost and CO2 emissions with current and proposed networks. Since the feasibility of the proposed network is heavily affected by the dry port location, the current import/export container goods inspection centre in Orugodawatta was selected as one alternative dry port location. Moreover, due to the traffic congestion in the Colombo city area and infrastructure unavailability in Orugodawatta, the Sri Lankan government proposed a new project to move cargo inspection to Kerawalapitiya after a feasibility study done with the Asian Development Bank (ADB) [11]. Hence, the proposed location by ADB was also selected as the second alternative dry port of the study. The selected two dry port locations for the study and their access routes from the Port of Colombo are illustrated in Figure 3.

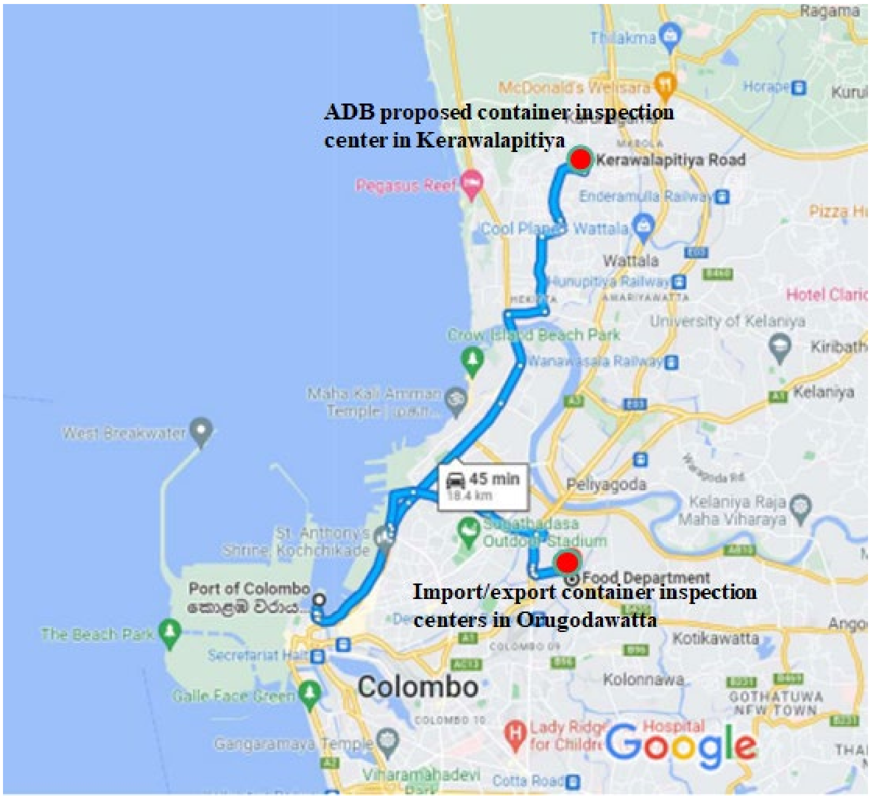


**Figure 3: Alternative Dry Port locations**

Since this study analyses the feasibility of a railway-based containerised cargo transportation network, multiple alternative network configurations can be considered depending on the extent of using railway corridors and road links on different segments of the entire network. Therefore, this study considers five scenarios on different network configurations for the analysis to give a broader view to decision-makers by evaluating the number of options listed in Table 1. Scenario A indicates the current road-based network, while scenarios B, C, D, and E represent alternative network configurations with the proposed railway-based network. Each scenario is analysed by estimating transportation cost and CO2 emission with current and future cargo volumes. Thus, considering two alternative dry port locations, ten analyses were analysed initially.

**Table 1: Scenarios based on Alternative Network Configurations**

| Scenario | Description |
|---|---|
| **A** | Current containerised cargo transportation system between Colombo Port and EPZs using road trucks. |
| **B** | The total transportation network between Colombo Port and EPZs operates by rail through a dry port. |
| **C** | Colombo Port to dry port by railway lines and from dry port to each EPZ by road trucks. |
| **D** | The train operates between Colombo Port and dry port and up to the nearest railway station for each EPZ. Road trucks are used from the nearest Railway station to EPZs. |
| **E** | Colombo Port to dry port by railway lines. Only the selected EPZs with high cargo volumes will be served by rail from the dry port. The rest of the EPZs will be served by road trucks. |

The model development was done with the following assumptions. Here, movements are assumed to be restricted between the Port of Colombo and EPZs.

- For the cost estimation, a fixed charge is assumed for lift-on/ lift-off of laden containers from/to the container stack yard to/from prime movers or rail wagons, and a variable charge is assumed in proportion to the transport distance.
- Since Sri Lankan Railway container handling charges are not published, the calculations were done based on their latest quoted price (Rs. 600 per wagon per Km).
- According to Sri Lanka Railways, the maximum number of wagons per cargo train in Sri Lanka is 12. The study assumed each cargo train is operated with maximum capacity.
- The numbers of containerised cargo trucks to/ from Colombo Port from/to EPZs were calculated based on December 2022 figures provided by BOI, Sri Lanka.
- Although 14 EPZs are available, this study focuses only on the EPZs which have monthly commercial FCL cargo operations greater than five. Hence, Mawathagama, Bingiriya, Wagawatta, and Mirijjawila are excluded from the study due to low cargo movement and insufficient data availability.

To decide the feasibility of the proposed network, the estimated total cost and emissions of the current road-based network and proposed railway-based integrated networks with two alternative dry ports are compared. For each proposed network, four sub-scenarios with B, C, D, and E network configurations are analysed. Equations (1) calculate the total transportation cost with the current road-based network (Scenario A), while Equations (2), (3), (4), and (5) estimate those of proposed scenarios B, C, D, and E, respectively.

Notations

| | |
|---|---|
| $p$ | Colombo Port |
| $j$ | Dry port |
| $i$ | BOI (EPZ) ($i$ =1,2,…0) |
| $i_h$ | BOI (EPZ) with high cargo volumes, as considered in Scenario E |
| $k_i$ | Nearest railway station to $i$ th EPZ |
| $m$ | Mode of transportation ($m = r$ if railway or $m = t$ if road trucks) |
| $D_{(x,y,m)}$ | Transportation distance between two points $x$ and $y$ using mode $m$ |
| $V_{(20FT,x,y)}$ | Number of 20FT containers transported between points $x$ and $y$ |
| $V_{(40FT,x,y)}$ | Number of 40FT containers transported between points $x$ and $y$ |
| $VC_{(20FT,m)}$ | Variable transportation cost (USD/Km) for transporting 20FT by mode $m$ |
| $VC_{(40FT,m)}$ | Variable transportation cost (USD/Km) for transporting 40FT by mode $m$ |
| $FC_{(20FT,m)}$ | Fixed loading/ unloading cost for transporting 20FT by mode $m$ |
| $FC_{(40FT,m)}$ | Fixed loading/ unloading cost for transporting 40FT by mode $m$ |

$$TC = \sum_{i=1}^{10} V_{(20FT,i,p)}[(V_{(20FT,t)} * D_{(i,p,t)}) + FC_{(20FT,t)}] + \sum_{i=1}^{10} V_{(40FT,i,p)}[(V_{(40FT,t)} * D_{(i,p,t)}) + FC_{(40FT,t)}] \quad (1)$$

$$TC = \sum_{i=1}^{10} V_{(20FT,j,p)}[(V_{(20FT,r)} * D_{(j,p,r)}) + FC_{(20FT,r)}] + \sum_{i=1}^{10} V_{(40FT,j,p)}[(V_{(40FT,r)} * D_{(j,p,r)}) + FC_{(40FT,r)}] + \sum_{i=1}^{10} V_{(20FT,i,j)}[(V_{(20FT,r)} * D_{(i,j,r)}) + FC_{(20FT,r)}] + \sum_{i=1}^{10} V_{(40FT,i,j)}[(V_{(40FT,r)} * D_{(i,j,r)}) + FC_{(40FT,r)}] \quad (2)$$

$$TC = \sum_{i=1}^{10} V_{(20FT,j,p)}[(V_{(20FT,r)} * D_{(j,p,r)}) + FC_{(20FT,r)}] + \sum_{i=1}^{10} V_{(40FT,j,p)}[(V_{(40FT,r)} * D_{(j,p,r)}) + FC_{(40FT,r)}] + \sum_{i=1}^{10} V_{(20FT,i,j)}[(V_{(20FT,t)} * D_{(i,j,t)}) + FC_{(20FT,t)}] + \sum_{i=1}^{10} V_{(40FT,i,j)}[(V_{(40FT,t)} * D_{(i,j,t)}) + FC_{(40FT,t)}] \quad (3)$$

$$TC = \sum_{i=1}^{10} V_{(20FT,j,p)}[(V_{(20FT,r)} * D_{(j,p,r)}) + FC_{(20FT,r)}] + \sum_{i=1}^{10} V_{(40FT,j,p)}[(V_{(40FT,r)} * D_{(j,p,r)}) + FC_{(40FT,r)}] + \sum_{i=1}^{10} V_{(20FT,k_i,j)}[(V_{(20FT,r)} * D_{(k_i,j,r)}) + FC_{(20FT,r)}] + \sum_{i=1}^{10} V_{(40FT,k_i,j)}[(V_{(40FT,r)} * D_{(k_i,j,r)}) + FC_{(40FT,r)}] + \sum_{i=1}^{10} V_{(20FT,i,k_i)}[(V_{(20FT,t)} * D_{(i,k_i,t)}) + FC_{(20FT,t)}] + \sum_{i=1}^{10} V_{(40FT,i,k_i)}[(V_{(40FT,t)} * D_{(i,k_i,t)}) + FC_{(40FT,t)}] \quad (4)$$

$$TC = \sum_{i=1}^{10} V_{(20FT,j,p)}[(V_{(20FT,r)} * D_{(j,p,r)}) + FC_{(20FT,r)}] + \sum_{i=1}^{10} V_{(40FT,j,p)}[(V_{(40FT,r)} * D_{(j,p,r)}) + FC_{(40FT,r)}] + \sum_{i_h=1}^{10} V_{(20FT,i_h,j)}[(V_{(20FT,r)} * D_{(i_h,j,r)}) + FC_{(20FT,r)}] + \sum_{i_h=1}^{10} V_{(40FT,i_h,j)}[(V_{(40FT,r)} * D_{(i_h,j,r)}) + FC_{(40FT,r)}] + \sum_{i=1}^{(10-i_h)} V_{(20FT,i,j)}[(V_{(20FT,t)} * D_{(i,j,t)}) + FC_{(20FT,t)}] + \sum_{i=1}^{10} V_{(40FT,i,j)}[(V_{(40FT,t)} * D_{(i,j,t)}) + FC_{(40FT,t)}] \quad (5)$$

In addition to the transportation costs, this study focuses on the environmental emissions of transport networks by estimating the total CO2 emissions generated by container transportation under each network scenario. The average fuel consumption per KM of a particular vehicle type is considered when estimating emissions. Thus, rail fuel consumption per KM is calculated using the railway administration report as an average value of all M series locomotives. Moreover, only CO2 emissions are considered in this study. When estimating emissions, fuel consumption per KM of trains, 20FT and 40FT container trucks were considered and together with the emission factor of the respective fuel type. Then, considering the total number of trips between each trip segment and their respective travel distances, the total transportation emissions generated with each network configuration under proposed railway-based networks and that of the current road-based network were estimated. Detailed calculations were not summarised here to maintain the brevity of this paper.

## 4. FINDINGS AND DISCUSSIONS

### 4.1. Descriptive Analysis

The questionnaire was distributed among 40 individuals with experience in related sectors/industries such as Sri Lanka Port Authority, import/export industry, transport industry, BOI Sri Lanka, and Sri Lanka Railways. Accordingly, out of the sample of 40 respondents, 37.9% work in the import/export industry, and 27.6% work in BOI Sri Lanka. The rest of the responders work in the transport and logistics sectors, Sri Lankan Railways, and Sri Lankan Port Authority. The years of experience in the industry of the sample vary from 1-29 years, representing respondents from entry-level, mid-level, and senior levels.

### 4.2. Issues Related to the Current Road-Based Container Transportation

After identifying a range of issues related to the current road-based container transportation system, this study groped them into two categories: Colombo Port-related issues and road transport issues. Table 2 lists the Colombo Port-related issues from top to bottom based on their priorities as highlighted by the respondents. Out of the total sample, 32% and 42% strongly agreed and agreed that Colombo Port's cargo handling inefficiencies badly affect local importers and exporters to delay their shipments, confirming the significance of addressing this problem. Moreover, none of the respondents disagreed with the statement that there is a long TTT in the Port of Colombo, while 31% strongly agreed with this. Besides, as highlighted by the majority, the Colombo Port currently does not have sufficient value-adding facilities inside port premises: this is adversely affecting port operation efficiencies and resulting in missed opportunities to generate more revenue for Colombo Port. Moreover, respondents highlighted the significance of several other issues, such as insufficient capacity, lengthier documentation, and shipment inaccuracies.

**Table 2: Colombo Port-related Issues**

| Colombo Port-related issues | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|
| Colombo Port cargo handling inefficiencies badly affect local importers and exporters to delay their shipments | 6.5% | 3.2% | 16.1% | 41.9% | 32.3% |
| There's a long truck turnaround time in the port of Colombo | - | - | 24.1% | 41.4% | 31% |
| Currently, Colombo Port does not have sufficient value-adding facilities inside port premises. It's badly affecting port operation efficiencies and evades opportunities to generate more revenue for Colombo Port. | 3.2% | 12.9% | 19.4% | 38.7% | 25.8% |
| The insufficient capacity in the port of Colombo is causing port inefficiency. | - | 6.5% | 29% | 38.7% | 19.4% |
| Colombo Port has a lengthier documentation time with too many conventional documentation processes for import/export containerised cargo operations | 3.2% | 6.5% | 6% | 48.4% | 7% |
| Cargo trucks have to wait for a considerable time (waiting time) before entering the Colombo Port at the port gates. | - | 6.5% | 12.9% | 58.1% | 5% |
| Colombo Port has a lengthier custom clearance time for import/export containerised cargo operations | 6.5% | 3.2% | 22.6% | 54.8% | 4% |
| The shipment inaccuracies (Errors in loading containers to the correct truck/vessel) of import/export containerised cargo in the port of Colombo is a major issue. | - | 45.2% | 16.1% | 25.8% | 12.9% |

Moreover, Table 3 summarises road transportation issues from top to bottom based on their priorities. According to the questionnaire survey conducted with 40 experts, 74% agreed that Colombo Port's cargo handling inefficiencies badly affect local importers and exporters and delays their shipments, which confirmed the need to address this problem. Moreover, 31% of respondents agreed about the long TTT in the Port of Colombo.Besides, respondents highlighted issues such as cargo damages while transporting, congestion in urban areas, and high transport cost, among others, which confirm the necessity of improving the current road-based containerised cargo transport system. Respondents also highlighted environmental concerns due to road transportation, such as a polluted environment caused by road congestion with heavy cargo trucks, high fuel consumption, and greenhouse gas emissions.

**Table 3: Road Transportation Issues**

| Road transportation issues | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|
| The current inefficient containerised cargo transport network caused delays in receiving imported shipments by local consignees | - | 3.2% | 12.9% | 16.1% | 67.7% |
| You have experienced vessel missing incidents (Can’t meet the cut-off time of exporting vessel) due to the current inefficient containerised cargo transport network | - | 9.7% | 12.9% | 19.4% | 58.1% |
| The current inefficient containerised cargo transport system causes damage to the goods while transporting | - | - | 9.7% | 35.5% | 54.8% |
| Congestion in urban areas is a huge problem for the import/export containerised cargo transportation industry. | 3.2% | 3.2% | 9.7% | 41.9% | 41.9% |
| With the increasing truck transportation charges and the unstable current transportation network, companies must bear a huge cost for their logistics operations | - | 3.2% | 12.9% | 45.2% | 38.7% |
| Road congestion due to heavy cargo trucks is causing to pollute the environment. | | 3.2% | 9.7% | 41.9% | 45.2% |
| There's a significant environmental impact by current import-export containerised cargo transportation due to the high fuel consumption of cargo trucks | | | 6.5% | 58.8% | 38.7% |
| The current heavy road trucks used for container transportation generate significant greenhouse gases, carbon, and other emission particles that threaten the environment. | | 3.2% | 9.7% | 58.1% | 29% |
| The congestion due to cargo trucks in urban areas is badly affecting the country's overall logistics performance. | 3.2% | 6.5% | 19.4% | 38.7% | 32.3% |
| The delays in picking up export shipments from the factories and import shipments from the harbour by the local transporting agents is a serious issue faced by the logistics sector these days. | 3.2% | 12.9% | 35.3% | 45.2% | 3.2% |

However, the respondents were also able to highlight some barriers to using the proposed system in the questionnaire survey. Change management, getting all the cargo on time to the train might be impossible; the dry port concept is new and hard to implement railway operational issues may crop up and this may interrupt local passenger transportation. With government intervention and standardised procedures, these barriers can be overcome.

### 4.3. Advantages of Dry Port-based Containerized Railway Cargo Transportation Network

Apart from identifying issues with the current road-based container transportation system, the questionnaire survey focused on experts’ opinions on the advantages of the proposed railway-based transportation network. After obtaining their opinions, these advantages were grouped into two categories: Colombo Port-related and transportation-related. Table 4 summarises the Colombo Port-related advantages. Accordingly, experts agreed that the proposed network could attract more transhipment cargo to Colombo, reduce hinterland congestion and facilitate many value-adding activities. As another advantage, moving import/export cargo handling to a dry port-based system can eliminate issues such as customs operations delays, inspection delays, and documentation delays. Besides, this network would help to minimise capacity-related problems and inefficiencies in Colombo Port while reducing TTT and waiting time in Colombo.

**Table 4: Colombo Port-related Advantages of the Proposed Network**

| Colombo Port-related Advantages | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|
| By implementing the proposed network, the port of Colombo can attract more transhipment cargo to generate more profits. | | 6.5% | 25.8% | 38.7% | 29% |
| The proposed network is a possible solution to reduce hinterland congestion occurred by import/export containerised cargo trucks. | | 6.5%. | 12.9% | 54.8% | 25.8% |
| Through the dry port system, many value-adding activities can be facilitated for the import/export cargo handling process | 3.2% | 6.5% | 9.7% | 58.1% | 22.6% |
| By moving import/export cargo handling to a dry port-based system, the issues such as customs operations delays, inspection delays, and documentation delays can be eliminated. | | 9.7% | 9.7% | 58.1% | 22.6% |
| The proposed network is a possible solution to overcome issues occurring due to insufficient capacity inside the Colombo Port | | 6.5% | 22.6% | 51.6% | 19.4% |
| The proposed network is a possible solution to eliminate port inefficiencies in import/export containerised cargo handling | | 3.2% | 16.1% | 61.3% | 19.4% |
| The proposed network is a possible solution to eliminate the long truck turnaround time inside the Colombo Port. | | 6.5% | 9.7% | 64.5% | 19.4% |
| The proposed network is a possible solution to eliminate the long waiting times at the port gates | 3.2% | | 19.4% | 61.3% | 16.1% |

Next, Table 5 summarises the transportation-related advantage of the proposed network. Accordingly, most respondents highlighted the advantages such as financial profitability, positive impacts on the country's logistics performance, fewer emissions and environmental benefits, eliminating unnecessary costs, demurrage charges, waiting time, vessel missing, etc. Moreover, as highlighted by respondents, since cargo transportation is comparatively more profitable than passenger transportation for Sri Lankan Railways, the proposed network will generate more profits for the Sri Lankan Railways.

**Table 5: Transportation-related Advantages of the Proposed Network**

| Transportation-related advantage | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|
| Since railway freight charges are comparatively lower than road transportation, the proposed network will be more financially profitable than the current system. | - | - | 19.4% | 45.2% | 35.5% |
| The proposed network will positively affect the country's overall logistics performance. | - | - | 12.9% | 51.6% | 35.5% |
| Railway transportation is less emission, a holistic and sustainable solution that resulting low fuel consumption. Hence the proposed solution will be benefitted to the environment. | - | - | 19.4% | 51.6% | 29% |
| By introducing the proposed network, importers and exporters will be able to handle their business efficiently and effectively by eliminating unnecessary costs, demurrage charges, waiting time, vessel missing, etc. | - | 6.5% | 6.5% | 64.5% | 22.6% |
| Since cargo transportation is comparatively more profitable than passenger transportation for Sri Lankan Railways, the proposed network will generate more profits for SLR. | | 3.2% | 16.1% | 51.6% | 29% |
| Since there's an under-utilized railway track inside the Colombo Port, by having some additional infrastructure for handling operations, the implementation of the proposed network will not be a significant challenge | 3.2% | 6.5% | 16.1% | 61.3% | 12.9% |
| The proposed network is a possible solution to eliminate the damage to the goods while transporting | 6.5% | 6.5% | 29% | 54.8% | 3.2% |
| With the current capabilities, Sri Lanka railways will be able to implement such a system. | 3.3% | 6.7% | 33.3% | 50% | 6.7% |

## 4.4. Estimated Transportation Cost and Emissions with Scenarios

### 4.4.1. Estimated Transportation Cost

Figure 4 summarises the transportation cost associated with the current scenario (A) and four alternative scenarios (B, C, D, E) under Orugodawaththa and Kerawalapitya dry port-based networks. Accordingly, Kerawalapitya dry port location which was proposed by ADB for container inspection is not feasible for the proposed network in the cost aspect as it derives the highest cost in all scenarios. Scenario B and E with the Orugodawaththa network derived lower costs than the current road-based transport network. In Scenario B, the entire network between Colombo Port and EPZs will be served by rail through a dry port, thus cost-effectiveness of railway mode could make this network more cost-effective than the current road-based network.

Furthermore, in Scenario E, although the railway will be used between Colombo Port and dry port, only the selected EPZs with high cargo volumes will be served by the railway, while the remaining EPZs will be served by road trucks. Thus, the Scenario E network derived a lower cost than Scenarios A, C, and D.

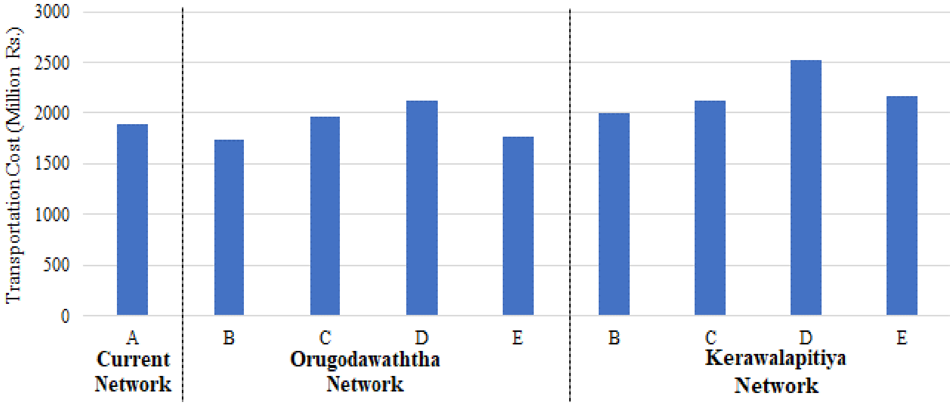


**Figure 4: Cost Comparison with Alternative Networks**

Based on previous BOI import/export data from 2001-2022, the total BOI import/ export volume for 2050 was forecasted. The previous data was mainly obtained from BOI annual reports, and reports of the Research and Policy Advocacy Department, BOI Sri Lanka. Accordingly, 16528.47 and 10367.57 BOI exports and imports were estimated in Millions of USD. Thereafter, the total volume is redistributed among EPZs based on their current percentages out of total BOI handling volumes. Hence, the costs associated with each scenario under future cargo volumes are summarised in Table 6. Even in the future scenario, the Kerawalapitiya network does not indicate cost-effective performance, while the Orugodawatta network with scenario B and E derive lower cost than the current network.

**Table 6: Transportation Cost with Future Cargo Volumes**

| Scenario | Cost (Millions Rs.) | |
|---|---|---|
| A | 2259 | |
| | Orugodawatta network | Kerawalapitiya Network |
| B | 2109 | 3381 |
| C | 2418 | 4529 |
| D | 2582 | 5280 |
| E | 2148 | 4529 |

### 4.4.1.1. Effects of Reducing Fixed Costs

From the descriptive analysis and expert interviews, the study identified the Public-Private Partnership as the most suitable administration method for the proposed network. Hence, through government intervention and optimising cargo handling processes, it will be possible to reduce fixed charges associated with container handling at dry ports. Here, the effect of lowering fixed charge by 50% is analysed to derive related implications. Accordingly, even with the reduced container handling charges at the dry port, the Kerawalapitiya network cannot be more cost-effective than the current network in any scenario. However, by lowering fixed charges by 50%, all scenarios with the Orugodawatta network become more cost-efficient than the current road-based network.

**Table 7: Transportation Cost after Reducing Fixed Costs**

| **Scenario** | **Cost (Millions Rs.)** | | | |
|---|---|---|---|---|
| A | Current (2022): 1756 and Future (2050): 2103 | | | |
| | **Orugodawatta network (Million Rs.)** | | **Kerawalapitiya Network (Million Rs.)** | |
| | **Current (2022)** | **Future (2050)** | **Current (2022)** | **Future (2050)** |
| B | 1408 | 1641 | 1983 | 2624 |
| C | 1767 | 2106 | 2112 | 4025 |
| D | 1666 | 1958 | 2241 | 4270 |
| E | 1442 | 1684 | 2021 | 4025 |

### 4.4.1.2. Effects of high-capacity trains between Colombo Port - Dry Port

According to the Sri Lanka Railways, the maximum number of wagons allowed for cargo trains is 12, and each wagon can transport one 40FT container and two 20FT containers. This limitation is mainly due to the current conditions of the railway tracks and the maximum length of interchange tracks. However, this limitation can be evaded for the rail track segment between the Colombo Port and the dry port. Hence, in the Kerawalapitiya network, a new line should be built between Ragama and Kerawalapitiya. Accordingly, the newly built railway track should be capable of transporting at least 20 railway wagons at a time, and the existing railway track which connects the Dematagoda-Orugodawatta-Colombo Port should be renovated to transport at least 20 railway wagons at a time. The rest of the network between the dry port and EPZs will be operated with the normal train capacity.

Table 8 summarises the cost associated with each network under five scenarios. Increasing the wagon quantity caused a reduction in the cost figures for every railway mode engaging scenario. But it doesn’t change any scenario cost feasibility. Still, Orugodawatta network, scenarios B and E have less total network cost than the current scenario.

**Table 8: Transportation Cost with High-Capacity Trains**

| Scenario | Cost (Millions Rs.) | | | |
|---|---|---|---|---|
| A | Current 2022: 1889 and Future 2050: 2259 | | | |
| | **Orugodawatta network (Million Rs.)** | | **Kerawalapitiya Network (Million Rs.)** | |
| | **Current 2022** | **Future 2050** | **Current 2022** | **Future 2050** |
| B | 1741 | 2072 | 1993 | 3400 |
| C | 1968 | 2341 | 2125 | 4337 |
| D | 2131 | 2536 | 2519 | 3825 |
| E | 1771 | 2108 | 2163 | 4523 |

### 4.4.2. Estimated Transportation Emissions

In terms of CO2 emissions, all scenarios with the Orugodawatta network were more environmentally friendly than Scenario A with both current (2022) and future (2050) cargo volumes as summarised in Table 9. When considering the Kerawalapitiya network, only scenarios B, D, and E were more environmentally friendly than Scenario A with current cargo volume, although no scenarios were environmentally friendly with future cargo volume.

**Table 9: Transportation Emissions among Alternative Networks**

| Scenario | CO2 Emissions (Thousand Kg) | | | |
|---|---|---|---|---|
| A | Current 2022: 1841 and Future 2050: 2192 | | | |
| | **Orugodawatta network (Thousand Kg)** | | **Kerawalapitiya Network (Thousand Kg)** | |
| | **Current 2022** | **Future 2050** | **Current 2022** | **Future 2050** |
| B | 986 | 1143 | 1546 | 2947 |
| C | 1779 | 2132 | 2087 | 3977 |
| D | 1110 | 1293 | 1671 | 3184 |
| E | 1045 | 1241 | 1611 | 3070 |

Moreover, the author has identified that the proposed system will be able to further reduce the total emissions by using high-capacity trains between Colombo Port and dry port, as summarised in Table 10. Here the high-capacity trains will help to reduce the number of railway trips, thus, the CO2 emission can be reduced. Hence, with high-capacity trains of up to 20 wagons, all scenarios with the Kerawalapitiya network also will be more environmentally friendly than Scenario A with its current cargo volume. Furthermore, by adding high-capacity trains to the Orugodawatta network, total transportation can be further reduced with both current and future cargo volumes.

**Table 10: Transportation Emissions with High-Capacity Trains**

| Scenario | CO2 Emissions (Thousand Kg) | | | |
|---|---|---|---|---|
| A | Current 2022: 1841 and Future 2050: 2192 | | | |
| | Orugodawatta network (Thousand Kg) | | Kerawalapitiya Network (Thousand Kg) | |
| | Current 2022 | Future 2050 | Current 2022 | Future 2050 |
| B | 923 | 1098 | 1301 | 2471 |
| C | 1716 | 2041 | 1841 | 3498 |
| D | 1068 | 1271 | 1425 | 2708 |
| E | 982 | 1168 | 1365 | 2594 |

## 4.5. Simulation-based Approach to Optimize the Transportation Cost

Although Section 4.4 summarises the transportation cost and emissions estimated with a mathematic model under proposed networks with two alternative dry port locations, these costs and emissions can be further reduced by optimising the dry port location. Therefore, a simulation-based approach was considered to optimise the dry port location by using the Greenfield analysis method with "Supply Chain Guru" software. The feasibility of dry port location can be assessed by comparing the total network cost resulting from simulation results and previously discussed results. From the Greenfield analysis, the optimum location for the dry port was selected as Aluthmawatha as given in Figure 5. Based on that identified location, the Colombo Port-dry port-EPZ transport network was created using Supply Chain Guru Transportation Optimization as illustrated in Figure 6.

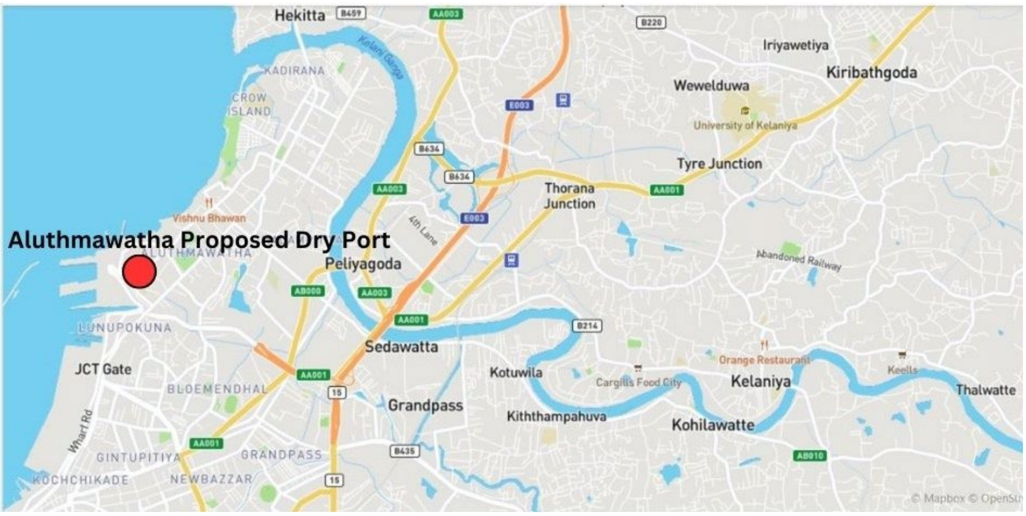


**Figure 5: Optimum Dry Port Location from Greenfield Analysis**

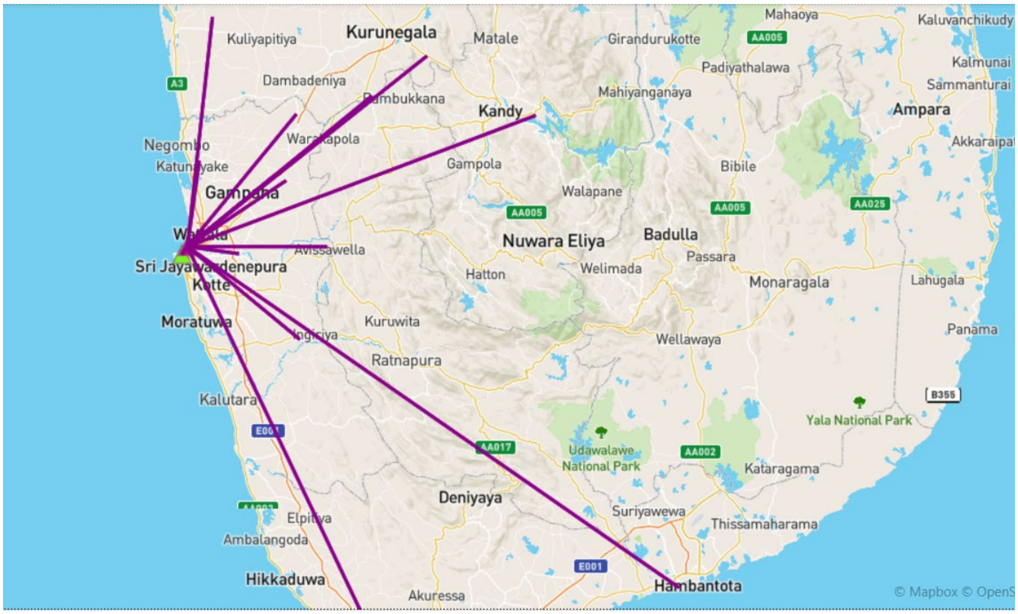


**Figure 6: Optimized Transportation Network**

Thereafter, the cost of the optimised network scenario based on the Aluthmawatha dry port location is compared with scenario A (current scenario). When considering the Aluthmawatha network, although four alternative network arrangements with scenarios B, C, D, and E can be considered, only Scenario C in which railway line operates between Colombo Port to dry port and road trucks are used between the dry port and EPZs is considered to maintain the brevity. To compare the feasibility of all three alternative dry port locations, the cost associated with Orugodawatta and Kerawalapitiya networks with Scenario C is also summarised in Table 11. Accordingly, the Aluthmawatha network suggested by Greenfield analysis indicates a lower cost than the current scenario (A) and it derives a lower cost than the both Orugodawatta and Kerawalapitiya networks with Scenario C.

**Table 11: Cost Comparison between Proposed and Optimised Networks**

| Scenario | Cost (Millions Rs.) | | |
| --- | --- | --- | --- |
| A | 157 | | |
| | Orugodawatta Network | Kerawalapitiya Network | Aluthmawatha Network (Optimized) |
| C | 164 | 177 | **134** |
| % cost increase compared to scenario A | 4.45% | 12.7% | **-7.5%** |

## 5. CONCLUSIONS

This study analyses the feasibility of a railway-based integrated containerised cargo transport network in Sri Lanka considering the issues related current road-based network for transporting import/export containerised cargo. Despite the advantages associated with the railway mode for freight transportation, this mode is used in a minimal scope in the Sri Lankan context, directly affecting the country's logistics performance. Although several railway tracks connected each terminal in the Port of Colombo, cargo trucks are currently the dominant mode of hinterland containerised cargo transportation. The inefficiencies in the current road-based network caused many problems for the importers and exporters while reducing their competitiveness in the international market due to high hinterland logistics costs. Moreover, significant environmental emissions are associated with road-based containerised cargo transportation networks in Sri Lanka. When considering the import/export operations, BOI companies mainly located in EPZs play a significant role. Therefore, this study proposes a more cost-effective and environmentally friendly transportation network connecting EPZs and the Port of Colombo.

This study consists of three main stages of analysis as follows. First, the issues related to the current road-based containerised cargo transportation system and the benefits of an integrated railway-based containerised railway cargo transportation network were identified based on a questionnaire survey conducted with 40 experts from related industries. Based on experts' opinions, two alternative dry port locations (Orugodawatta and Kerawalapitiya) were selected, and four alternative network configurations (scenarios B, C, D, and E) were developed for each dry port location. A mathematical model was developed to estimate each network scenario's total transportation cost and emissions, and results were compared with the costs and emissions derived from the current road-based network (scenario A). Finally, a simulation approach is used to select the optimum location for a dry port using the Greenfield analysis method with "Supply Chain Guru" software, and Aluthmawatha was selected as the optimum dry port location. Finally, the costs of all three alternative dry port-based transport networks were compared with the current road-based network (scenario A), and implications were discussed.

According to the questionnaire survey conducted with 40 experts current transportation was analysed based on their priorities. Accordingly, the current inefficient containerised cargo transport network caused delays in receiving imported shipments by local consignees, and customers experienced vessel-missing incidents due to the current inefficient containerised cargo transport network, as highlighted by respondents. Moreover, the current inefficient road-based cargo transportation network leads to delays and vessel-missing incidents, resulting in more cargo damages and high transport costs. Besides, environmental emissions, congestion, and pollution were highlighted by many respondents. These highlighted issues confirmed the necessity of improving the current road-based containerised cargo transport system. Then, the advantages of the proposed network, the ability to attract more transhipment cargo, the congestion reduction, the ability to facilitate many value-adding activities, and minimising customs operations delays, inspection delays, and documentation delays, among others, were highlighted. Besides, the proposed network would minimise capacity-related issues and inefficiencies in Colombo Port, including long TTT, and will result in higher logistics performance, environmental benefits, and financial profitability because rail freight transportation could be more profitable than rail passenger transportation for Sri Lankan Railways.

From the economic perspective, the transportation network through Orugodawatta dry port is more cost-efficient than the current road-based network (A) in some scenarios, with a considerable transport cost reduction. However, Kerawalapitya dry port was not feasible, because it would result in higher costs than the current scenario. A significant cost saving was observed in scenario B in which the total transportation network between Colombo Port and EPZs is operated by rail through a dry port, and in Scenario E, where a railway line is used between Colombo Port-dry port and dry port-selected EPZs with high cargo volumes while road trucks are used between remaining EPZs and dry port. Finally, when comparing the network cost associated with optimum dry port location, Aluthmawatha dry port, which is selected by simulation approach, this network derives a lower cost than the current road-based network (scenario A) and dry port-based Orugodawatta and Kerawalapitya networks.

When considering the environmental aspects with estimated CO2 emissions, all scenarios except Scenario C are more emission efficient than Scenario A in Orugodawatta dry port-based network. Also, the study identified that Scenario B, D, and E are more emission efficient than Scenario A in the Kerawalapitiya Dry Port-based network with current cargo volume, although no networks are environmentally friendly with future cargo volume. Moreover, the proposed Orugodawatta network is more environmentally friendly if using higher capacity trains between Colombo Port and dry port. Thus, all these findings from both economic and environmental feasibility analysis and the questionnaire survey results would help policymakers develop more sustainable hinterland transport infrastructure for import/export containerised cargo which will enhance the logistics performance of the entire country.

Although multiple network configurations were analysed, this study does not consider the proposed network's investment cost, which can be considered in future studies. Although this study focused on the transportation of containerised cargo between the Colombo Port and EPZs - which represent a significant portion of the country's import/export activities - it may be beneficial to expand the scope of the study to include the entire import/export cargo transportation. This would give a more thorough insight into the logistics and transportation challenges of the country and could potentially lead to more effective solutions and strategies for improving the transportation system.

## REFERENCES

[1] J. Rathnayake, L. Jing, and D. Erandi, "Truck turnaround time problem at the port of Colombo and a solution through inland ports," International Journal of Logistics Systems and Management, vol. 21, no. 4. 2015. doi: 10.1504/IJLSM.2015.070208.

[2] C.A. Kavirathna, T. Kawasaki, and S. Hanaoka, "Transshipment Hub Port Competitiveness of the Port of Colombo against the Major Southeast Asian Hub Ports", Asian Journal of Shipping and Logistics, vol. 34, 2018, doi: 10.1016/j.ajsl.2018.06.004

[3] K. Jayatilaka, L. Abanwela, K. Dahanayake, A. K. Kulatunga, and U. Dharmapriya, "Railway based container transportation to greening supply chains: a case study in Sri Lanka," Sustainable Built Environment At Kandy, Sri Lanka, Dec 2012. https://www.researchgate.net/publication/301551034, (accessed Mar. 09, 2023)

[4] G. Lubulwa, Malarz and S. Awang, "An investigation of best practice landside efficiency at Australian container ports", ATRF 2011 - 34th Australasian Transport Research Forum, 2014, https://www.bitre.gov.au/publications/2011/sp_003

[5] A. C. McKinnon and M. I. Piecyk, "Measurement of CO2 emissions from road freight transport: A review of UK experience," Energy Policy, vol. 37, no. 10, 2009, doi: 10.1016/j.enpol.2009.07.007.

[6] E. Andiç, Ö. Yurt, and T. Baltacioğlu, "Green supply chains: Efforts and potential applications for the Turkish market," Resour Conserv Recycl, vol. 58, 2012, doi: 10.1016/j.resconrec.2011.10.008.

[7] "The Fuel Price Hike: Repositioning Transport & Logistics Sector To Lead Economic Recovery In Sri Lanka - Colombo Telegraph." https://www.colombotelegraph.com/index.php/the-fuel-price-hike-repositioning-transport-logistics-sector-to-lead-economic-recovery-in-sri-lanka/ (accessed Mar. 10, 2023)

[8] A.S. Kumarage, "The Fuel Price Hike: Repositioning Transport & Logistics Sector to Lead Economic Recovery in Sri Lanka", 2022, Accessed: Mar. 20, 2023. [Online]. Available: https://www.colombotelegraph.com/index.php/the-fuel-price-hike-repositioning-transport-logistics-sector-to-lead-economic-recovery-in-sri-lanka/

[9] P. (Dr.) L. Edirisinghe and J. Zhihong, "Trucking Industry Perceptions of Congestion Problems and Potential Solutions to Container Transportation in Sri Lanka," Aug. 2014, Accessed: Mar. 10, 2023. [Online]. Available: https://papers.ssrn.com/abstract=2966003

[10] B. Sirimanna, "Better public transport key to reducing city traffic congestion, experts say", 2013, https://www.sundaytimes.lk/130728/business-times/better-public-transport-key-to-reducing-city-traffic-congestion-experts-say-54075.html

[11] "50184-001: National Port Master Plan | Asian Development Bank." https://www.adb.org/projects/50184-001/main (accessed Mar. 09, 2023).

[12] A. Heinold, "Comparing emission estimation models for rail freight transportation," Transp Res D Transp Environ, vol. 86, 2020, doi: 10.1016/j.trd.2020.102468.

[13] J. Maes & T. Vanelslander, "The use of rail transport as part of the supply chain in an urban logistics context", Distribution and Urban Freight Transport: Multiple Perspectives, 2011, doi:10.4337/9780857932754.00018

[14] V. Roso, J. Woxenius, and K. Lumsden, "The dry port concept: connecting container seaports with the hinterland," J Transp Geogr, vol. 17, no. 5, 2009, doi: 10.1016/j.jtrangeo.2008.10.008.

[15] E. Kurtulus, "Optimizing Inland Container Logistics and Dry Port Location-Allocation from an Environmental Perspective" Research in Transportation Business & Management. https://doi.org/10.1016/j.rtbm.2022.100839.