Sri Lanka Society of Transport and Logistics

Journal of South Asian Logistics and Transport
Volume 5 Issue 1 Month 2025
JSALT 5.1.2: pp. 25-48
DOI: https://doi.org/10.4038/jsalt.v5i1.102

PASSENGER DEMAND AND SERVICE SUPPLY IMBALANCES IN THE COLOMBO SUBURBAN RAILWAY SYSTEM: FINDINGS OF A GAP ANALYSIS ON MAIN AND PUTTALAM LINES

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ABSTRACT

An adequate supply of rail services in the Colombo suburban network is critical to meeting the needs of the current passenger clientele. Despite the increasing demand due to urbanisation and population growth, limited research has hitherto been undertaken on whether train services align with commuter needs, especially during peak hours. Using the Gap Analysis approach, this study examined the extent to which the provision of rail services met the demand of the current clientele in the Colombo suburban network. It focused specifically on the Main Line between Colombo Fort and Polgahawela, and on the Puttalam Line between Ragama and Chilaw. In this study, demand was estimated as revealed from ticket sales using the Origin-Destination (OD) Matrix, and supply was estimated based on the seating capacity of trains operated during peak hours. The stations with high and low demand were thereby identified analysing the patterns of passenger flows and sectional load factors. Even though the socio-economic benefits associated with increased railway mode share were found to be substantial, the outcomes of the study suggest that the potential to attract more passengers to the railway mode, especially on the Main Line, may be limited due to existing high load pressures. Alleviation of such pressures requires strategic interventions to reform the operating schedules and structures providing more express trains to stations with substantial demand and sections with high load factors while selectively removing stops at stations fetching lower demand. The alternative would be to augment the supply capacity, which will be highly capital-intensive.

Keywords: *Colombo sub-urban railway service, demand-supply gap analysis, origin-destination matrix, train load factor, train operations planning*

JEL Codes: R41, R48, L92, H54

1. INTRODUCTION

Railway transportation is an essential component of economic infrastructure, and it is recognised as a significant contributor towards the socio-economic development of nations, by providing cost-effective, safe, reliable and environmentally sustainable mobility of passengers and freight. In Sri Lanka, the railway network plays a vital role in transportation, facilitating the movement of both passengers and freight while linking urban centres and rural areas. The network of Sri Lanka Railways (SLR) spans 1,561 kilometres of rail tracks on seven different lines within the small island of approximately 65000 square kilometres of land area, in which approximately 396 trains are operated daily, providing mobility to around 3.72 million passengers per day [1].

In this network, the Colombo sub-urban railway segment is of particular importance as it is the most frequented by passengers and train operations. Literature reveals that nearly 8 million passenger kilometres would have been transported by railway within the Western Province prior to COVID-19 pandemic [2], representing nearly 30% of the total passenger kilometres transported within the entire network. A substantial share of this would have taken place within the Colombo sub-urban railway segment [3]. This segment has also been credited for its significant contribution towards the growth of the urban setting because it facilitated commuter access to the suburban areas and the business district [4].

Despite its importance, rapid urbanisation and population growth have changed the patterns of demand for railway transportation, presenting several challenges for the Colombo suburban train network [5]. Overcrowded trains, frequent delays, and widespread dissatisfaction of passengers are increasingly observed. This observation, common to all lines of the suburban railway network, points to a possible supply gap in meeting the demand. It is important and useful to research this critical issue. By identifying whether there is a demand-supply imbalance, and if so, in which corridors and traffic segments, and to which scale, policymakers could devise strategic interventions to improve the efficiency and attractiveness of the railway services possibly stimulating the overall economic growth and its sustenance [6].

It was in this realisation that the present research was undertaken to identify the gap between the supply of and demand for railway services in the Colombo suburban area, specifically focusing on the routes from Polgahawela to Colombo Fort in the Main Line and Chilaw to Ragama in the Puttalam Line (Figure 1). This railway segment was selected as a case study because it is one of the most patronaged areas of urban transportation, directly relating to the daily life of passengers and people living in the Colombo suburban region [7].

Figure 1: Railway Segments of the Main Line and the Puttalam Line in CSRN

Source: Authors' emphasis on *http://www.maps-of-the-world.net/maps/maps-of-asia/maps- of-sri*-lanka/large-detailed-map-of-sri-lanka-with-all-cities-roads-railroads-airpors-and-other-marks.jpg

2. BACKGROUND AND REFLECTIONS FROM LITERATURE

Rail transport plays a vital role in fulfilling the mobility needs of communities in developing countries, especially where population density is high. It offers numerous social benefits including domestic, labour, educational and daily life-related values to different groups [8]. In Sri Lanka too, the substantial socio-economic contributions made by the Colombo sub-urban railway services were amply reflected in the estimates made by Gunaruwan & Dilrukshi in their research on economic costs and externalities associated with urban mobility in the absence of railway services when Sri Lanka eased COVID-19 restrictions on domestic transport, with effect from

October 01, 2021, without resuming train operations [2]. Moreover, Kumarage found that the disruption of train services in the Western Province was a major issue that impacted many people, particularly those in the low-income bracket who rely on railway transport [4]. According to him, the daily movement of people to Colombo for work or schooling, among other essential needs, and then back to their residential areas, is a regular mobility cycle. This movement leads to major traffic jams, especially in the morning and evening peak hours. Rail transport helps in reducing these challenges while enhancing the overall transport interconnectivity in Colombo city [4].

In the developing world, the impact of public transport on the efficiency of urban functioning and the overall growth of the economy is a significant policy concern [9]. Ineffective transport systems significantly induce inefficiencies in cities and even entire countries, as concluded by Pojani & Stead [10]. This is further substantiated by Peftitsi who found that an increased demand pressure on public transport and the consequent congestion in public transport systems due to overcrowding are significant issues public transport operators face [11]. On the other hand, supply overcapacity in urban rail networks leads to inefficiencies, as the corresponding resources could otherwise be better utilised in other critical areas such as energy, sanitation, health, and education, as emphasised by Wijeweera et al. [12]. In capital-scarce developing economies, prioritising capital deployment is essential. Given that the railway industry may consist of supply and demand imbalances possibly leading to capital deployment inefficiencies [13] [14], perceiving the gaps between transit system supply and demand, and identifying localities or segments where either oversupply or undersupply prevails, together with corresponding quantitative estimates, become prerequisites vis-à-vis formulating strategic interventions [15] [16]. Such interventions would ensure that public transport systems effectively cater to demand while minimising operating costs [17] [18].

Kaeoruean [17] describes two types of "gaps": The first type estimates the gap between public transit capacity and the number of public transit riders per area, while the second type estimates the gap between demand and supply as a normalised index. The first type could yield a more realistic estimation of results, yet it relies heavily on data about passengers, which might be hard to obtain. The second type becomes useful when disaggregated passenger information is unavailable because it estimates demand values under its weighting scheme [17]. An analysis of the first type of gap described by Kaeoruean can be performed in Sri Lanka, given the availability of both Origin-Destination (OD) Matrix data to estimate the demand and information on train set formations and their timetables to reflect the supply capacity [17] [19].

3. MATERIALS AND METHODS

The primary technique used in this research to identify and quantify disparities between passenger demand for train travel and the supply of train service in each direction of travel,[1] was a systematic comparison of the "effective supply capacity" offered against the "revealed" demand within the selected sections in the Colombo suburban railway system [20].

The concept of railway service supply capacity can be understood in two main ways, as proposed in Ison, et al. [21], namely, (a) the "Theoretical Capacity", being the largest number and size of trains that can be included in the timetable so that its plans provide the required reliability, and (b) the "Effective Capacity" representing the number of seats or rail tracks that can meet the required demand of passengers or freight transportation. The present research adopted the "effective capacity" definition, in which service supply is the aggregate number of seats in the trains passing through each corridor within a given time frame. The analysis relied on the official train timetables of the Sri Lanka Railway, which enabled the calculation of passenger capacity based on the number of seats (40 in TVs, 80 in TCs and 56 in SCs) in trains serving at each station and operating within each segment.

On the other hand, the Origin-Destination (OD) Matrix contains data pertaining to the number of people travelling within a given time interval between each origin-destination pair in a traffic network, enabling estimation of the travel demand [22]. The OD Matrix as of September 2019 was used for this purpose.[2] The demand to and from each station was calculated by adding the total number of ordinary tickets purchased daily, and season tickets purchased monthly or quarterly assuming 22 effective working days per month of such "periodic ticket" usage. This would yield a reasonable approximation of the "revealed" demand for the service.[3] However, given that the suburban railway tickets purchased could be used for travel within the date of issuance, the exact time of travel by a purchaser of tickets cannot be known from data sourced from the OD Matrix. Therefore, an assumption was made in the present analysis to the effect that 80% of the tickets purchased would be used within the peak

[1] On the Main and Puttalam lines, train movement towards Colombo is identified as "Down Direction" travel, while "Up Direction" travel signifies movement away from the Colombo city.

[2] This was the latest available Origin-Destination Matrix at the time of carrying out the study.

[3] Data derived from the OD Matrix would reflect the "realised demand" as those have already expressed their preference through ticket purchases. The actual demand for rail travel is likely to be more if those unrealised trips (for various reasons) of "willing travelers" also are included.

commuting hours,[4] namely between 6.00 am - 9.00 am in the mornings and 4.00 pm – 7.00 pm in the evenings. For the purposes of this analysis, the peak period during the mornings was defined based on the "arrival time" in Colombo, which would be common to an overwhelming majority of passengers regardless of the differences in their embarking times at respective stations of origin, as their destinations are schools, offices or commercial establishments located in the Colombo city area. The departure time from Colombo of the majority of passengers, regardless of their respective times of arrival at destinations, was taken into account defining the evening peak period.

The demand and supply imbalances prevailing in the segments between Polgahawela and Colombo Fort (on the Main Line), and Chilaw and Ragama (on the Puttalam Line) were thereby examined,[5] reflecting the "first type" of gap analysis described by Kaeoruean [17].[6] For this purpose, the Demand/Supply Ratio per each entraining station (in the morning peak) and detraining station (in the evening peak) were estimated, reflecting the level of service capacity shortfall compared to demand at each station. The relationship expressed in Equation (1) was adopted in this exercise.

$$\text{Level of supply shortfall against demand at each station} = \frac{\text{Demand}}{\text{Supply}} \quad \text{--(1)}$$

However, the station-based demand to supply ratios are mere "static" pictorial views at each station, and do not reflect evolving load pressures in trains, particularly in the morning peak, when moving towards Colombo. This is because trains do not arrive "empty" at stations, but with passengers entrained at previous stops, and their loads get adjusted when passengers entrain and detrain at stations.

Therefore, to reflect the evolving loads in trains, particularly towards down direction during morning peaks where load levels tend to gradually increase, sectional Load Factors, represented by the ratio between the cumulative load of passengers in trains travelling within each section (adjusted by net additional loading[7] at the starting station of the section), were computed using the Equation (2).

$$\text{Sectional load factor} = \frac{\text{Passengers in trains along the section}}{\text{Capacity served}} \quad \text{----------------(2)}$$

[4] This assumption, though is not precise, would enable perceiving the "patterns" of demand and supply gaps. Refined data on train tallies would be necessary to work out more accurate percentages, which were beyond the reach of this analysis.

[5] Selection of the segment was based on the premise that the Main Line was the most frequented line in the entire rail network while the Puttalam line a branch-off from the Main Line at Ragama (Figure 1).

[6] The "second type" expresses the gap between demand and supply as a normalised index.

[7] Net additional loading at each station is defined as the entraining passenger load at each station for onward journey minus the on-coming load detrained at the same station.

It is noteworthy that the supply capacity within sections is subject to increasing pressure when a net additional demand is exerted at the beginning of sections. This is the situation generally expected (unless special circumstances apply) when moving closer to Colombo in the down direction during morning peaks. The opposite dynamics could be anticipated during the evening peak when moving away from Colombo in the up direction.

The service supply gaps in relation to demand were intended to be examined through this approach. It was expected that such an analysis would reveal critical imbalances, if any, calling for policy and managerial intervention.

4. ANALYSIS AND RESULTS

4.1. Transport Services Provided and Associated Externalities

At the very outset, the data provided in the O/D matrix enabled the estimation of passenger kilometres transported within the selected railway segment. It was revealed that the railway trips originated and ended within the Polgahawela – Colombo Fort and Chilaw – Ragama segment would correspond approximately to 3.3 million passenger kilometres on average per working day, as summarised in Table 1.

Table 1: Passenger km per day transported by railway within the selected segment

	Main Line	Puttalam Line	Both Lines
Down Direction (during morning peak)	1.48 Mn	0.19 Mn	1.67 Mn
Up Direction (during evening peak)	1.47 Mn	0.16 Mn	1.63 Mn
Both directions (within peak periods)	2.95 Mn	0.35 Mn	3.30 Mn

Source: Author compiled, based on statistics provided in the O/D Matrix - 2019

This implies that the passenger kilometres transported by railway within the selected railway segment would be approximately 40% of that in the Western Province, and around 16% of the total railway passenger kilometres within the entire network of the country. This amply demonstrates the significant importance attributable to the study area; within which, the Main Line, with around 90% of the demand catered in both lines, standing out being the most prominent.

Based on the estimates made by Gunaruwan & Dilrukshi in 2022, it could be estimated that every passenger kilometre transported by train would save approximately 0.0053 litres of diesel to the national economy, compared to transporting the same by bus [2].[8] This implies that the train services provided within the selected segment, regardless of the difficult conditions, would be saving the nation approximately of 17300 litres per day, or USD 11300 per day of foreign exchange saving, compared to that passenger kilometres having to be transported by bus. This saving would be few-fold greater if the comparison is made considering motorcycles, there-wheelers or private cars as alternative modes of transport.

This finding points at the importance of diverting more and more passengers away from road-based transport modes towards railway. A 10% increase in the railway patronage in the study area, corresponding to 0.33 Mn passenger km per day (or, approximately 87 Mn per year [9]), by diverting the same passenger traffic away from bus transport, for instance, would be saving 0.45 Million litres of diesel per year, or 1.2 Mn litres of petrol, if motorcycle mode is compared as the alternative (Table 2).

Table 2: Economic and environmental benefits expectable from increased railway patronage[10]

10% increase in rail passenger km within the study area = 0.33 Mn/day or 87 Mn / Yr	Bus mode as the alternative	Motorcycle mode as the alternative
Fuel saving potential per year	0.45 Mn litres of diesel	1.2 Mn litres of petrol
Foreign exchange saving on fuel per year	USD 0.30 Mn	USD 0.78 Mn
CO_2 emission reduction potential	1.19 Mn kg per year	2.86 Mn kg per year

Source: Author compiled, based on Gunaruwan & Dilrukshi [2], and on CO_2 emissivity (2.6 kg/l of diesel, and 2.4 kg/l of petrol) published in 2022 by Ecoscore [23]

The economic benefits of increasing railway patronage in the main Line and Puttalam Line transport corridors are thereby evinced. The fuel savings per year that could be expected through an assumed 10% augmentation of the current railway ridership within the Polgahawela – Colombo and Chilaw – Ragama railway segments alone would give rise to USD 0.30 Mn saving of foreign exchange per year if the mode shift would come entirely away from Bus transport. The foreign exchange saving

[8] This estimate has been made based on an average of 1000 passengers per train and 40 passengers per bus, throughout. It basically approximates to “seating capacity” in trains and buses. This saving intensity could be more (or less) depending on higher (or lower) average load factors in trains, or on lower (or higher) average load factors in buses.

[9] If only those 264 working days per year (22 days x12) are taken into account.

[10] The above estimates are for a hypothetical 10% augmentation of Passenger Km transported by Railway within the selected Segment away from the alternative modes considered.

would be much greater, at around USD 0.78 Mn per year, if the same is compared against the motorcycle mode. Thus, an increase in railway mode share, however small that could be, against road-based modes, would be extremely healthy to a country facing foreign exchange shortages and already shouldering a heavy foreign debt burden.

The sustainable mobility provided by rail transportation also is yet another factor that has to be considered in this regard. As estimated in Table 2, a reduction of combustion emissions to the tune of 1.19 Mn Kg of CO_2 per year could be realised within the study area if a 10% increase in railway ridership can be achieved instead of catering to the same passenger demand by bus service. This saving would become nearly 140% more, at around 2.86 Mn Kg of CO_2. if the same augmentation of railway ridership takes place as a result of deviation from the motorcycle mode.

It is evident, therefore, that augmentation of the railway mode share in the urban sector, as revealed from the results of the analysis of the Polgahawela – Colombo Fort and Chilaw – Ragama railway segments, could yield substantial economic and environmental benefits to the nation. In this respect, the scope and opportunities for attracting more passengers to railway mode merit exploration. For this purpose, it is necessary that existing demand and supply gaps in the study area and prevailing loading patterns of trains are examined.

4.2. Estimation of Demand for Travel and Supply Capacity Served

Based on the revelations of foregone analysis, an initial attempt was made to map the demand for train services (computed in terms of passenger kilometres, as revealed through the purchase of ordinary and season tickets, made available in the O/D Matrix) onto the supply capacity offered (by working out train kilometres operated, using the train time tables that prevailed during the period subject to analysis), pertaining to the Main Line and Chilaw Line railway corridors subject to analysis. The results are summarised in Table 3.

Table 3: Average passenger km per train km in the morning and evening peaks

	Main Line	Puttalam Line	Both Lines
Passenger km	2.95 Mn	0.35 Mn	3.3 Mn
Train km	1762.6	776.3	2538.8
Average Passenger km / Train km	1671.1	452.0	1298.4

Source: Authors' construct

Several findings pertaining to the two lines were made through the above aggregate analysis. First, it became evident that the Main Line is over-congested, with nearly

1670 passengers on average per train. While the exact capacity of each train may differ depending on their type (DMU or locomotive hauled train) and length (single DMU or Double DMU, and number of coaches per train), this average load level would represent an average overloading level of more than 65% if 1000 passengers per train is to be considered an acceptable loading level. Second, the Puttalam Line shows a relatively lighter overall loading, with less than 50% of such an "acceptable loading level" in trains, possibly reflecting greater scope for attracting more passengers towards the railway, deviating away from road-based transport modes. Third, the average loading of over 1200 passengers per train is likely to indicate that the trains within the section between Ragama and Colombo Fort, where trains running on both Main and Puttalam lines operate parallelly, would be relatively lighter compared to the sections in the Main Line just beyond Ragama. Finally, the outcomes of the research also enlightened the decision makers and train operations planners on the necessity of studying the present schedules, and also of examining the possibilities of easing existing loads in trains, possibly by rescheduling the stopping stations in existing services as well as by attempting to introduce new trains operated, particularly between Colombo and Gampaha. A medium-term target of 1000 passenger-km on average per train km could be feasible if the necessary resources could be injected and the available resources are effectively deployed. Achieving a significant shift of passengers away from road-based modes towards the railway mode could be feasible only if conducive strategies are implemented; formulation of which would call for further detailed analyses at more disaggregated levels, specifically focusing on identifying station-based demand-supply gaps and examining section-by-section train loading patterns.

4.3. Examination of Station-wise Demand - Supply Gaps

It was to step into a more detailed gap analysis that the train service supply capacities served at each station were compared against the average travel demand originating at the same stations in the selected segments of the suburban network. In this first stage of disaggregated analysis, the station-by-station demand was estimated using the data published in the OD Matrix for September 2019, where average daily demand for entraining at each station for down direction travel (during the morning peak) and for detaining at the same stations after up-direction travel (during the evening peak), was assumed to be 80% of the issuance of tickets (both daily tickets and season tickets). The train service supply capacities served at each such station during the morning peak (for entraining into down-direction trains), and during the evening peak (for detraining from up-direction trains) were estimated using the information sourced from the Sri Lanka Railways, about train formations and operating schedules. The estimates so made on Demand and Supply were thus used to work out a Demand/

Supply Ratio at each station, reflecting the relative shortfall of station-based supply capacity served compared to the demand during the period subject to analysis. These Demand/Supply estimates for the Main Line and Puttalam Line, made using Equation (1) above, are depicted in Figure 2 (in the down direction during the morning peak), and in Figure 3 (in the up direction during the evening peak).

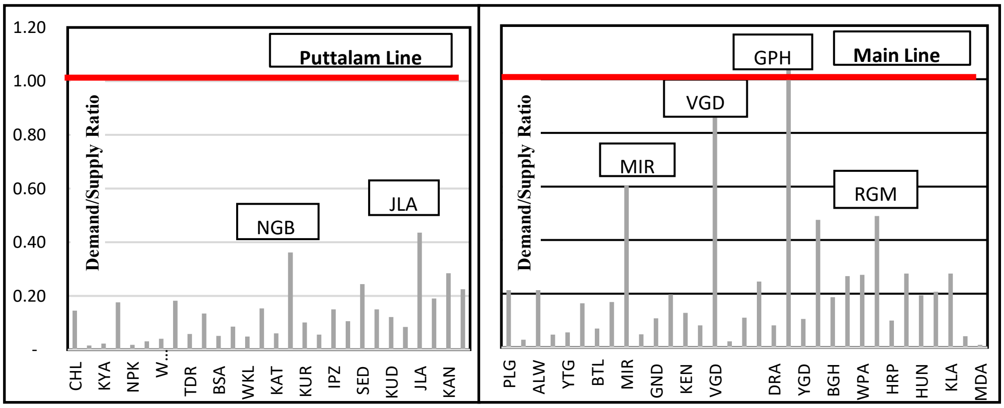

Figure 2: Demand/supply ratios at entraining stations during an average morning peak - (down direction)

Source: Authors' estimates

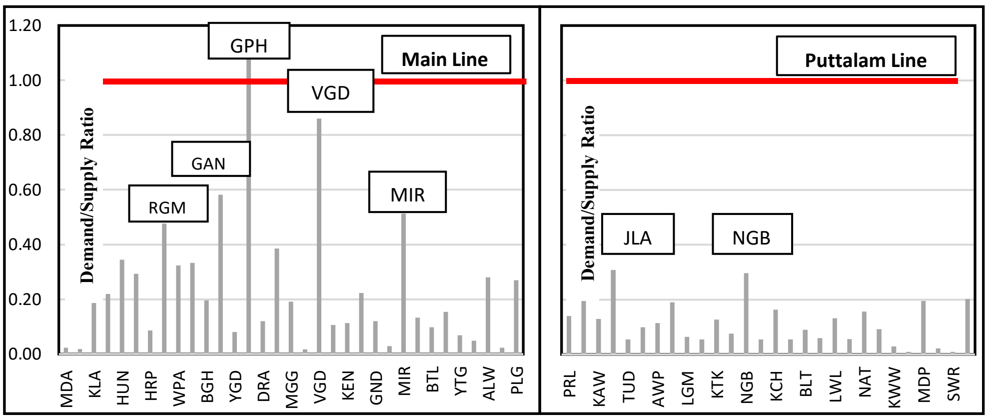

Figure 3: Demand/supply ratios at detraining stations during an average evening peak - (up direction)

Source: Authors' estimates

The above analysis enabled several characteristic revelations. First, it became evident that the Main Line was bearing much lighter demand pressure than the Puttalam Line compared to their respective supply capacities served, both in the up direction (in the evenings) and in the down direction (in the mornings). A few stations such as Gampaha, Veyangoda, and to a lesser extent Mirigama and Ragama, appeared to have high ratios reflecting comparatively heavier demands for the supply capacity served. Gampaha station on the Main Line, in particular, with a Demand/Supply ratio of above 1.0, indicated inadequacy of supply capacity compared to passenger demand.[11] In the Puttalam Line, a lower level of demand pressure was reflected in Demand/Supply ratios below 0.5. However, a few stations such as Negombo, Ja-Ela, and Kandana recorded somewhat significant Demand/Supply ratios, both in the down direction (in the mornings) and in the up-direction (in the evenings). This may be an indication of comparatively significant levels of mobility-related activity around those areas. Third, several stations, both in the Main Line (such as Heendeniya-Pattigoda, Walakumbura, or Bujjomuwa) and Puttalam Line (such as such as Sawarana and Nelum Pokuna) appeared facing much lighter demand pressure, as reflected by relatively smaller Demand/Supply Ratios.

It may be pertinent to realise that the service supply shortfalls, indicated through the above examined station-based demand/supply ratios, are likely to be under-estimates of congestion pressures in trains, and difficulties faced by passengers when boarding at stations for down-direction travel in the mornings. This is because the down-direction trains during the morning peak do not arrive empty when reaching individual stations, except when commencing the journey at those very stations. Therefore, the congestion in trains is likely to be much more severe than the service inadequacy levels reflected by station-wise Demand/Supply ratios, particularly at stations such as Gampaha or Veyangoda on the Main Line, where local pressure exerted alone appeared quite heavy. This effect applies to stations such as Negombo and Ja-Ela on the Puttalam Line as well.

4.4 Analysis of Sectional Loading of Trains

The second stage of the disaggregated analysis attempted to estimate the sectional train loading patterns during the morning and evening peaks on the Main Line and the Puttalam Line in the Colombo sub-urban railway system. This attempt was made with a view to delving deeper into the level of the demand pressure in trains. Selected stations were paired to form "sections". The sectional loading of trains was computed using Equation (2), which depicts the average train Load Factors during each of the studied peak periods. Loading on the Puttalam Line was integrated with that of the Main Line when the pattern between Ragama and Colombo Fort was examined.

Results of this analysis of the down direction on the Puttalam Line and Main Line during the morning peak are depicted in Figure 4, while the corresponding results about up- direction in the evening peak are represented in Figure 5.

[11] This inadequacy is bound to be harder if the actual travel share in the peak period is greater than 80%.

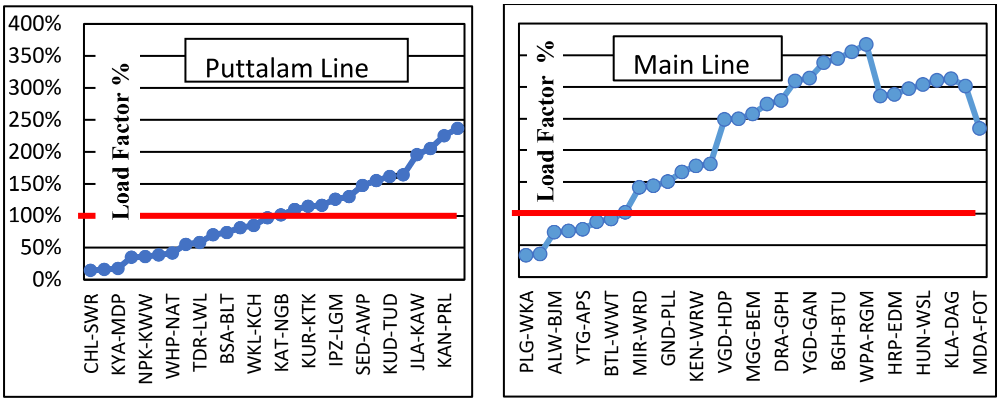

Figure 4: Train loading pattern - down direction during the morning peak

Source: Authors' estimates

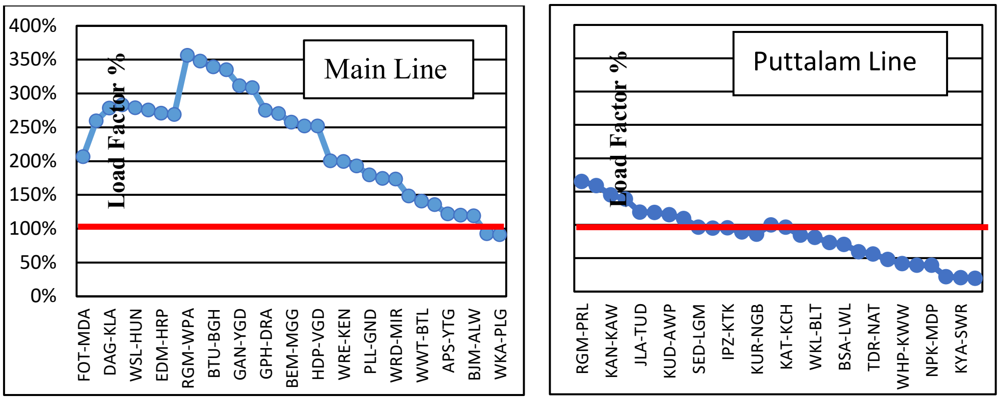

Figure 5: Train loading pattern - up direction during the evening peak

Source: Authors' estimates

The sectional analysis of train loading in the down direction of the Main Line (Figure 4) reveals a pattern where the load factor increases steadily from Polgahawela station downwards. Particularly sharp augmentations could be observed around Mirigama, and Veyangoda, which also correspond to the findings of the demand/supply analysis, which revealed significant demand pressures at those stations. The highest demand/supply ratio found at Gampaha station (Figure 2) did not appear to reflect such a jump in train loading pattern, possibly owing to down-direction trains commencing afresh from Gampaha, thus leading to a somewhat easing of loading. The sharp drop observed in the loading curve just below Ragama (Ragama-Horape section) could be understood as the outcome of integrating the Main Line with the Puttalam line at Ragama; trains on the latter appear noticeably less loaded than those on the Main Line when approaching Ragama. Therefore, the load factor would be averaging to a lower level than that experienced on the Main Line down to Ragama, and to a higher level than that on the Puttalam Line.

A similar pattern, but in the reverse order, is apparent in the loading patterns in the up-direction during the evening peak (Figure 5). Loading levels rapidly increasing up to Dematagoda, naturally owing to the entraining of large numbers of passengers for outbound travel from Colombo in the evenings, reduces gradually there-onwards up to Ragama. A sharp augmentation observed on the Main Line, just beyond Ragama (Ragama-Walpola section), is noteworthy. In addition, Figure 5 also revealed an increase in the Load Factor beyond Negombo up to Kochchikade on the Puttalam Line during the evening peak, reversing the gradually declining loading pattern before and after that section. These peculiarities need explanation and possibly would call for further investigation.

To understand the congestion severity the passengers would be experiencing during their train travel, the shares of track lengths with different loading levels in the two lines were examined as the next stage of the analysis; the results being summarised in Table 4 (for the Main Line) and Table 5 (for the Puttalam Line).

Table 4: Load factors and share of distances - Main Line

Load Factor	Segment	Distance (km)	Share
Down Direction (in the Morning Peak)			
< 100%	Polgahawela (PLG) – Wilwatta (WWT)	21.72 km	30%
100% - 200%	Wilwatta (WWT) – Veyangoda (VGD)	14.63 km	20%
200% - 300%	Veyangoda (VGD) – Gampaha (GPH)	10 km	14%
> 300%	Gampaha (GPH) – Dematagoda (DAG)	23.87 km	33%
Up Direction (in the Evening Peak)			
> 300%	Maradana (MDA) – Gampaha (GPH)	25.63 km	35%
300% - 200%	Gampaha (GPH) – Veyangoda (VGD)	10 km	14%
200% - 100%	Veyangoda (VGD) – Alawwa (ALW)	28.2 km	38%
< 100%	Alawwa (ALW) – Polgahawela (PLG)	8.16 km	11%

Note: Load factor appears becoming slightly below 300%, just at RGM up to HRP

Source: Authors' Estimates

Table 5: Load factors and share of distances - Puttalam Line

Load Factor	Segment	Distance (km)	Share
Down Direction (in the Morning Peak)			
< 100%	Chilaw (CHL) – Kattuwa (KAT)	40.33 km	60%
100% - 200%	Kattuwa (KAT) – Kapuwatte (KAW)	21.58 km	32%
200% - 300%	Kapuwatta (KAW) – Ragama (RGM)	5.01 km	8%
Up Direction (in the Evening Peak)			
200% - 100%	Ragama (RGM) – Seeduwa (SED)	12.51 km	19%
< 100%	Seeduwa (SED) – Chilaw (CHL)	54.41 km	81%

Source: Authors' estimates

High train load factors, indicated in Table 4, revealed the crowded conditions and potential discomfort experienced by passengers and possible safety risks as well, in the Main Line, particularly in sections such as Veyangoda – Gampaha (between 200%-300%), Gampaha-Dematagoda (exceeding 300%)[12] in the down direction, and Maradana - Gampaha (above 300%) and Gampaha – Veyangoda (between 300% - 200%) in the up direction. It is noteworthy that little over one-third (35%) of the entire distance of 73 km between Dematagoda and Polgahawela in the Main Line studied, appears to have train load factors above 300%, in both directions, reflecting a severe short-supply of train service capacity.

In contrast, the Puttalam Line (Table 5) appears to have a much lower imbalance between supply and demand compared to the Main Line (Table 4). Its lower and moderate train loading levels suggest relatively smoother travel conditions throughout. The section from Chilaw to Kattuwa, with a load factor below 100%, covers a significant portion (60%) of the route, indicating the possibility of attracting more passengers through a mode shift from road to railway. Only 8% of the distance of the Puttalam Line examined showed load factors exceeding 200% towards the down direction during the morning peak, while no section with Load Factors above 200% beyond Ragama could be observed during the evening peak on the Puttalam Line.

In summary, the localities and sections where significant overloading is indicated, particularly on the Main Line, do not offer promising scope for attraction of any further mode shift towards the railway, unless new capacity is added or existing operating schedules are amended to introduce more express trains, at least reducing

[12] Except for the very short distance between Ragama and Horape in the down direction during the morning peak

travel time, if not easing in-train congestion and discomfort. The section between Veyangoda and Ragama, and particularly between Veyangoda and Gampaha, appears of prominence in that regard. On the contrary, the stations and sections with an over-supply of service, in both lines and Puttalam Line in particular, might be implying an under-utilization of available capacity. Yet, those would offer scope for attraction of more passengers to trains, compared to the section where the demand has already exceeded supply capacity representing over-crowded conditions, distracting even the existing clientele.

5. FINDINGS AND DISCUSSION

The findings of the analysis led to several important insights. Firstly, it is evinced that the railway system contributes significantly towards meeting the mobility needs in the Colombo sub-urban area. The main line, in particular, is hauling approximately 2.95 Mn passenger km per day, during peak periods of working days. The train loading is the highest on the Main Line, with the section between Gampaha and Ragama having load factors over 300%, which even exceeds 350% in sections approaching Ragama in the down direction during the morning peak. Gampaha, Veyangoda, Mirigama and Ragama are stations with high demand/supply ratios, possibly reflecting their importance as residential nodes, as well as urban townships within the Colombo Metropolitan area.

Secondly, the Puttalam Line appears to be carrying much lower passenger loads relative to its supply capacity, when compared to the Main Line. This may be owing to direct competition from road transport, particularly from buses plying along the A3 Highway which runs almost parallel to Puttalam line. The Main Line faces no such direct competition from alternative road-based transportation because the Main Line Corridor runs at a distance from, and almost splitting into two segments the land mass in between, the A1 (Colombo – Kandy) and A3 (Colombo – Puttalam) Highways. Therefore, it is quite understandable that the Main Line captures a relatively high demand for railway travel compared to the Puttalam Line as also indicated from the results of this study, and deserves further strengthening of its supply capacity.

Thirdly, several characteristic features in loading patterns were revealed through train loading analysis, particularly in and around Ragama on the Main Line, and also just beyond Negombo in the Puttalam Line. The sharp drop in train loading pattern at Ragama (Ragama - Horape section) appears to be stemming, as discussed above, from the integration of down-direction trains coming along the Puttalam Line with those in the Main Line. However, the increasing loading pattern continues thereafter, until Dematagoda, and reduces from where downwards, an observation that was expected owing to large numbers detraining at stations within the Colombo region; Dematagoda being the first such station when entering into the city from the northern end. Conversely, the similar, but opposite, characteristic increase of passenger loading could be observed in the Main Line up-direction trains, just beyond Ragama (Ragama – Walpola section) as indicated in Figure 5. This could be owing to two reasons; first, the deviation away at Ragama of relatively lightly loaded trains running on the Puttalam Line (reducing the denominator of the ratio), and second, those down-direction passengers coming along the Puttalam Line in the evening peak to Ragama and boarding to Main Line trains for up-direction travel there-onwards. This short-lived increase appears getting reversed once again after Walpola station, quite understandably, with subsequent detraining of more passengers than entraining at stations beyond Ragama, causing a gradual drop of the train load factors in the sections thereafter.

Fourthly, the significant upward shift of load factor beyond Negombo, but only up to Kochchikade, is worth analysing further. A possible cause behind this peculiar dent in the Load Factor profile could be the termination of several up-direction trains at Negombo, while passenger demand continued to be relatively high up till Kochchikade. This resonates with the long-standing remark by the veteran transport professional John Diandas to the effect that up-direction trains on the Puttalam Line terminating at Negombo should be extended to Kochchikade, treating it (and not Negombo) as the boundary of the Colombo sub-urban railway service along the Puttalam Line [24]. This claim could be looked at favourably also because Kochchikade is the further-most motorway junction and township in the Western Province along the Colombo-Puttalam Highway (A3), closer to which both B228 (Kochchikade – Halpe Road) and B419 (Thoppuwa – Madampe Road) join the A3 Highway. Besides, on Puttalam Line, Kochchikade would potentially be the closest railway station at the north-most end of the Western Province for rail-bus modal interchange, particularly for bus route numbers 242 (Negombo – Mirigama via Halpe) and 34 (Negombo – Kurunegala, via Kochchikade and Thoppuwa).

Fifth, it could be perceived also that there are stations recording significantly low Demand/Supply ratios, on both the Main Line and the Puttalam Line. Lesser demands giving rise to relatively lower Demand/Supply ratios could be reflecting specific local conditions and usage patterns such as lower population densities or less economic activity, resulting in fewer commuters using rail services. This revealed demand through the issuance of tickets, however, could also be a result of the behaviour of passengers tending to purchase tickets to (or from) a larger nearby station instead of the station closest to their residential locality. This is often done because larger stations typically offer better facilities, more frequent train services, and greater connectivity, making those more convenient for passengers. Therefore, what is estimated based on data sourced from the Origin-Destination (O/D) Matrix could tend to be less than the natural demand that would correspond to socio-demographics at smaller stations located closer to such larger townships. An example would be Heendeniya – Pattigoda (HDP) station on the Main Line, where passengers may be buying tickets, particularly season tickets, to (and from) Veyangoda, a much larger nearby city that offers more amenities and services. As a result, there is lower demand indicated at HDP based on the pattern of purchasing train tickets. This may also be the case pertaining to stations in the Puttalam Line, such as Sawarana (SWR) or d Kakkapalliya (KYA) near Chilaw (CHL).

Next, it may be opportune also to take note of the low demands/supply ratios observed, in both down direction (in Figure 1) and up direction (in Figure 2), at both Dematagoda (DAG) and Maradana (MDA). These observations are quite normal and expected, because there could only be very few passengers buying tickets for journeys (a) *originating* from those two stations for further down-direction travel on the Main Line destinations in the morning peak, and (b) *terminating* at those two stations as trip destinations, having originated from either MDA or FOT, in the evening peak. These are stations within the Colombo city where passengers, in large numbers, disembark after down direction travel in the mornings and embark into trains for up direction travel in the evenings, when both Main and Puttalam lines are concerned.

It is evident therefore that several factors are crucial for comprehending the pattern of gaps in demand and supply within the Colombo sub-urban railway system. These include peculiarities associated with joining two railway lines at junction stations (in this case, Ragama in both directions), possibilities of rail-road interchange, specificities pertaining to travel nodes such as stations within the Colombo city, as well as socio-demographics at different localities. Such understanding also is necessary when considering formulation of strategic interventions towards improving the train services and easing public mobility.

Finally, the study outcomes also indicated that the Colombo sub-urban railway system, in spite of its numerous limitations, is yielding substantial socio-economic benefits to the nation. If not for the nearly 3.3 million passenger kilometres hauled by train daily, more than 40,000 bus kilometres would have had to be operated within the study area (assuming that each bus would carry 80 passengers in all times). This implies at least 400 more buses would be required at an assumed average utilisation level of 100 km of operation per bus, which requirement would be more if lesser kilometres operated in average per bus, or if lesser average passenger loads were carried in buses. Therefore, fuel saving, combustion emission reduction, and foreign exchange saving benefits would have accrued to the society and to the national economy, in addition to alleviation of road congestion and associated safety risks. The strategic importance of striving towards increasing the railway patronage within the Colombo sub-urban transport system, thus was amply demonstrated.

5.1. Insights for Further Research

In addition to the significant revelations made about the gaps between the demand for and the supply of railway services in the chosen segment of the Colombo suburban railway system, the results of the present study also enabled insights on possible avenues for broadening and deepening the examination through future research. First, an expansion of the examination to cover the entire Colombo sub-urban railway system, including Coastal Line and Kelani Valley Line as well, could be suggested to fathom into broader systemic issues and interactions, so that the outcomes of the present study could be tested and validated for generalisation across the system with different technical features and economic, social, and demographic characteristics. This will automatically alleviate the limitation in the present analysis where the trips originated or terminated outside the selected segment had to be excluded. Second, the analysis may be furthered to undertake train-by train tallies of passenger entraining and detraining at stations, which would enable more accurate examination of passenger loading levels, and more precise identification of scope for operational improvements. Third, the different types of train sets and their different characteristics (such as S8, S9, and S10 with their longitudinal seat arrangements with higher standing capacity, compared to coaches in locomotive hauled trains, their lengths with number of coaches and multiple units per train, etc) could be specifically focused, which would enable estimating the effective supply capacity served and corresponding in-train congestion levels, leading to a much refiner understanding of the “discomfort levels” felt by passengers boarded in trains. Finally, it may also be recommended to adopt modern IT-based tools to obtain more accurate information of train operations and passenger loading patterns, enabling refiner examination leading to the formulation of more effective strategic interventions.

6. CONCLUSIONS AND RECOMMENDATIONS

The outcomes of the research revealed that the Main Line and Puttalam Line corridors of the Colombo suburban railway system cater substantially to provide public passenger transport mobility in the country; the segments studied in the two lines being found transporting over 40% of railway travel within the Western Province, and nearly 16% of that in the entire network of the Country. The socio-economic benefits yielded to the nation, including saving on fuel combustion and reduction of associated greenhouse gas emissions, as well as economising on foreign currency-intensive imports of petroleum products, pointing at the strategic importance of further augmenting the railway mode share in Colombo sub-urban passenger transportation.

However, the results of the analysis also brought suggestive evidence to infer that any such augmentation of railway mode share within the Colombo sub-urban region, would not be promising owing to high levels of congestion in trains, particularly on the Main Line during the peak periods, which represent certain deterrence vis-à-vis attraction of more passengers to railway. The section between Gampaha and Dematagoda on the Main Line, with loading levels over 300%, is of particular significance in this regard. Even on the Puttalam Line, though with much lower comparative loading levels, a significant portion (60%) was found to have loading levels over 100%. Moreover, given the fact that these results corresponded to two explicit assumptions; namely, (a) that only 80% of the daily demand reflected in the O/D Matrix would travel in trains during peak hours, (b) that the down-direction trains commencing from origins beyond Polgahawela (in the Main Line) and Chilaw (in the Puttalam Line) entered the railway segments subject to analysis with insignificant passenger loads, and (c) that the passengers buying tickets at stations on the Coast Line or Kelani Valley line and travelling to stations in the Main Line or Puttalam Line, as well as those passengers travelling to destinations beyond Polgahawela (in the Main Line) and beyond Chilaw (in the Puttalam Line) in the up-direction, were excluded from the computations, the actual overloading level in trains could be even more severe than what was indicated in the findings of this research.[13]

Thus, it could be inferred that to attract more passengers to the railway mode, a strategic approach would have to be formulated and adopted, particularly with respect to the Main Line corridor, aiming at easing the existing passenger loads in trains within the Colombo sub-urban region. In this respect, (i) reforming the existing train operating structure and schedules, and (ii) expanding the train service supply capacity, could be recommended for exploration. In respect of the former strategy, possibly pursuable in the short-term given its non-involvement of capital infusions, the localities and sections where over-supply was indicated could be focused with priority. This is because, those could offer scope for attracting more passengers, or for selectively removing train stops at such stations so that more express trains could be provided, through timetable rescheduling, to significant travel-node stations and to sections with heavy loading levels on both Main and Puttalam lines, found in this research. That could potentially enable achieving an improved utilisation of existing

[13] A train-by-train compilation of passenger tallies and broader coverage of lines and areas of focus would be required for a more refined analysis alleviating the apparent limitations of this study, which were beyond the scope of this research but could be seeded for future research.

resources for a better quality of service supply. Enhancing information systems and introducing flexible ticketing options aligned with passenger behaviours could further optimise the network's functionality and appeal. On the other hand, resorting to the latter option, at least to a certain extent, is unlikely to be avoidable in spite of resource constraints involved, given the fact that the overall average load levels in trains plying in the segment subject to analysis appear standing high, over 1200 passenger kilometres per train kilometre. Thus, an appropriate combination of the two strategic options, determined based on the outputs of the present study as well as from further research in the future which could help validate the findings of this research, would be desirable [25].

It may therefore be concluded that the research outcomes have underscored the importance of a balanced approach combining the dual strategy of short-term operational improvements and long-term infrastructure development to address immediate passenger needs in the Colombo sub-urban railway network, while possibly laying the groundwork for sustainable growth in the railway sector of the entire country. In that respect, the findings of the present research would be policy-relevant, and furthering and refining those through future research could possibly be conducive towards formulating and implementing a national and railway sectoral policy framework, potentially enabling the nation to benefit from an efficient, sustainable, and passenger-friendly railway system.

REFERENCES

[1] "Department of Railways - Overview," 2023. [Online]. Available: https://www.railway.gov.lk/web/index.php?option=com_content&view=article&id=138&Itemid=0&lang=en.

[2] T. L. Gunaruwan and M. H. S. Dilrukshi, "Contributions of railway services towards socio-economic equity and environmental sustenance: Reflections from post-lockdown restrictions on train operations in the Western Province of Sri Lanka," University of Colombo review, vol. 3, no. 1, pp. 182-196, August 2022.

[3] "Annual Report 2018 | Central Bank of Sri Lanka," 2018. [Online]. Available: https://www.cbsl.gov.lk/en/publications/economic-and-financial-reports/annual-reports/annual-report-2018.

[4] A. S. Kumarage, "Urban Traffic Congestion: The Problem & Solutions," Economic Review, Sri Lanka, vol. 28, no. 6/7, pp. 17-20, 2002.

[5] B. Weeraratne and C. Karunanayake, "TOWARDS A DEVELOPED URBAN TRANSPORTATION SYSTEM: LESSONS FOR SRI LANKA," Institute of Policy Studies of Sri Lanka, Colombo, Sri Lanka, 2022.

[6] G. Tiwari, "Urban transport priorities – meeting the challenge of socio-economic diversity in cities: a case study of Delhi," The International Journal of Urban Policy and Planning, vol. 19, no. 2, pp. 95-103, 2002.

[7] "CSRP | Colombo Suburban Railway Project - Sri Lanka," [Online]. Available: https://www.csrp.lk/main_line.php?id=3.

[8] P. Patarchanov, "Railway Transport in Regional and Local Development of the Rural Areas - Challenges and Opportunities," International Multidisciplinary Scientific GeoConference SGEM, June 2019.

[9] N. Ittyerah, N. Korattyswaroopam and J. Pucher, "The crisis of public transport in India: overwhelming needs but limited resources," Journal of Public Transportation 7, pp. 1-20, 2004.

[10] D. Pojani and D. Stead, The Urban Transport Crisis in Emerging Economies: An Introduction, Springer, 2o17.

[11] S. Peftitsi, "Public transport demand and supply management under uneven passenger distributions," 2022. [Online]. Available: https://trid.trb.org/View/2075206.

[12] A. Wijeweera, H. To, M. Charles and K. Sloan, "A time series analysis of passenger rail demand in major Australian cities," Economic Analysis and Policy, vol. 44, no. 3, pp. 301-309, August 2014.

[13] N. Seth, S. Deshmukh and P. Vrat, "Service quality models: A review," International Journal of Quality & Reliability Management, vol. 22, no. 9, pp. 913-949, 2005.

[14] V. Jain, S. Wadhwa and S. Deshmukh, "Enhancing flexibility in supply chains: Modelling random demands and non-stationary supply information," International Journal of Computer Integrated Manufacturing, vol. 22, no. 8, pp. 812-822, 2009.

[15] J. Jiao and M. Dillivan, "Transit Deserts: The Gap between Demand and Supply," Journal of Public Transportation, vol. 16, no. 3, pp. 23-39, 2013.

[16] K. Koh, C. Azevedo, K. Basak and M. Ben-Akiva, "Simulation of demand and supply of urban rail in a multimodal environment," International Conference on Intelligent Transportation, pp. 647-654, 2017.

[17] K. Kaeoruean, S. Phithakkitnukoon, M. Demissie, L. Kattan and C. Ratti, "Analysis of demand–supply gaps in public transit systems based on census and GTFS data: a case study of Calgary, Canada," Public Transport, vol. 12, pp. 483-516, 2020.

[18] H. Yang and Y. Liang, "Examining the Connectivity between Urban Rail Transport and Regular Bus Transport," Sustainability, vol. 15, 2023.

[19] M. Lee and H. Nam, "Origin-Destination-based public transport service gap," International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, vol. XLII, no. 4, pp. 283-290, 2018.

[20] Z. Karim and F. Jawab, "Measuring urban public transport performance on route level: A Literature Review," in MATEC Web of Conferences 200,00021 (2018), 2018.

[21] S. Ison, M. Frost and R. Watson, "UK rail transport: a review of demand and supply," in Transport, vol. 165, 2012, pp. 225-234.

[22] Y. Yang, J. Liu, P. Shang, X. Xu and X. Chen, "Dynamic Origin-Destination Matrix Estimation Based on Urban Rail Transit AFC Data: Deep Optimization Framework with Forward Passing and Backpropagation Techniques," Journal of Advanced Transportation, pp. 1-16, 2020.

[23] Ecoscore, "How to calculate the CO2 emission from the fuel consumption?".

[24] Minutes (unpublished) of the discussions at the National Development Council’s Working Group on Transport and Railways, National Development Council, 1997.

[25] National Transport Commission, "National Transport Commission Report 2019," National Transport Commission, Colombo, 2020.

APPENDIX

Station Name	Abbreviation	Station Name	Abbreviation
Polgahawela	PLG	Peralanda	PRL
Walakumbura	WKA	Kandana	KAN
Alawwa	ALW	Kapuwatte	KAW
Bujjomuwa	BJM	Ja-Ela	JLA
Yattalgoda	YTG	Tudella	TUD
Ambepussa	APS	Kudahakapola	KUD
Botale	BTL	Alawatupitiya	AWP
Wilwatta	WWT	Seeduwa	SED
Mirigama	MIR	Liyanagemulla	LGM
Wijaya Rajadahana	WRD	Trade Zoone	IPZ
Ganegoda	GND	Katunayake	KTK
Pallewala	PLL	Kurana	KUR
Keenawala	KEN	Negombo	NGB
Wadurawa	WRW	kattuwa	KAT
Veyangoda	VGD	Kochchikade	KCH
Heendeniya Pattigoda	HDP	Waikkala	WKL
Magalegoda	MGG	Bolawatte	BLT
Bemmulla	BEM	Borelessa	BSA
Daraluwa	DRA	Lunuwila	LWL
Gampaha	GPH	Tummodara	TDR
Yagoda	YGD	Nattandiya	NAT
Ganemulla	GAN	Walahapitiya	WHP
Buugahagoda	BGH	Kudawewa	KWW
Batuwatta	BTU	Nelumpokuna	NPK
Walpola	WPA	Madampe	MDP
Ragama	RGM	Kakkapalliya	KYA
Horape	HRP	Sawarana	SWR
Enderamulla	EDM	Chilaw	CHL
Hunupitiya	HUN	Dematagoda	DAG
Wanawasala	WSL	Maradana	MDA
Kelaniya	KLA	Colombo Fort	FOT