Connectivity Analysis as an Alternative Predictor of Transit Demand: A Case Study of the Railway Network, Sri Lanka

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Abstract

Rapidly increasing traffic congestion in urban and suburban roads raises the urgent need for an efficient railway service in Sri Lanka. In studies on rail transportation planning, however, travel demand has often taken a back seat to design and engineering features; perhaps due to the lack of adequate data availability. Taking its cues from this insufficiency, this study explores the potential of using "Connectivity Analysis" to serve as an alternative methodology of travel demand forecasting. The connectivity of railway stations in termsof railway and road access were computed separately by using 'Connectivity Analysis' and by analysing the relationship with travel demand for stations within the railway network of Sri Lanka. Results revealed a significant correlation between transit demand and the connectivity of railway stations, such that connectivity values have the capability to explain over 77% of the variation in rail transit demand. Therefore the study suggests that the "Connectivity Analysis" method can serve as an alternative predictor of transit demand, in the absence of good, quality data on trip-making and employment trends.

Keywords: connectivity analysis, transit demand, station, railway network, road network

Introduction

If cities are to be the sites of economic development, then transportation systems have to be, to a large extent, the foundation on which the efficiency and convenience of that development depends (Leda 2010; Singh 2005). The promotion of public transport as the backbone of mobility in urban agglomerations, or at least as an alternative to the dominance of the automobile, has become a prominent policy in some of the largest and medium sized cities around the world. Public transportation is also an essential component for the sustainability of cities (Munshi 2003; Singh 2005; Leda 2010). However, while some cities have been successful in shifting from car journeys to rail and buses, others are struggling, despite considerable efforts, to make public transport more attractive (Scheurer, 2006). Since many cities now emphasize the desirability of increasing the share of public transport (at least in their policy rhetoric, if not in their practical priorities) it has become commonplace for cities with weaker public transport systems to look closely at the success factors in cities with stronger public transport systems. The most important of these success factors are:

- A configuration of the system in terms of network coverage and service frequencies that offer a viable alternative to the car for most, if not all, travel purposes across the urban area (Laube 1998, Nobis 1999)
- A legible network structure that is efficient to operate, easy to navigate and offers a choice of routes wherever possible (Mees 2000, Vuchic 2005)

- A speed advantage of urban rail over road traffic along a city's main corridors (Newman 2005)

- The integration of public transport facilities with supportive urban development, in particular high-density, mixed-use, walkable nodes around rail stations and major interchanges (Bernick and Cervero 1997, Cervero 1998)

- An institutional framework that allows for integrated, publicly accountable capital investment and service planning (Mees 2005, Mees et al 2006)

On the other hand most fast developing Asian cities give greater priority towards railway networks in order to attract more users to railway transport, due to its higher capacity, comfort and speed when compared to bus transport. Similarly, the government of Sri Lanka is attempting to improve the railway network by launching the 10-year Railway Development Strategy in early 2010. The strategy included upgrading the track on the Southern line (which was damaged in the 2004 tsunami), rebuilding the Northern line (which had suffered from three decades of civil war), extending the Southern line from Matara to Kataragama in order to serve the growing city of Hambantota, adding a new railway line to link Horana to Kottawa, and adding an express railway line from Avissawella to Colombo etc .Furthermore there are proposals to construct high speed railway lines to attract more users. Despite these attempts however, the bus still holds a significant share of 68% (in terms of passenger km) of the national modal split,whereas the railway amounts for a minimal of5%(in terms of passenger km).(Kumarage, 2011).This could be because Sri Lanka Railway has not integrated its services with other modes of transport. Unlike transport systems in some other countries, Sri Lanka does not provide dedicated feeder-bus services to the railways, resulting in commuter rail and buses acting as isolated systems in relation to each other that create a loss in efficiency. Furthermore Sri Lanka railway has failed to identify factors which lead to an increase in transit demand for rail transport (Sri Lanka Railways, 2011). This challenge is also an opportunity to develop sustainably, if demand can be adequately forecasted and planned for. In development strategies for the railway network however, travel demand has often taken a back seat to design and engineering features; perhaps due to the lack of an adequate and robust method to forecast demand and lack of data availability. As Iseki et al (2007) points out, the research is inconclusive as to whether improving the design of transit stations can actually increase ridership.

Thus, there is a need to develop alternative methods to measure transit demand in the railway system. Methods that can be relied upon in the face of data and cost constraints, which many Sri Lankan agencies experience. Taking its cues from trends in transportation planning and new policies that emphasize the integration of travel behaviour and land use, this study explores the potential of using the "Connectivity Analysis" method to serve as an alternative methodology to forecast transit demand in the railway system. The 'Connectivity Analysis' is a method derived from the principal of 'Graph theory' (Erdos and Renyi, 1960). Among previous studies done on "Connectivity Analysis" and public transit, none have focused on cities in developing countries, while only a few studies have been carried out to find out the relationship between the urbanization level and road connectivity(Jayasinghe and Munasinghe 2009), where such research is, perhaps, needed the most. As findingsfrom many studies in the developed world are not directly applicable to cities in developing Asian cities (Kishimoto, 2007; Hasuan, 2008; Munshi, 2009), there is a need to look at the applicability of these simplistic models in defining transit demand in the

Sri Lankan context. This research seeks to explore the applicability, if any, of 'Connectivity Analysis' as a method to estimate transit demand for railway transport in Sri Lanka.

Literature Review

1. Connectivity analysis method

'Connectivity' is a subject of interest in many fields of study, and it is particularly popular in areas such as information technology and computer engineering, etc. However, its recent applications can be seen in spatial planning to model, forecast, and explain matters related to accessibility (Jayasinghe and Munasinghe 2009). Connectivity Analysis could be performed in many different forms (such as the simple connectivity analysis, or weighted network analysis...etc.), furthermore, highly advanced and sophisticated mathematical operations could be used to compute and explain the results related to connectivity. Erdos and Renvi's (1960) 'Random Graph' model can be considered as the base on which most of the subsequent analysis on connectivity was developed. In simple terms, the method involved is the computation of relative connectivity among systematically linked points, lines and areas. The relative connectivity is measured in terms of the number, distance, travel time, optimal path, etc. This method has developed into the status of a comprehensive technique with a number of applications in many fields such as geography, demography and economics. Among them Barabasi and Albert (1999) studied the connectivity of physical networks in relation to properties such as robustness and vulnerability. Batty and Shiode's (2000 and 2001) study promoted the development of this field into quantitative analysis within a twofold perspective with special reference to the World Wide Web. Claremont and Jiang (2004) attempted to describe transportation networks by conceptualizing streets into nodes and intersections into edges, and named this method the 'Dual Graph'.

Although not as widespread as its applications in IT and related fields, a few studies on the connectivity of spatial networks, which has a direct relevance to urban and regional planning, can be noted. The study of topology of the Indian railway network (Sen, 2003), the study on the US interstate highway network and airport network (Gastner and Newman, 2004) and study on the Italian power grid (Crucitti et al., 2004) are examples for such studies. Barrat's (2004) studies on 'weighted network' further developed the conceptual base associated with the connectivity analysis technique. 'Weighted graph representation' provided a commendable solution for many existing limitations of the technique, and answered a series of questions that were fundamental to the understanding of spatial networks. Study of the worldwide airport network, including traffic flow and their correlation with the topological structure (Barrat's, 2004) introduced weighted graph representation for spatial analysis. Jayasinghe and Munasinghe (2009) introduced the connectivity analysis as a method to identify the urban agglomeration trend of locations in Regional studies.

In summary, the literature indicates that connectivity has been used as an attribute to measure many aspects such as the accumulation of traffic at intersections and concentration of people at urban centres. Further, they show that the analysis of connectivity of a given location can be a method to ascertain and predict the capacities of that location on many fronts.

2. Factors Affecting Transit Demand

Most of the research identifies different factors that affect transit demand for the various transit modes. Taylor and Fink (2001) pointed out that total ridership will increase as density increases as a greater number of people have access to transit. Spillar and Rutherford (1998) examined the relationship between urban and residential transit ridership. Similarly, Pushkarev and Zupan (1977) found that residential densities in transit corridors, together with the size of the downtown and the distance of the station from downtown, explained the level of demand for a variety of transit modes. Brons M., Givoni M., and Rietveld P. (2008) found that improving access to the rail network has the potential to increase the use of rail and can attract new passengers. Crockett and Hounsell (2005) reached a similar conclusion, that investments in measures such as those associated with the convenience or ease of rail travel, including better access, might provide greater benefits for rail users. Wardman and Tyler (2000) pointed out that rail use can be strongly influenced by changes to accessibility to the rail network and access is mainly based on distance from the station.

On the other hand as the first point of contact between a passenger and the transit network, transit stops play an important role in travel demand. Their accessibility is a key component in trip travel time (TCRP 1996). Numerous studies have shown that the location of transit stops also affect ridership (Johnson 2003; Holtzclaw 1994; Rodriguez 2009; and Murray and Wu 2003, cited in Foda 2010). Other qualities of transit stops that affect ridership include: land use, design, and measures of accessibility. Land use variables include residential and employment densities, as well as the relationship between land use mix and network connectivity (Cervero 1993; Chung 1997; Crane 2000; CUTR 2004; Gomez-Ibanez 1996; Hendrickson 1986; Kain and Liu 1995; Nelson and Nygaard 1995; Pushkarev and Zupan 1977; Spillar and Rutherfod 1998; TCRP 1996). Design variables include factors perceivedas safety en route to and at the station, as well as overall station legibility (Abdel-Aty and Jovanis 1995; Cervero 1990; Mees 2000; Syed and Khan 2000; Vuchic 2005). Accessibility variables include walkability and the availability of parking near the stop (Abdel-Aty and Jovanis 1995; Bernick and Cervero 1997; Cervero 1993, 1998; Dittmar and Ohland 2004; Syed and Khan 2000; TCRP 1996).

According to findings of the above discussed literates, the factors affecting the decision of transit users in selecting a transit stop have been conceptualized as follows (figure 1). It depicts the essential components of the complete door-to-door journey by public transport. Transit modes used to travel the longest distances (main mode) are indicated in purple (direct journey) or red (with transfer journey) colour arrows, while the mode used to reach the public transit (access mode) is indicated in black colour arrow on the left side circle and the mode used to reach destinations in black colour arrows on the right side circle (egress mode). Selections of an origin transit stop depend on individual or aggregate levels of accessibility, walkability or legibility of the origin transit stop from the origin point (residential or employment area) of use. On the other hand, selection of egress stop depends on individual or aggregate level of accessibility, walkability or legibility of the destination point (surrounding land use; employment location, education location, recreational location etc) from transit stops. Accordingly, transit stops which have greater accessibility, walkability or legibility from surrounding land use attract more transit users than other transit stops. Selection of main transit mode depends on the level of accessibility from origin stop to the destination stop in terms of travel time, service frequency transfers and connectivity of the stop to downstream land use. The other important factor is the availability of parking facilities at the origin transit stop, however, this is less significant in bus transit in comparison to rail transit.

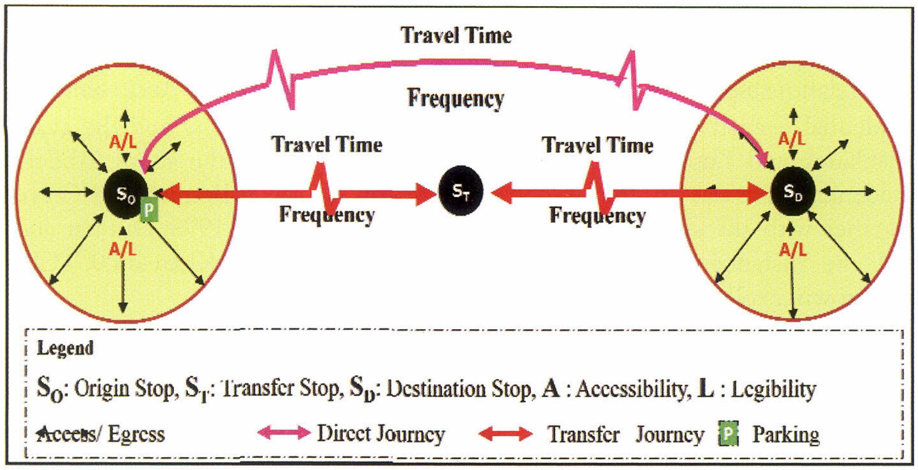


Figure 1: Diagrammatic outline of transit user decision making for selecting transit stops
Source: Prepared by Authors

Study Area

The railway system in Sri Lanka is comprised of 4 railway lines (1449 kilo meters) and 336 railway stations. 300 passenger trains are operating daily and carry 290,000 passengers per day (Sri Lanka Railways, 2011). Rail transport amounts for about 3600 (million) (5%), of the national mode share in passenger kilometres. This case study covered 1/3rd (132 stations) of the railway stations and 1/4th (380.2km) of the railway lines in Sri Lanka. Boundaries are set, along the main line up to Polgahawela,the coastal line up to Galle, the Puttlam line up to Puttlam and the Kelani vally line up to Awissawella. The study area mainly belongs to the Colombo Operating Region (Figure 2).

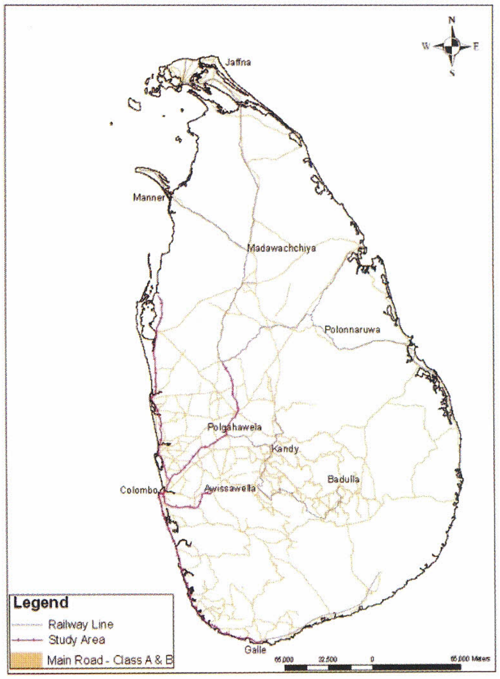


Figure 2: Railway Network in Sri Lanka
Source: Sri Lanka Railways

Methodology

In this study, the transit demand for railway stations were only evaluated for their accessibility effect in terms of connectivity and the methodology was designed to measure this effect (Figure 3). Accordingly the level of accessibility from one railway station to anther was measured in terms of the 'level of connectivity of the railway station though railway network with other stations', while level of accessibility to a railway station from the surrounding areas were measured in terms of the 'level of connectivity of railway station through road with surrounding areas' (refer figurer 3). Therefore the study developed two connectivity indexes separately for the railway station to measure the level of connectivity of the railway station through the railway network and road network.

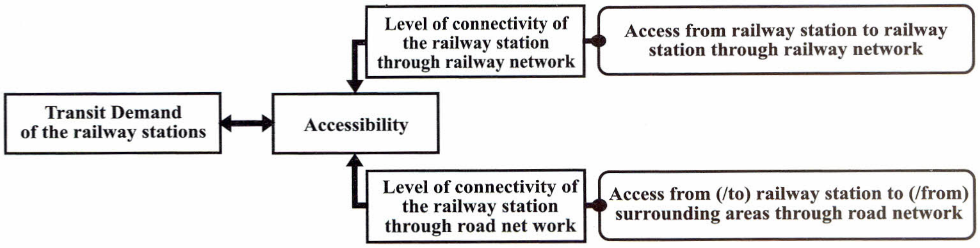


Figure 3: Designed methodology relating to transit demand of the railway stations and connectivity Source: Prepared by Authors

To do so, the first step was to prepare a nodal axial map for the road and railway network. Thus axial maps were prepared in two different ways namely axial map type A and axial map type B and the connectivity of railway station were calculated.

1. Assessment of Connectivity of Railway Stations Through Railway Network

In order to analyze the connectivity of certain railway stations through the railway network in comparison to other stations in the network, the selected area (indicated in a map) is reduced in to a 'node-axial' diagram.The 'nodes' are stations, and 'axial' are the segments of railway lines between those nodes which are represented as straight lines. The diagram is called an 'axial map'.

lines that one has to pass through to get into the particular node selected from all other nodes.

The computation was based on an 'interactive matrix' of nodes. The connectivity value of each node is computed by the following formula. Accordingly, those that obtained a high Dj value have a high level of connectivity and accessibility while those that obtained low Dj values have a low level of connectivity and accessibility.

$$Dj = \frac{1}{\sum_{i=1}^{n} \left(\frac{A_{ij}}{\sum_{i=1}^{n} A_{ij}} \right)}$$

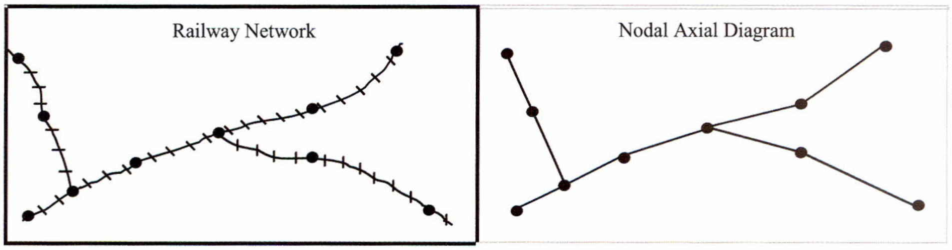


Figure 4: Steps of the preparation of Axial Map – A Source: Prepared by Authors

This axial map is used to compute the 'relative connectivity' of each station with other stations through the rail network (refer figure 4).

The relative connectivity is considered as the sum of normalized values of the relative connectivity of nodes that are computed in terms of the number of axial

Dj : relative connectivity of the node 'j',

Aij: level of accessibility/adjacency between node 'i' and 'j'

Here, the virtual connectivity is still 'relative' because the accessibility or adjacency depends on the selected area of influence. The area of influence is decided by setting up a radial distance from each node in consideration. When the radial distance is 'n', only the nodes that fall within the area demarcated by that circle are taken into account for the computation of connectivity of the node at the centre. The relative connectivity, analysed in this manner, can be considered as an indication of the topological centrality of a node. This computation can be made more effective to achieve results with a higher level of accuracy by assigning weights to the axial connections. The weight factors may be decided upon the distance between centres, travel frequency, etc.

However, as stated earlier, in this study only simple connectivity analysis was adopted with no weights assigned to the connections.

2. Assessment Of Connectivity of Railway Stations Through The Road Network

First, centrelines of all motorable roads (road networks available within a 10km buffer area from the railway network are taken to prepare an axial map), where they are converted into links and nodes. In order to do so, each road centreline was broken at the intersection; place where two or more centrelines meet. Then, the railway network was overlaid and the centrelines were further were broken at stations. Finally as 'Axial Map – B' indicates, road intersections and railway stations represented as nodes; while links which connect two nodes are represented as axial lines.

Then 'Axial Map –B' is used to compute the 'relative connectivity' of each station with other nodes through roads. The computation was based on an 'interactive matrix' of nodes and the connectivity value of each node that is presented by the same formula used at the stage discussed above. Simple connectivity analysis does not consider the effect of distance; rather it is based on the number of nodes. The demarcation of the areas of influence is done at the local level (10 km radius area from the railway station), based on the authors' observations in the study area.

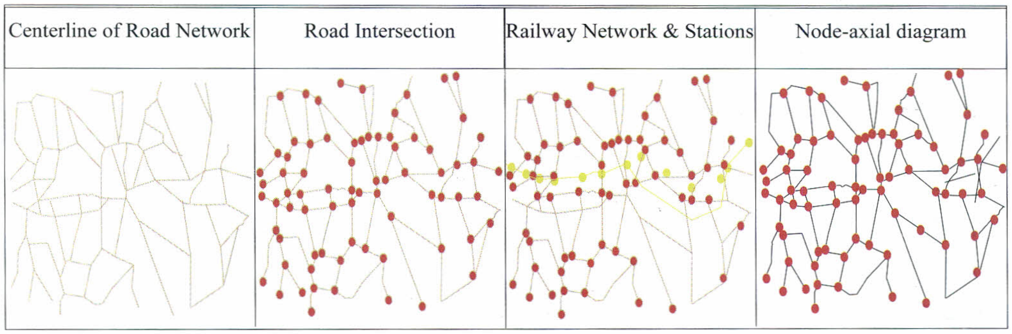
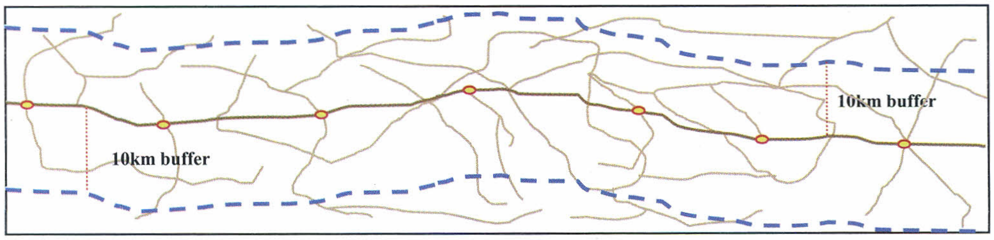


Figure 5: Steps of the preparation of Axial Map – B Source: Prepared by Authors



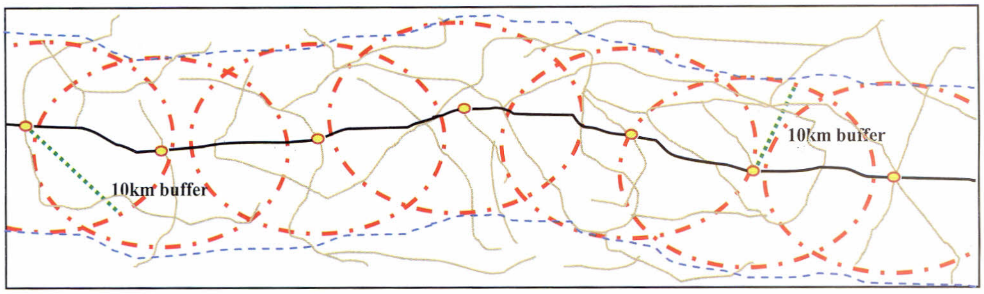


Figure 6: Conceded Area for radius area from the railway station Source: Prepared by Authors

The following table shows that the represented objects by nodes and links in axial maps Type A & B.

Table 1: Represented objects by nodes & links in axial map A & B

	Axial Map – A	**Axial Map – B**
Nodes	Railway Station	Railway stations & Road intersections
Links	Railway track/ line	Railway track/ line &Road
Data Source	1: 50,000 topographic map, 2001 Survey Department. Sri Lanka	1: 50,000 topographic map, 2001 Survey Department. Sri Lanka

Source: Prepared by Authors

3. Preparation of Transit Demand Index

The 'Transit Demand Index' was prepared based on railway passenger boarding information. The study used both daily tickets sales and season tickets (monthly pass) issued at each station in 2010. By taking the average of all daily tickets and season tickets which were sold at each station within the one year period, the average daily transit demand index was prepared.

$$
\begin{aligned}
&TransitDemandatStation \\
&\qquad = (Toalnumberofdailyticketsoldinyear\ 2010)/365 \\
&\qquad + (TotalNumberofmonthlyseasonssoldinyear\ 2010
\end{aligned}
$$

4. Analysis

Finally, the study compared the two connectivity indices with the transit demand index, in order to test their correlation. First, the study analyzed the two indices' results visually using maps. Next, the study used regression analysis to estimate the nature and strength of the relationship between the indices.

From this initial analysis, the study was then able to focus on connectivity values that had relevance and develop additional regression models to explain and predict travel demand at railway stations.

The Analysis and Results

1. Transit Demand of the Stations (TD)

According to the transit demand index prepared for railway stations, the highest transit demand is recorded in Colombo Fort railway station (18,829). The second highest transit demand is recorded in Gampaha Railway station. The histogram indicates that mean transit demand value for the railway station is 766 and standard deviation is about 2017.159. (Ref. annexure 1)

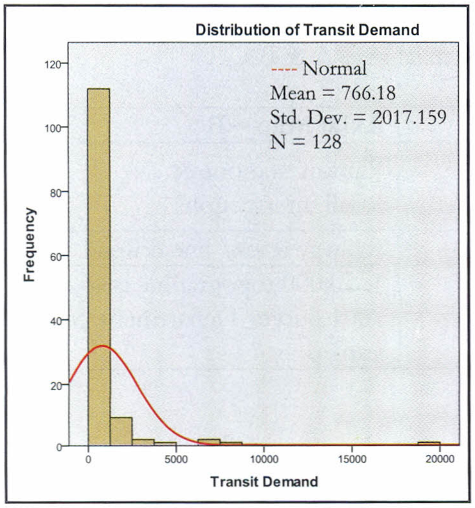


Figure 7: Distribution of transit demand (Source: Prepared by Authors)

Approximately 90 %(115) stations obtained values less than the mean value (i.e.776). A very few stations (about 10%) recorded the highest transit demand, with more than 1000 passengers per day. Those stations are Fort, Gampaha, Ragama, Maradana and Veyangoda. This means that the highest transit demand recorded in a few railwaystations act as major transit modesin the network; while the lower transit demand recorded at the majority of station indicate that they act as regular stops in the network.

2. Analysis of Connectivity of Railway Stations Through Railway Network

The relative connectivity of nodes, which measure the connectivity of each station to all other station through the rail network has a range between 0.607 (Piyadigama) to 1.692 (Maradana). The mean value of this data range is 1.088 and the standard deviation is 0.325. The highest peak is recorded within the range of 0.75 – 1.0 and the second highest value is recorded within the range of 0 – 0.75. (Ref. annexure 1)

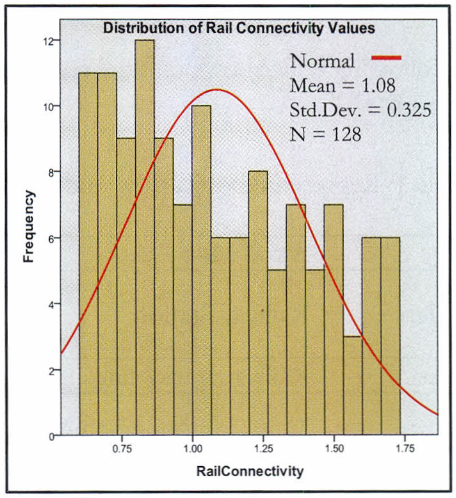


Figure 8: Histogram of distribution of railway connectivity values
Source: Prepared by Authors

3. Analysis Of Connectivity Of Railway Stations Through Road Network

Road connectivity values represent the degree of connectivity of stations to the surrounding areas through the road network. According to the histogram, the average values for the data distribution is about 0.56.and the Standard deviation is 0.289. Similar to section (5.3) discussed above, the highest value is recorded in a small number of railway stations, while the majority of stations recorded lower values for road connectivity. The Peak is represented in the data range 0 – 0.5. (Ref. annexure 1)

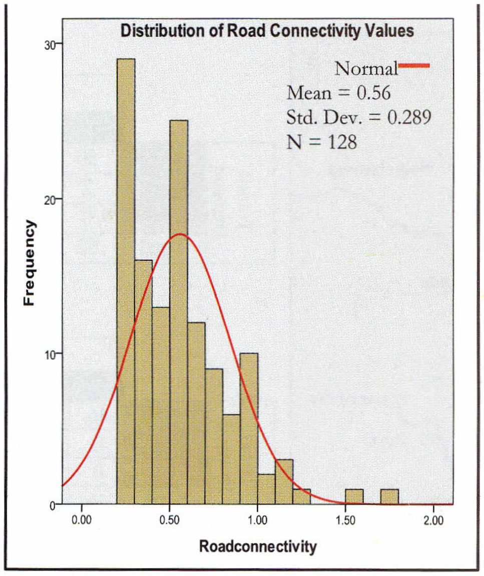
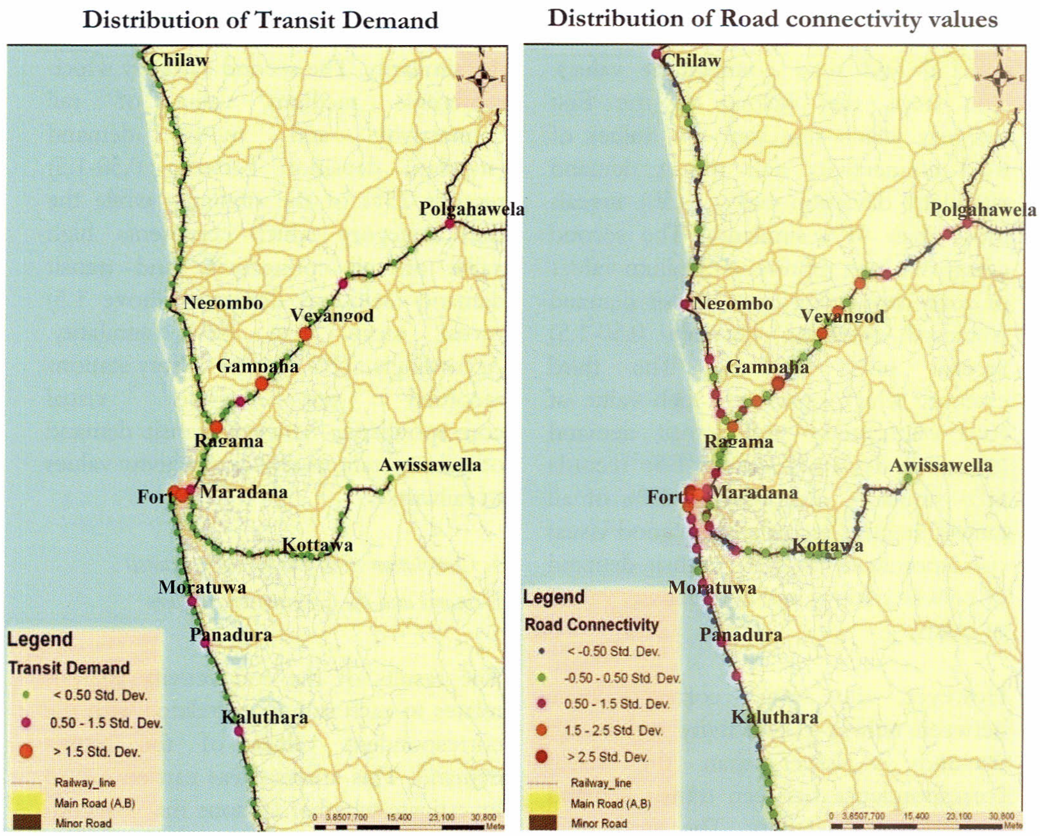
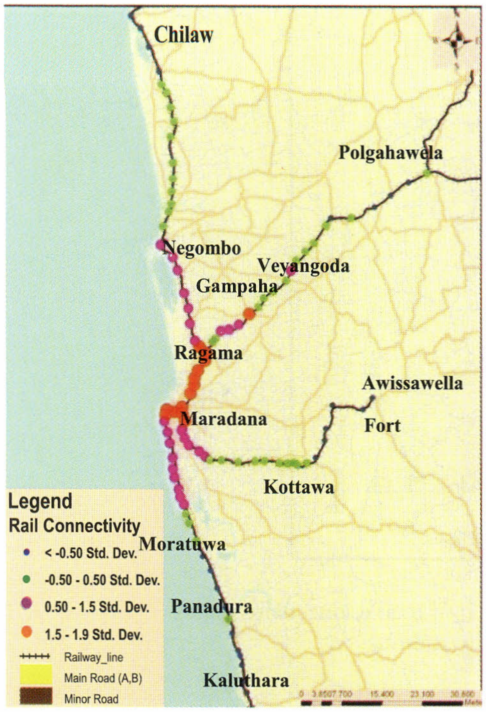


Figure 9: Histogram of the distribution of road connectivity values
Source: Prepared by authors

4. Visual relationship analysis between transit demand and the connectivity values of stations



Distribution of Railway Connectivity Values



		Railway connectivity				
						Total
Transit Demand		50	34	23	9	117
		2	3	2	1	8
		0	0	1	4	5
	Total	52	37	26	14	130

		Road connectivity					
							Total
Transit Demand		46	49	20	2	0	117
		0	1	5	2	0	8
		0	0	0	3	2	5
	Total	46	50	25	7	2	130

Figure 10: Visual representation Of Distribution of Transit demand and Connectivity Values

Source: Prepared by authors

The results indicate that there is a good visual correspondence between transit demand and road connectivity values. The stops that belong to the first category which represent low values of road connectivity and transit demand (standard deviation below 0.50) reveals more than 41% similarity. The second category which represents medium values of road connectivity and transit demand (standard deviation between 0.50-1.5) records 62% similarity. The third category which represents high value of road connectivity and transit demand (standard deviation above 1.5) records 60% similarity. Accordingly, 43% of all railway stations recorded very good visual correspondence between transit demand of railway stations and connectivity values of roads.

However, the visual correspondence between railway connectivity and transit demand is lower than the visual correspondence between transit demand and road connectivity. The stops that belong to the first category which represent lower values of rail connectivity and transit demand (standard deviation below 0.50) records more than 28% of the similarity. The second category which represents medium value of rail connectivity and transit demand (standard deviation between 0.50-1.5) records 25% of the similarity while the third category which represents high value of rail connectivity and transit demand (standard deviation above 1.5) reveal more than 80% similarity. Accordingly, 32% of total railway stations recorded very good visual correspondence between transit demand of railway stations and connectivity values of railways.

5. Correlation Analysis between Transit Demand and the Connectivity Values

The results of the connectivity analysis relates to each station correlated with the correspondent values of the transit demand. This analysis was carried out to investigate whether stations that a record higher transit demand had higher connectivity values though road or railway network.

For this purpose a bi-variant correlation coefficient test on SPSS version 19 was employed to test the strength of the relationship between transit demand and the connectivity values. The following table summarizes the correlation values.

Table 2: Correlation results between connectivity values and TD

Variables	Correlation with TD
Level of connectivity of the railway station through railway network (RiC)	.382**
Level of connectivity of the railway station through road network (RoC)	.689**
	Correlation with Ln(TD)
Ln(RiC)	.623**
Ln(RoC)	.790**

**. Correlation is significant at the 0.01 level (2-tailed).
Source: Prepared by authors

The results indicates that correlation values between Ln(TD) and the Ln(RoC) as 0.790 and correlation is significant at the 0.01 level. Correlation values between Ln(TD) and Ln(RiC) is 0.623 and significant at the 0.01 level. Accordingly, the highest correlation value is recorded between transit demand and the level of connectivity of the railway station through the road network.

The outcome of Log values and actual values are different. The correlation coefficient of the RoC is 0.689 for the actual values and 0.790 for the log values. This shows that log values have a higher correlation coefficient value than the actual values, because, the numerical variation of log values is lower than that of actual values. However the result demonstrates the same initiatives, indicating there is the significant correlation coefficient of the RoC which is higher than the RiC for transit demand.

6. Regression Analysis between Transit Demand and Connectivity Values

A regression analysis was carried out to find out the relationship between transit demand and station connectivity. For this purpose a linear regression model was used. The model summery illustrates the linear regression model with a confidence interval at 99% level. It shows that railway is also significant for the change in transit demand. However when compared to road connectivity, rail connectivity has obtained insignificant F change and beta values.

Together the two variables, Ln(RoC) and Ln(RiC), explain over 77% of the variation in transit demand Ln(TD). Individually, Ln(RoC) explains 64% of Ln(TD) variation and Ln(RiC) explains only 34% of the variation (Table 4). This result indicates that the most significant factor to change the transit demand is road connectivity.

Table 3: Regression model summery of the road and railway network

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.790[a]	.624	.62	.9370233	.62	209.0	1	126	.0	
2	.845[b]	.773	.70	.8214624	.08	38.9	1	125	.0	1.03

a. Predictors: (Constant), Ln(Road Conn)
b. Predictors: (Constant), Ln(Road Conn), Ln(Rail Conn)
c. Dependent Variable: Ln(TD)
Source: Prepared by authors

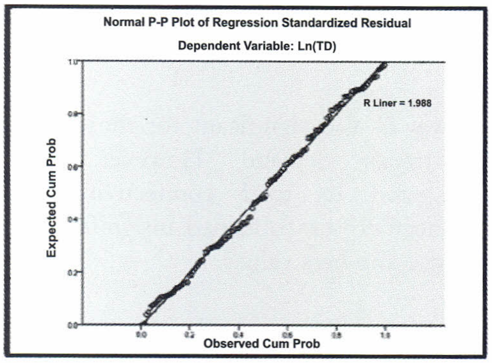


Figure 12: Normal P-P Plot of regression Standardized residual
Source: Prepared by authors

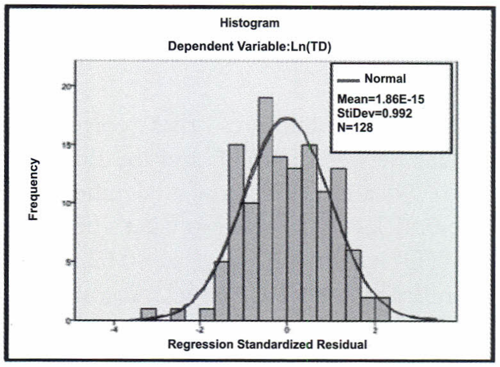


Figure 13: Histogram of the regression standardized residual
Source: Prepared by authors

Table 4: Coefficients – Regression Model

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.	Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	10.489	.142		73.903	.000					
	Ln(RoC)	2.363	.163	.790	14.458	.000	.790	.790	.790	1.000	1.000
2	(Constant)	10.110	.138		73.015	.000					
	Ln(RoC)	1.912	.161	.639	11.910	.000	.790	.729	.570	.797	1.255
	Ln(RiC)	1.683	.270	.335	6.241	.000	.623	.487	.299	.797	1.255

a. Dependent Variable: Ln(TD)
Source: Prepared by authors

Results indicate that travel demand at railway stations can be predicted through the developed regression models, which have more than 77% accuracy.

Ln(TD) = 10.110 + 1.912 Ln(RoC) + 1.683 Ln(RiC),
(R Square = 0.773)

Accordingly, the influence of connectivity values on transit demand varies on railway stations accordingly:

- The connectivity level of railway stations through the road network to the surrounding areas or the level of accessibility to railway stations from surrounding areas determines 64% of the transit demand for the station.

- The connectivity level of railway stations though the railway network with other stations or the level of accessibility from one railway station to another determines 34% of the transit demand for stations.

Conclusion

The main objective of this research was to study the applicability of utilizing the connectivity analysis technique as an alternative predictor of transit demand for the railway network in Sri Lanka. Results indicate that the connectivity analysis technique is useful as an indicator of transit demand. These findings might inform future plans to extend the railway network; specifically, with reference to the rail-road integration.

In view of that, connectivity values of railway stations through the railway network and through the road network were identified as appropriate indicators to measure the transit demand of railway stations. Results of the visual analysis demonstrate that there is a significant and equal distribution of values in transit demand and connectivity values of railway stations through the road network in comparison to the connectivity values of the railway station through railway network. Through the results of the correlation analysis it was identified that there is a significant correlation coefficient (0.790) between connectivity values of railway stations through the road network and transit demand in comparison to connectivity values of railway station through the railway network (correlation coefficient 0.623). The regression analysis also concluded that there is a significant change in transit demand that influence the connectivity values of railway station through the road network. This accounts for about 64% of change while the connectivity values of railway stations through the railway network explain 34% of the change in transit demand. This, regression model, which was developed to explain transit demand of railway stations based on connectivity values, is more than 77% accurate.

Building on these preliminary findings, future studies might explore the relationship of connectivity analysis to passenger transfers, as well as the effect of temporal change in transit demand. This research has contributed a robust, dynamic planning tool that offers promise for spatial planning and transport planning applications in a Sri Lankan context. Specifically, this application may have relevance in identifying the impact of adding stations or altering existing stations, as well as for locating future railway lines or integrating stations with road networks or bus systems.

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Annexure 1: Distribution of Station according to the Transit Demand & Connectivity
Source: Prepared by authors