'CENTRALITY MEASURES' AS A TOOL TO IDENTIFY THE TRANSIT DEMAND AT RAILWAY STATIONS; A CASE OF RAILWAY NETWORK, SRI LANKA

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ABSTRACT
Rapidly increasing congestion of traffic in urban and suburban roads raises the urgent necessity of better and quicker railway service in Sri Lanka. In development strategies of railway network, though, travel demand has often taken a back seat to design and engineering features; perhaps due to the lack of adequate robust method and data availability. Taking its cues, this study explores the potential of "Centrality Measures" to serve as an alternative methodology of travel demand forecasting. In this study, the centrality of railway stations in terms railway and road access were computed separately by using 'centrality measures' and analysis the relationship with travel demand of station within the railway network of Sri Lanka. Results revealed a significant correlation between transit demand and centrality of railway stations and centrality values have capabilities to explain over 79% of the variation in rail transit demand. Therefore the study suggests that "Centrality Measures" method can serve as an alternative predictor of transit demand, in the absence of good, quality data on trip-making and employment trends.

Key words**:** Centrality measures, Transit demand, Railway Network, Method

1. 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 [1,2]. The promotions of public transport as a backbone of mobility in urban agglomerations, or at least as an alternative to the dominance of the automobile, has become a prominent policy focusing on the largest and medium size cities around the world. Public transportation is also an essential component in the sustainability of cities [1,2,3]. On the other hand most of the fast developing Asian cities give more attention towards the railway network and attracts more users to the railway transport because capacity, comfort and speed are higher than the bus transport.

The government of Sri Lanka responded to improve railway network by launching 10-year Railway Development Strategy in the early 2010s. Despite of above effort in Sri Lankan situation, the bus holds a significant share of 68% (in terms of passenger km) from the national modal split but the share of railway is minimal as 5% [4]. On the other hand 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. This creates a loss in efficiency. And also it has not identified the factors that lead to increase the transit demand in rail mode of transport [4]. This challenge is also an opportunity to develop sustainably, if demand can be adequately forecast and planned for. In development strategies of railway network, though, travel demand has often taken a back seat to design and engineering features; perhaps due to the lack of adequate robust method and data availability. As Iseki et al (2007) points out, research is inconclusive as to whether improving the design of transit stations can actually increase ridership.

This study focused on an emerging set of research literature those employed in transit demand applications in public transit modes of cities in developed countries. Those researches have based on network centrality parameters that revealed successful results in measuring transit demand. Amongst, Scheurer, J. et al (2007) [5]; Kazerani, A. and Stephanr, W. (2009) [6]; Porta, S. and Latora, V (2007) [7] works in Australia; Jun, C. et al (2007)'s [8] work in Seoul, Korea; Kishimoto, T. et al (2007)'s [9] work on Japan are some of admirable recent studies which applied centrality parameters in transit networks. Yet, all above studies based on developed countries and there are none or very limited applications with referring to the emerging cities in developing world where such research need the most. Further, many researches those are focused on cities in developed world do not directly applicable to cities in Asian Context [3,10, 11]. Therefore, there is a need to look at the applicability of these simplistic models in defining PT demand of cities in Sri Lankan context.

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 "Centrality Measures" as a tool to serve as an alternative methodology of transit demand forecasting in railway system.

2. METHODOLOGY

2.1. Study Area

Railway system of Sri Lanka has comprised with the 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). In the national mode share passenger kilometres carried by rail is about (million) 3600 (5%). This case study covered the 1/3rd (132 stations) of the railway station and 1/4th (380.2km) of the railway line in Sri Lanka. Boundaries are, in the main line up to Polgahawela, in the coastal line up to Galle, in the Puttlam line up to Puttlam and in the Kelani vally line up to Awissawella. Mainly study area belongs to the Colombo Operating region

2.2. Measuring the Centrality of Railway Stations

In this study, the transit demand of railway stations was evaluated for their accessibility effect in terms of centrality. Accordingly, the level of accessibility from one railway station to another was measured by 'Closeness Centrality' and 'Betweenness Centrality' measures, of the railway station through railway network'. The level of accessibility to railway station from surrounding areas was measured by 'Closeness Centrality' and 'Betweenness Centrality' masures of the railway station through road with surrounding areas. Therefore, the study developed two centrality indices separately for measuring the level of centrality of the railway stations through railway network and road network.

Two types of nodal axial maps that represent stations and road intersections as nodes and connections between them as links were generated to analyse the centrality of the railway stations. Centerlines of the road network (including all A, B, C & D class roads indicated in the Topographic map, 1:50,000, 2001 prepared by the Survey Department) were converted to links and nodes. In order to do that, each road centerline was broken at the 'intersection' -place where two or more centerlines meet. Then, railway routes were overlaid and centerlines were further broken at stations. Links of the first type of nodal axial map (i.e. type-A), were weighted by physical distance while the second type of nodal axial map (i.e. type-B) by travel time based impediment value (denoted as 'd_{ij}'). Type B is a modified version of type A and to compute travel time links were weighted by route speed and service frequency. Because this study assumes that when travelling from a node to any other node, people choose the path with the lowest-travel time. Therefore, the lower the score (i.e. d_{ij}) greater the ease of movement (by travel time and service frequency) along the associated link.

$$d_{ij} = t_{ij}/f_{ij}$$

d_{ij} = **impediment value** of link segment between nodes i and j (average of both directions)
t_{ij} = **travel time** between nodes i and j (average of both directions)
f_{ij} = **service frequency** in departures per hour per direction between nodes i and

Next, MCA Extension in ArcGIS 9.1 and 'CLI' software (developed by Prof Sergio Porta and National Institute of Nuclear Physics of Catania, Sicily, Italy) were used to compute centrality values of nodal axial maps. Based on computed values, 'Network Centrality Index' was prepared. 'Network Centrality Index' comprised with different centrality values (calculated based on different centrality parameters) (table 1) of railway stations. Axial Map-A was used to measure Local Closeness Centrality (LCC) of the stations while axial map B was used to measure Global Closeness Centrality (GCC) and Betweenness Centrality (BC) of the railway stations.

2.3. Preparation of Transit Demand Index

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

Transit Demand at Station = (Total number of daily ticket sold in year 2010)/365 + (Total Number of monthly seasons sold in year 2010)/12

Table 1: Centrality Parameters

Local Closeness Centrality (LCC)	$LC_i = (N-1) / \sum_{j=1, j \neq i}^{N} L_{ij}$ Where *N* is the number of neighboring nodes (1km) locate in the network, and Lij is the shortest distance between nodes *i* and *j*. Were calculated for the nodes located within a 1km distance from each node i. [7]	To measures the extent that a node is **near to neighbouring nodes** in the transit network along the shortest paths. It also captures the notion of accessibility of a place at the neighborhood scale. The closer a place is to other places, the more accessible it is.
Global Closeness Centrality	$GC_i = (N-1) / \sum_{j=1, j \neq i}^{N} L_{ij}$ Where *N* is the total number of nodes locate in the network, and *Lij* is the shortest distance between nodes *i* and *j*. [7]	To measures the extent that a node is **near to all nodes** in the transit network along the shortest paths. It also captures the notion of accessibility of a place at the city scale. The closer a place is to other places, the more accessible it is.
Betweenness Centrality (BC)	$Be_i = \frac{1}{(N-1)(N-2)} \sum_{j=1; k=1; j \neq k \neq i}^{N} \frac{n(i)_{ik}}{nik}$ Where n_{jk} is the number of shortest paths between nodes *j* and *k*, and $n_{jk}(i)$ is the number of these shortest paths that contain node *i*. [7] Betweenness centrality calculate the shortest path based on impediment distance (depend on service frequency and speed) which use in Axial Map – B	To capture the idea that a **node is central** if it lies on the shortest paths that link many other nodes with each other. It is based on the idea that a node is more central when it is traversed by a larger number of the shortest paths connecting all couples of nodes in the network. It captures a special property for a node in a transit network: it does not act as an origin or a destination for trips, but as a pass-through point. [7]

2.4. Analysis

Finally, the study compared the Network Centrality Index (NCI) with the Transit Demand Index (TDI), in order to test their correlation. First, the study used correlation and regression analysis to estimate the nature and strength of relationship between the indexes. From this initial analysis, the study was then able to develop models to explain and predict travel demand at railway stations based on network centrality.

3. RESULTS

For this purpose Bivariate correlation coefficient test in SPSS 19th version was employed to test the strength of relationship between transit demand and the centrality values. The following table summarizes the correlation values.

Table 2: Correlation results between connectivity values and TD

Variables	Correlation with Ln(TD)
Ln(LCC)	.593**
Ln(GCC)	.211
Ln(BC)	.790**

**. Correlation is significant at the 0.01 level (2-tailed).

Regression analysis was carried out to find out the relationship between transit demand and the centrality of the station. For this purpose linear regression model was used. Model summery illustrated the linear regression model with confidence interval at 99% level. Results indicate that travel demand at railway station can be predicted through the developed regression models, which have more than 79% accuracy.

Ln(TD)= 8.101 + 1.211 Ln(RBC) + 1.531Ln(LCC), (R Square = 0.79)

Table 3: Regression model summery

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	8.101	.135		52.01	.00
Ln(BC)	1.211	.164	.683	10.82	.00
Ln(LCC)	1.531	.256	.321	5.32	.00

R = 0.889 & R square = 0.791

Accordingly, the influence of centrality values on transit demand varies railway stations as follows:

- Level of intermediary (BC) of railway station to the shortest paths (depend on travel time; service frequency and speed) connecting other nodes in area is influenced by 68% of the transit demand of the station.

- Nearness (LCC) to neighboring (1km) nodes in terms of physical distance is influence on 30% of transit demand of the station.

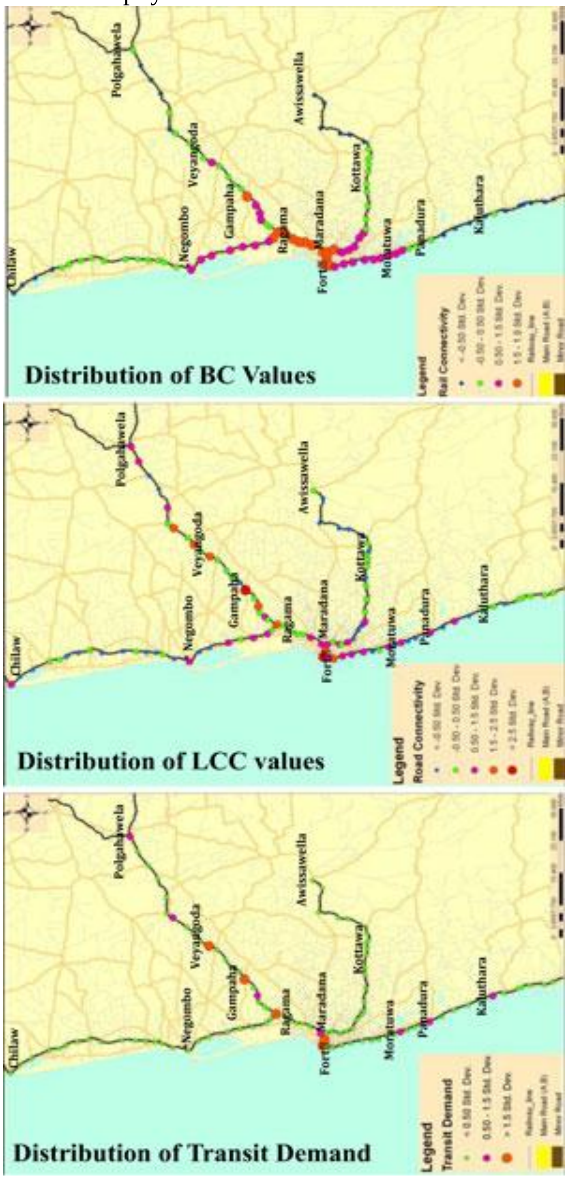

Figure 1: Visual representation Of Distribution of Transit demand and Connectivity Values

5. CONCLUSION

The main objective of this research was to study the applicability of centrality measures to explain transit demand of the railway station. Accordingly, this study concluded that centrality measures are useful to measure transit demand of railway station. Closeness and Betweenness were identified as appropriate centrality parameters that can use to measure street and transit network centrality of stations. Two parameters revealed a significant correlation with transit demand. By considering that, regression model (about 80% accuracy) was developed, to explain transit demand of station based on centrality values.

Though this research successfully achieved the desired objective yet this can be further developed into much advance analysis in relation to network centrality and passenger transfers, temporal change in transit demand and impact of city form on network centrality of PT systems. This research has contributed with a robust, dynamic planning tool that will offers promise for transport planning applications in Sri Lankan context as; to identify the impact from network augmentation to transit demand of existing stations; to identify the impacts of proposed land use plans to transit demand of existing stations; and to select location for transit stations or to plan multimodal system.

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