Preliminary analysis of ring rail lines for the western province of Sri Lanka

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Abstract— *The Western Province of Sri Lanka is a developing urban conglomerate and the economic engine of the nation. In the long run, it will require an upgrade of the existing radial rail lines and possibly one or two partial ring rail lines. We investigate two such partial ring lines based on some theories developed by Saidi (2013) et al.*

Keywords— **Rail transport, Ring rail lines, Urban Transportation System**

I. INTRODUCTION

This introduction is mainly summarised from Saidi et al (2013). There are at least 33 ring rail transit lines in 26 cities worldwide. Few studies exist on the planning, design or performance of such lines. Ring transit lines may not necessarily be whole circles and may only connect a portion of a circle around the central core of the city. In addition to the possible savings in transit rider travel and waiting times, increased transit network reliability and the reduction of the transit load in the downtown core, the presence of ring lines also increases accessibility and, thus, development of new satellite centers that are often being recommended as part of smart growth plans (Deakin and Porter, 2004). While an auto ring road usually encourages development to take place on the outskirts of a city beyond the ring, a transit ring line can encourage higher density, mixed-use development to take place along an inner city corridor. A circular transit line is also important for public transit users, in terms of their mobility and accessibility needs.

We will apply some theories developed by Saidi et al (2013) to the Western Province of Sri Lanka to consider whether there is room for partial ring lines that connect the existing radial lines and possible future radial lines.

In a totally radial rail network, trips with destinations away from the center have to be made along the radial lines passing through the city center. For cross-town trips, this can cause unnecessary passenger loads on some corridors, high transfer loads in the city center, and additional passenger travel distances, travel times and transfers. For instance, many passengers have to go to the center city, make a transfer and take another line to go to the other side of the city. A ring line would provide better connectivity and decrease a network's vulnerability, since there are alternative routes to reach each destination. However it can cause an extra transfer for some trips. However, it is clear that in cities with a highly concentrated CBD from which many radial lines emanate, and clearly the majority of trips are to and from the CBD, it will be difficult to justify a ring line.

II. SOME THEORIES IN SAIDI ET AL (2013)

A study on exploration of ring lines in rail transit networks by Saidi et. al. (2013) evaluates through regression analysis the relationship between urban transit networks with parameters such as population, city area and density. It also compares cities with circumferential transit services to identify the parameters that would justify the implementation of one in a city. The main attribute of ring rail lines is that it improves the connectivity and directness of a transit network and thus improve its ridership and reliability.

The main relationships derived in the study are summarized below. These relationships can be applied to the local rail transit network in the western province to compare the state of the ridership in Sri Lanka with the rest of Asia and the world and also as preliminary input for future expansions of the railway network especially a ring rail line.

The first part of the analysis is done to assess the relationship between population and the ridership in different regions. Based on the results it could be seen that the countries with a rich tradition of public transportation such as the large cities in Europe and Asia has the highest coefficient in the linear regression model developed for population and annual ridership. The case for Asia is further established by the analysis of annual ridership with the age of the rail network, where Asia has higher ridership compared to both Europe and North America, although both European and North American cities have old rail networks there is higher ridership coefficients in Asian cities due to other attributes such as population density. This aspect is verified from the multi variable regression analysis carried out for annual ridership and ridership per unit length, where the parameters that were significant were population and network length for annual ridership and population density and age for ridership per unit length respectively.

A. Model Development

The models developed from the regression analysis are as follows.

No.	Regression Model
Model 1	Annual Ridership = 109.21xPopulation (in millions) - 1.199 (Asia below 5 m population) Annual Ridership = 266.9 xPopulation (in millions) - 1196.9 (Asia above 5 m population)
Model 2	Annual Ridership (in millions) = 19.2xPopulation (in millions) + 4.00xNetwork Length (in kilometers)
Model 3	Ridership per Unit Length = 1.07xPopulation Density + 108.81xAge (in years)
The analysis of ring rail lines in cities yielded the following equations	
Model 4	Length of Circle = 0.003369xPopulation Density + 0.037355xLength of Network
Model 5	AnnualRidershipofCircularLine=17.29xPopulation + 8533567xLength of Line

Table 1. Regression Models for Rail Transport

B. Application of Regression Model for Western Province of Sri Lanka

Based on these set of equations a case study was done on the Western Province in Sri Lanka. The ridership values etc. were estimated using the models developed by Saadi et.al. (2013) for the given variables and then compared with the actual values to assess where the rail transit ridership stands in comparison to world norms. The models were applied to Western Province as well as the three districts Colombo, Gampaha and Kalutara separately. Results are summarized in Table2 and Table 3.

The results for ridership estimates show that the actual ridership levels are well below the world average based on the regression model estimates. The Ratios were calculated by dividing the model estimates with the actual ridership volumes. This ratio was used to estimate the ridership volumes for 2024 for increased population (estimated based census data for population growth rate for 2002-2012 (CBSL, 2012; DCS, 2012), population density and network length values (assumption was made that there will be new lines added to the existing network as given in Table 2). These method can adopted to make preliminary estimates on rail transit ridership for different scenarios for population as well compare how investments in expanding the railway network will materials in terms of ridership. The ratios for Colombo in particular reveal the extent to which rail ridership has deteriorated and the potential it has to absorb the majority component of urban public transport demand.

Regression models were developed based on data available on circumferential rail lines in cities and their ridership with other parameters such as total rail network length, city population and density by Saidi et al. (2013). These models can be utilized as an indicator on the viability of adding a circumferential rail line (circle line) to the existing network based on parameters such as population density, network length etc. and it also estimated the expected ridership on such circle lines if implemented is applied for the three districts in the Western Province. Application of model which estimates the length of the circle line from input parameters, population density and network length gives a value of 15.6, 9.2, 4.0 for Colombo, Gamapha and Kalutara respectively. Furthermore to estimate the passenger demand for the proposed circle line, result from Model 5 is adjusted by the actual vs. estimated demand ratio in Model 2 to come up with the final value of 6 million for 2012.

			Western Province			Colombo District		
			2004	2012	2024	2004	2012	2024
	Population (CBSL, 2012)	mn	5.5	5.8	6.4	2.2	2.3	2.4
	Population density (DCS., 2012)	persn/km^2	1526	1623	1780	3344	3438	3585
	Network length (CBSL, 2012)	km	208	208	255	91	91	120
	Actual Annual Ridership (Hyatt,2007)	mn	77.1			18.3		
Model No.	**Ridership Models**							
1	f(*Population*)	mn	268	361	511	246	252	263
	Ratio (actual vs empirical model)		0.29			0.07		
	Estimated ridership_1	mn		103	146		19	20
2	*f(Population,Network length*)	mn	937	943	954	406	407	409
	Ratio (actual vs empirical model)		0.08			0.04		
	Estimated ridership_2	mn		78	79		18	18
3	f(*Population density, Age*)**Network length*	mn	1289	1491	1752	739	827	940
	Ratio (actual vs empirical model)		0.06			0.02		
	Estimated Ridership_3	mn		89	105		20	23

Table 2. Application of Regression Models - Results for Western Province and Colombo

			Colombo District			Gampaha District			Kalutara District		
			2004	2012	2024	2004	2012	2024	2004	2012	2024
	Population	mn	2.3	2.3	2.4	2.1	2.3	2.6	1.1	1.2	1.4
	Population density	Pers/km^2	3344	3438	3585	1580	1714	1936	699	771	893
	Network length	km	91	91	120	83	83	100	35	35	35
Model No	**Ring Rail Line**										
4	Length = f(*Population density, Network length*)	km	15.2	15.6	17.2	8.7	9.2	10.7	3.8	4.0	4.5
5	Ridership = f(*Population, Length of line*)	mn	129.9	132.7	146.8	74.5	78.5	90.9	32.3	34.5	38.1
	Estimated Ridership *Ratio for Model 2	mn		6.0	6.6						

Table 3. Ring Rail Line - Estimated Parameters

III CASE STUDY : DEVELOPMENT OF RING RAIL LINES FOR WESTERN PROVINCE OF SRI LANKA

A. Circle Line Option 1

From the previous analysis, combining the estimated length for Colombo and Gampaha gives a total length of 24.8 km. Approximately similar length (21.7 km) was used to connect main cities in Colombo and Gampaha districts with a circle line which also connects the three existing rail lines. A circle line connecting Wellawatta (Coast Line)- Kirilapone (KV Line) - Battaramulla - Mahara - Ragama (Main Line). Considering increased population in the projected year, longer route could be used to develop a circle line connecting main suburban areas in Colombo district. This is given as Option 1 in Figure 1.

B. Circle Line Option 2

The second approach adopted to assess the possible route for a circle line is to first find the centre of gravity for passenger demand along each main line starting from Colombo. The average passenger demand during peak towards Colombo at each train station along the four railway lines from a study by Prasantha (2002) were used to calculate the centre of gravity for each of the railway line. The nearest train station to the centre of gravity for the railway lines are as follows.

Main line - Gampaha

Coast line - Moratuwa

Puttalam line - Seeduwa

KV line - Maharagama

A line connecting these locations creates a circumferential line connecting all the four railway lines in the existing network, with a total length of 51.7 km.

Total distance 21.7 km

Fig 1. Circle Line Option 1 (Colombo + Gampaha Districts)

Total distance 51. 7km

Fig 2. Circle line Option 2

Fig 3. Circle line Option 1 & Option 2

IV. CONCLUSION

The methodology and the regression models developed by Saidi et. al. (2013) provides a basis to evaluate the existing state of railway system and provides a useful tool to plan for expansion in the railway network especially with respect to development of ring rail lines.

The two options developed for Colombo and Western Province in Sri Lanka can provide input to preliminary planning of a new circle line to the existing rail network which would provide better accessibility and more direct routes from the suburban areas in Colombo, which in turn will improve the rail transit modal share in public transport.

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