Methodology to Identify the Optimum Network for an Urban Rail System

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Declaration of the candidate

"I declare that this is my own work and this thesis/dissertation does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any University or other institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text"

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"I have supervised and accepted this thesis for the submission of the degree"

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Dedication

To my loving parents.

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Abstract

Planning of railway systems is very important in situations of urban Light Rail Transit (LRT) and Mass Rapid Transit (MRT) network development because, these transportation systems not only provides for the mobility of people and goods, but also affect public policy concerns such as air quality, environmental resource consumption, social equity, land use, urban growth, economic development, safety, and security. Only a reasonable rail system network, which fit to urban features and urban development, has been well planned, each rail line can be implemented efficiently. If not, it's very easy to lead to duplicate construction and waste.

The broad objective of a railway network development is minimizing the total cost that includes both construction and operation costs, maximizing social welfare and profit and minimizing travel time and negative environmental impacts. The question in transport network design is to determine a network that has an optimal performance given a specific set of design objectives. The network design problem becomes complicated due to its multi-objective nature and the non-linearity of the objective function that represents the total cost.

Many studied have been conducted on optimization of transport networks. Wirasinghe and Seneviratne have done a study on determination of optimal rail line length considering the less complex many to one travel demand pattern (Wirasinghe and Seneviratne 1986 cited in Wirasinghe et al 2002). Van Oort and Van Nes (2004) have done a study on a network structure which reduces the number of transfers. Chien and Schonfeld have developed a model for optimization of a rail transit line and its feeder bus system (Chien and Schonfeld, 2007). According to previous research studies, a methodology has been developed to identify the optimum railway route between two given stations using Geographic Information System (GIS) by considering the engineering, environmental and socio-economical factors (Vinoth et al., 2008). Another study has been carried out on identifying the optimum railway network, by considering the factors related to the construction cost and the passenger demand (Ansaf et al, 2009). It is observed that the latter two studies have considered on optimizing the rail network in the construction stage and the previously mentioned studied have considered some of the factors related to the operational stage of the

network. Operational stage is also very much important in a transport network because it will be very much costly or difficult to operate successfully if the cost components under operational stage are not considered in the planning stage. Although the network can be optimized by considering the construction stage, it is not completed until the operational stage costs are considered. Therefore it is very much important to consider the operational costs in developing methodologies to identify the optimum railway network.

This study is to develop a methodology to find the optimum rail road network considering the operational conditions in addition to the construction and user cost. Objectives considered in optimization are categorized under two main sectors as operator and the user. Objectives to be optimized in operators' view are minimizing fleet cost, operational cost and infrastructure and maintenance costs while objectives related to in users' view are minimizing in vehicle cost, waiting time cost and transfer cost.

At first stage of this study, ten locations in the Colombo metropolitan region are selected locations for station development and two networks are identified based on two different scenarios. First scenario is to generate a primary route network considering the demands between station locations. Routes are assigned to highest demands until all the nodes are connected at least by one route. In second scenario, all demand between node pairs are assigned along their possible shortest paths and add them up to calculate the total demand for each link. Primary network is generated by linking the highest demand links until all the nodes are connected. Routes are assigned for the network considering the highest demand for both cases.

The two route networks are checked for the above mentioned six cost components. Route networks are fine-tuned using a set of algorithms for route merging, adding links and route sprouting. Fine-tuned route networks are also checked for cost components and compare the values between the two networks. Network with least cost values and least sensitivity to cost values with route network changes is selected as the best network and the method to generate that network is considered as the methodology to find the optimum network. Sensitivity analysis is done to check the behavior of the selected network with varying passenger demand. The stage wise development of the network with time is also identified.

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