A New Approach for the Network Development of an Alternative Rail Transit System

Buddhika Patikirimudiyanselage[1] and Saman Bandara[2]

Abstract

Developing a methodology to build a network plan for an alternative rail system with fewer implications for future demand changes is a challenging yet critical task in transportation planning. This research proposes a comprehensive methodology for developing such a network plan, with a focus on the Western Province of Sri Lanka as a case study. While rail systems are known for efficiently transporting high volumes of passengers, heavy rail is not always appropriate for short-distance travel, to which alternatives such as LRT and monorail are better adapted. The key research questions considered in this study are: Identify the parameters that need to be considered in developing a rail track network, determine the nodes that should be directly connected to minimize the cost without compromising other parameters, establish the optimum chronology for linking nodes, define the most efficient number of links that should be connected and develop a strategy for staged construction. Linking an extensive demand model to transportation planning is a strategic approach that needs to consider many different variables and requires a large quantity of detailed data. The unavailability of this information, the sensitivity of such variables to socio-economic variations, and time consumption are matters of concern. Demand changes that occurred due to the COVID pandemic, economic downturns, and fuel price fluctuations are some examples of this. As such, developing a methodology to build a network plan for an alternative rail transit system with reduced sensitivity to demand variations is a prudent approach. Network indices have mainly been applied to measure the performance of developed rail networks. Thus, it has been attempted to use network indices as a decision-making criterion during the planning stage in terms of connecting nodes. The proposed network development plan consists of four stages: transport zoning, quantification of stations, positioning of stations, and the final stage, linking nodes (stations). Therefore, it is assumed that the transport zoning, quantification, and positioning of station stages have already been completed before they reach the station linking stage, which is the core issue being focused on in this research. To accommodate the demand aspect, the gravity model is utilized to identify the “Demand-based connected network” (GDBCN). The highest-demand pair is connected first and then the next until all nodes are connected while avoiding the potential crossing of edges and the formation of loops. The minimum spanning tree (MST) is employed to establish the minimum cost network. First, the minimum spanning tree based on the link cost is determined using Kruskal's algorithm. This represents the minimum cost network (GMCN). Superimposing the identified Demand-based connected network (GDBCN) into the GMCN of the given sets of nodes is the next milestone of this network development methodology. The output network of this is denoted as the GSEN. The duplicated edges of the GSEN are guides in identifying the nodes that must be connected to satisfy both higher demand and lower cost. This will be the initial phase of the network (GBN) development for a given set of nodes. To minimize the total network travel length, the immediate next link of the basic network (GBN) is connected using minimum journey lengths calculated from one node to each of the other nodes using Dijkstra's algorithm. This calculation is repeated iteratively until the link that results in the highest journey length reduction is determined while avoiding the formation of crossings or loops. The outcome of this step is utilized to make the immediate next link (GBN+1). The remaining network links (GBN+1 onwards) are sequentially connected using the same iterative approach that centers on minimizing journey length, with the exception that loop formation is allowed, and it determines the optimal point to conclude network expansion based on the marginal benefit of adding new links before reaching maximum connectivity. It is evident that network indices, such as the meshedness coefficient, graph density, and average cluster coefficient, show improvement as the network evolves from GMST. There is a notable reduction in journey length and a significant decrease in the marginal reduction of journey length per marginal network length, especially from GMST to GSEN+1. Subsequently, this trend continues with a gradual decline in gradient. In conclusion, the development of a methodology for creating a rail transit system with reduced sensitivity to demand variations presents a strong avenue for improving the stability and efficiency of transportation networks. Also, the proposed methodology facilitates developing a new alternative rail network in an optimized phased-out plan and extending an existing network or integrating it with an existing transit system. It is argued that when the developed network layout is robust and less sensitive to input parameters, it is possible to take care of operation efficiency and passenger convenience with an appropriate route plan. This way, any future demand variations could also be accommodated without changing the network layout.

Keywords: *Network Development Methodology, Phased Network Development, Transportation Network Efficiency, Rail Transit Network*

Authors Details;

1. Postgraduate Student, Department of Civil Engineering, Faculty of Engineering, University of Moratuwa, Sri Lanka. qsbuddhika1976@gmail.com
2. Senior Professor, Department of Civil Engineering, Faculty of Engineering, University of Moratuwa, Sri Lanka. bandara@uom.lk