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

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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 Gampaha District 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, establish the optimum chronology for linking nodes, define the most efficient number of links that should be connected with 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. 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. The proposed methodology blends the gravity model and the minimum spanning tree (MST) theories with link cost and network efficiency parameters. Any rail network development consists of four stages: transport zoning, quantification of stations, positioning of stations, and the final stage, linking nodes (stations). In the proposed methodology, it is assumed that the first three stages have already been completed before they reach the station linking stage, which is the core issue being focused on in this research. The gravity model is utilized to identify the "Demand-based network" (G_{DBN}) to accommodate the demand aspect. The highest population-based gravity pair is connected first and then the next until all nodes are connected while avoiding the potential crossing and the formation of loops. Then, using Kruskal's algorithm the MST establishes the minimum cost network (G_{MCN}) based on the link cost of each feasible link in the network. Superimposing the identified G_{DBN} into the G_{MCN} of the given sets of nodes is the next milestone. This output network is denoted as the G_{SEN}. The duplicated edges of the G_{SEN} guide the identification of the nodes that must be connected to satisfy both higher demand and lower cost characteristics. This will be the initial phase of the network (G_{BN}) development for a given set of nodes. To minimize the total network travel length, the immediate next link of the G_{BN} is determined based on the minimum journey lengths (MJL) 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 is utilized to make the immediate next link (G_{BN}+1). Using the same iterative approach, the remaining links (G_{BN}+1 onwards) are sequentially connected till all the nodes are connected and form the connected network (G_{CN}). Linking of nodes from G_{CN} onwards is carried out in the same manner with the exception that loop formation is allowed. Finally, it determines the optimal point to conclude network expansion based on the marginal

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benefit of adding new links. In conclusion, developing a methodology for a rail transit system with reduced sensitivity to demand variations enhances the stability and efficiency of transportation networks. The proposed methodology supports creating a phased-out alternative rail network or integrating it with existing systems. A robust, parameter-insensitive layout ensures operational efficiency and passenger convenience, allowing future demand variations to be accommodated without altering the network design.

Keywords: *network development methodology, phased network development, rail transit network, transportation network efficiency*

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