Optimum Spacing for Bus Stops for Local and Rapid Bus Routes

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Abstract

This research revisits the issue of determining the appropriate number of bus stops and optimal spacing for a bus route, which is crucial for enhancing transit efficiency and passenger satisfaction. The study adopts a comprehensive approach by initially approximating passengers' likelihood to choose between local buses, rapid transit, or a combination of both for their journeys. Secondly, it optimizes the overall cost function to determine the optimal number of bus stops along the route for both local and rapid transit buses. The study extensively reviews the existing literature on Discrete Choice Models (DCM), Utility Theory, and Objective functions pertinent to total transit cost. The methodology involves calculating the probability of passenger demand for given alternative options, minimizing the total cost function, determining the optimal number of bus stops along the route, and calculating the optimal spacing between the bus stops based on the total length of the route. A stated preference survey can be used to collect data for the actual development of the choice model and identify the probabilities for five alternative options: (i) Walk + Rapid bus + Walk, (ii) Walk + Rapid transit + Local bus + Walk, (iii) Walk + Local bus + Rapid transit + Walk, (iv) Walk + Local bus + Rapid transit stop + Local bus + Walk, (v) Walk + Local bus + Walk. A multi-level nested logit model is proposed to estimate the parameters of the utility function, and the overall fit of the model can be assessed using the trial and retrial method based on the maximum likelihood technique. The probability of choosing each alternative option to travel from origin to destination for a bus passenger can be identified based on the multi-level logit structure. The total cost of bus transit services depends on operator costs and user costs. Transit users aim to reduce their out-of-vehicle travel time, while transit operators aim to reduce operating costs. This study uses the total cost function proposed by Tirachini (2014), which considers the number of stops for the optimization.

$$C_t = c.f[\frac{L}{V_0} + \frac{\beta.N}{f} + st_s] + P_a\frac{L}{2.V_w s}N + P_w\frac{1}{2f}N + P_v\frac{l}{L}[\frac{L}{V_0} + \frac{\beta.N}{f} + st_s]N$$

N In this equation, the total cycle time considers the summation of the running time (L/V_0) and the delays due to stopping at bus stops [(?N/f)+st_s]. The objective of this study is to identify the optimal number of bus stops for a route that has both local and rapid transit buses in operation. To accomplish this, the above function is modified based on a scenario that includes transfers between local and rapid transit buses for certain alternatives. The total cycle time is modified as the sum of the running time, the delays due to stopping at bus stops, and the transfer time (t_f) between buses. Transfer time is a function of traffic congestion and route efficiency. To consider both local and rapid bus routes, the total cost function is modified as follows.

$$C_{t,i} = c_i.f_i[\frac{L_i}{V_0} + \frac{\beta.p_i.N}{f_i} + s_i t_s + t_f] + P_a\frac{L_i}{2.V_w s_i}p_i.N + P_w\frac{1}{2f_i}p_i.N + P_v\frac{l}{L_i}[\frac{L_i}{V_0} + \frac{\beta.p_i.N}{f_i} + s_i t_s + t_{f,i}].p_i.N$$

The optimal number of bus stops can be identified by minimizing the objective function for the total cost. The optimal number of bus stops for rapid routes (s_01) and for local routes (s_02) can be determined by taking the first derivative of the total cost function, setting it to zero, and solving for s_i $[s_i = L_i/(s_i - 1)]$. The ratio between the number of local bus stops and the number of rapid bus stops can also be calculated using these equations, providing valuable insights into how many local bus stops are required in between rapid bus stops to cater to passenger demand. By using the ratio of optimal bus stops, transit planners can strategically place rapid and local bus stops along a route to meet the needs of different types of passengers. This approach can help increase the efficiency and effectiveness of public transport services, ultimately resulting in improved mobility and accessibility for commuters. Upon analysis, it has been concluded that when demand for buses increases at a constant frequency, it would be advisable to increase the number of bus stops along a particular route. This research not only contributes to the theoretical understanding of transit planning but also offers practical implications for urban transportation systems. The research findings are substantiated with a detailed numerical example, utilizing specific assumptions of the probabilities of choosing a rapid bus route as 0.15 and a local bus route as 0.85. The optimal spacing between bus stops for the rapid and local routes is determined to be 1 km and 0.273 km, respectively. This results in a local-to-rapid bus stop ratio of 4, indicating that to maintain the optimal spacing between bus stops, there should be one rapid route bus stop for every four local route bus stops along a given route. It is important to note that local and rapid bus stops may not necessarily coincide with each other. The obtained results for the bus stop spacing align with industry norms, illustrating the application of the proposed methodology and ensuring a comprehensive and practical understanding for practitioners and researchers alike. In conclusion, this study significantly advances the field of transit planning by integrating passenger choice modeling, cost optimization techniques, and empirical analysis. The insights derived from this research not only enrich academic discourse but also offer actionable strategies for transit agencies and urban planners, thereby contributing to the enhancement of public transportation systems in urban areas.

Keywords: *Bus stop spacing, DCM, Total cost function, Bus stop optimizations*

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