Optimal planning of Transfer Instracture in a Multimodal Transport Network: Bi-level Modeling and Paradoxes

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ABSTRACT(in approximately 800 words):

OPTIMAL PLANNING OF TRANSFER INSTRACTURE IN A MULTIMODAL TRANSPORT NETWORK: BI-LEVEL MODELING AND PARADOXES

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With the growing attention towards developing multimodal transport system to enhance urban mobility, there is an increasing need to construct new, rebuild or expand existing infrastructure to facilitate current and accommodate newly generated travel demand.

Many researchers have been working on the approaches to integrate the multimodal transport services. In general, existing studies can be classified into three approaches. In the first approach, the decision variables associated with each transport mode, i.e., bus route, frequency, or link capacity, are exclusive to each transport mode. The second approach designs the allocation of exclusive lanes to specific transportation modes. The third approach designs the transfer location in a multimodal transport network, where intermodal trips are considered in the route choices. However, the studies within this approach are limited and there is no existing study on designing the location and capacity of transfer infrastructure simultaneously. Irrespective of the modelling approaches, a common framework for formulating the multimodal network design problem is the bilevel programming.

Therefore, this paper proposes a bilevel multimodal network design model that simultaneously determines the location, type, and capacity of the infrastructure that should be built. Road, transit, bike and walk networks are all considered as sub-networks in this study. The upper level problem is to determine the type of transfer infrastructure and its corresponding capacity would be built at a candidate transfer location. The lower level problem is the combined trip distribution and assignment model subjected to capacity constraints.The upper-level problem is a mixed integer linear programming problem, while the lower level problem depicts both destination and route choices of travelers by multinominal logit formula. As a well-known NP-hard problem, most existing studies adopt

heuristic algorithms to solve it. Thus, this paper develops a math-heuristic algorithm that integrates a Genetic Algorithm and a successive linear programming solution approach.

Numerical studies are conducted to demonstrate the optimal design of transfer capacity in a multimodal transport network and the existence of two paradox phenomena. One is a Braess-like paradox in the context of multimodal transport network under fixed demand, stating that constructing parking space to stimulate the usage of Park-and-Ride service could deteriorate the system performance, measured by the total passengers' travel time. Effects of θ and transfer capacity constraints on the occurrence of the Braess-like Paradox are examined. The result indicates that when the route choice behavior tends to follow user equilibrium (i.e., θ is large), it is more likely that the Braess-like paradox would happen. It is also interesting to notice that the Paradox could occurs either at a low capacity (below 115) or a high capacity (above 1824). The second one reveals that increasing the parking capacity for the Park-and-Ride to attract the usage of metro service may fail, represented by the decline in the modal share. Effect of θ under variable demand is examined. By comparing the results under different θ, it is easy to know: 1) The larger the value of θ is, the larger the maximum probability of using park and ride; 2) the gap among the three paths share rates becomes narrow with the increasing in the value of θ. The last experiment indicates some transfer node design recommendations: 1) It is better to build two nearby small transfer nodes rather than a large one with the fixed budget constraint; 2) the two nearby transfer nodes should be different typies and next to different metro stations.

Keywords: multimodal network design, bilevel programming, genetic algorithm, paradox.

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