A heuristic to solve the Transit network design problem

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This paper proposes a method to solve the transit network design problem (TRNDP). The problem is to find the best transit network for a given infrastructure network topology and fixed public transport demand represented by an origin-destination matrix. Approaches to the problem can be broadly divided into practical guidelines, analytical optimization and meta-heuristic procedures. Analytical methods comprise direct optimization models that ensure a globally optimal solution. However, these models are limited to the size of problem they can solve, and used to solve only literature ideal networks. Meta-heuristic methods entail the ability to address complex or large-scale problems, and therefore most popular in the last two decades. However, due to problem complexity, models include many unrealistic assumptions and/or not applicable for large scale networks. Therefore, in practice, planning is largely based on principle guidelines and rules of thumb.

Most models for the TRNDP formulates the decision variables as the routes and corresponding frequencies, while optimizing some system measure as the total travel time or system cost. Common constrains are minimal frequency, route minimal and maximal length, fleet size and vehicle capacity.

The TRNDP has a bi-level structure; the upper problem includes the network design (i.e., a set of routes and frequencies), and the lower problem includes the transit assignment (i.e., mapping the demand on the suggested transit network).

Two sub models of the TRNDP were developed so far: route set generation and transit assignment. The suggested study aims on integrating the previously developed sub models into a complete transit network design model. The general scheme of the suggested design model is presented in figure 1.

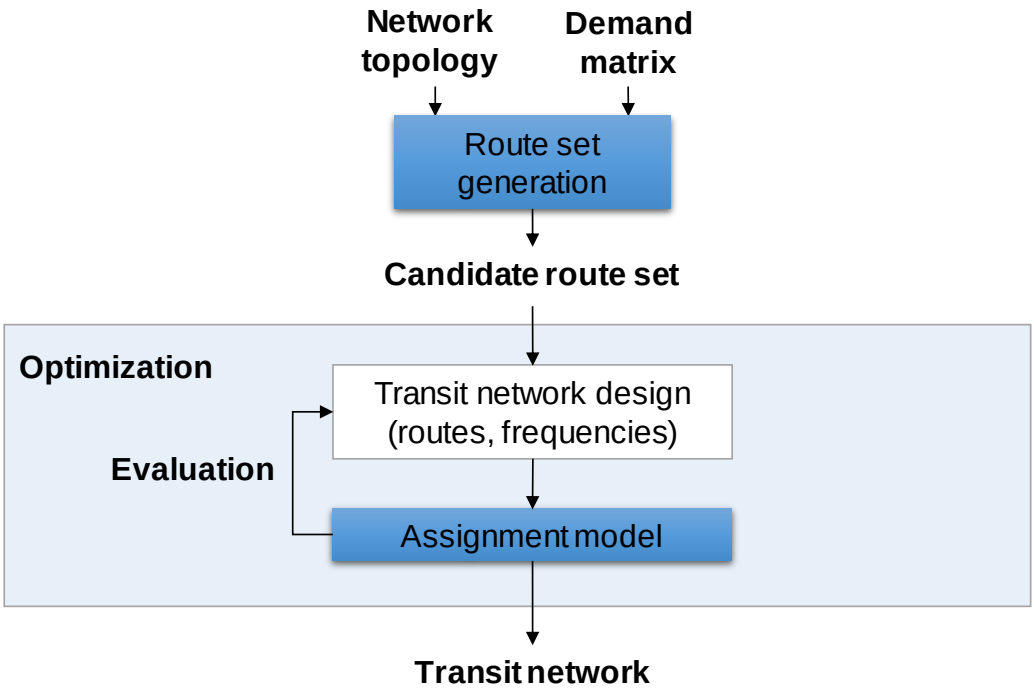

Figure 1: General scheme of the design model.

A key issue related to the TRNDP is the need to generate and evaluate candidate transit routes. As the TRNDP is highly complex and comprise enormous solution space, the route generation is commonly performed as a preliminary step to a meta-heuristic solution method. Existing methods for route generation are widely based on variations of shortest path algorithms, generating fast routes between high demand centers. The developed model (Oliker and Bekhor, 2017) form routes on corridor links, with high overall demand, in order to strengthen the service attractiveness. The suggested model form two types of routes: the commonly used shortest path and path that pass through high demand corridors. The model was compared to a shortest path method, and showed higher coverage of the network, producing a wider variety of routes.

The developed assignment model (Oliker and Bekhor, 2016) is a frequency based transit assignment model that considers online information of predicted arrival times is available to passengers. Passenger's route choice is assumed to consider the estimated arrival times together with the expected travel time. The methodology was developed for two information levels: (1) full info, where the arrival times are predicted for all intermediate stops in the candidate paths, and (2) partial info, where the arrival times are predicted at the boarding stop only. The assignment procedure includes the finding of attractive paths, the setting of decision rules for route selection in different cases of arrival times, and the probability calculation for these different cases. Model

application was illustrated for the network of Winnipeg. In comparison to the well-known optimal strategies method, the suggested model produced significantly different assignment results and a notable reduction in the total travel time. The application results illustrated the potential impact of online information on assignment results, and emphasize the need for its consideration in planning models.

In the development of the design model, special attention will be given to exploiting the properties of the problem in the heuristic of the solution. For example, the candidate transit route set will be used to execute a preliminary step to the assignment model. The assignment problem is solved for each candidate solution of the TRNDP; thus, its running time is critical for the applicability of the model for large scale network. The main time consuming element in the transit assignment is the finding of attractive path set for each O-D demand pair, given the suggested transit network. A route set generation is conducted as a preliminary step to the optimization, as described above. This procedure yield a large route set, comprise candidate routes for transit routes. Given the candidate route set, paths that are candidate for the assignment attractive path set can be also found in advance. This application can significantly improve the efficiency of the assignment model.

The main idea of the proposed heuristic is to generate choice sets that will not necessarily comply with the budget constraints. The assignment results will be used to rank the most attractive lines in terms of passenger loadings, and then prune the routes with fewer passengers (either the whole route, or parts of it). The pruning continues until the budget constraint is satisfied.

The expected contribution of the research is the development of novel and efficient model for transit planning, applicable for large scale network.

Reference

Oliker and Bekhor (2016) "A frequency based transit assignment model that considers online information at the boarding stop." Intelligent Transportation Systems (ITSC), 2016 IEEE 19th International Conference on. IEEE, 2016.

Oliker and Bekhor (2017) "A demand based route generation model for transit network design". Transport Infrastructure and Systems: Proceedings of the AIIT International Congress on Transport Infrastructure and Systems (Rome, Italy, 10-12 April 2017)