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MULTIMODAL NETWORK DESIGN AND ASSESSMENT

Proposal for a dynamic multi-objective approach

Ties Brands MSc[1], Gijs van Eck MSc[2]
[1]Faculty of Engineering Technology, Centre for Transport Studies,
University of Twente, the Netherlands
[2]Faculty of Civil Engineering and Geosciences, Department of Transport and Planning,
Delft University of Technology, the Netherlands

ABSTRACT

A framework is proposed for the design of an optimal multimodal transport network for the Randstad area. This research framework consists of a multi-objective optimization heuristic and a fast network assessment module, which results in a set of Pareto optimal solutions. Subsequently, a proper method reduces this set to an acceptably small size, after which every remaining solution is assessed in detail by a newly developed dynamic multimodal assignment model, which provides an overview of the different qualities (like environmental impact, accessibility and livability) of promising networks.

KEYWORDS

Network design, bi-level optimization, multimodal, multi-objective, dynamic traffic assignment, sustainability

INTRODUCTION

The expected densities of activities and flows in the Randstad for 2040 are too high to just rely on expansion of the automobile system, even if the environmental performance of the latter will drastically improve. On the other hand, the present public transport system does not appear to provide a sufficiently attractive alternative. Therefore, the NWO research program '*Strategy towards sustainable and reliable multimodal transport in de Randstad*' (SRMT) develops integral strategies to optimize the contribution of reliable transport chains with public transportation as backbone for a vital and accessible Randstad. As part of this research program we propose a method to design multimodal transport networks for the Randstad in which multiple objectives will be considered.

A multi-objective approach is adopted when assessing the transport network of the Randstad, because of the complex context of competing sustainability interests like environmental impact, accessibility and livability. Furthermore, a multimodal approach is needed, because car and public transport networks are likely to merge to a greater extent in the coming years, while current transport models are based on a rigid separation between modes. The definition of multimodal transport, as given by Van Nes (2002), is that two or more different modes are used for a single trip between which travelers have to make a transfer.

Decision variables in the research are related to public transport facilities (new transit links, rerouting of transit lines, frequency of transit lines, Intercity status of train stations) or to transfer facilities (P+R, new train stations). Budgetary and spatial constraints are taken into account. The outcome of this process is a set of possible future networks and their properties, which allow policy makers to make a proper trade off.

RESEARCH FRAMEWORK

The transit network design problem has been studied in many different ways (Guihaire and Hao, 2008). In our research the network design problem is defined as a bi-level system (see for example Viti et al., 2003 and Tahmasseby, 2009) as shown in figure 1. The upper level (**step 1a**) contains the behavior of the planner or government. At this level, the traffic network can be changed during the optimization process, within realistic bounds. The design problem in the upper level results in a set of networks, with values for multiple objectives. The lower level (**step 1b**) describes the behavior of the traveler. Each traveler minimizes his or her own costs (travel time, waiting time, monetary costs, etc.), by making its own optimal choices. This results in a network state (e.g. travel times, loads) for each solution, from which the objective values can be derived.

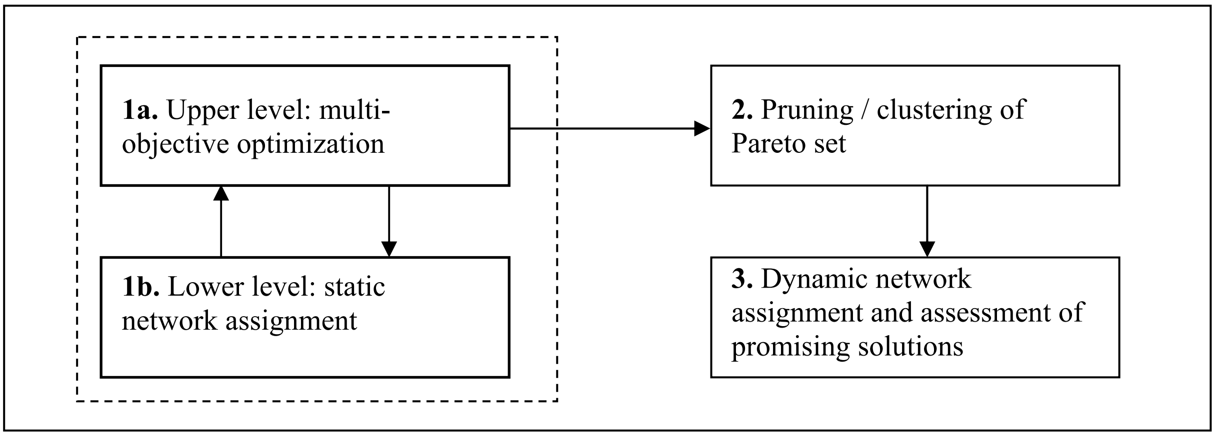

Figure 1: Framework of the network design approach

The resulting set of solutions from the optimization process (**step 1**, see section 3) is likely to be too big to be assigned dynamically, so some pruning and clustering techniques are applied (**step 2**, see section 4). This leads to a smaller set which is feasible to be assessed by a new dynamic network assignment model to be developed within this project (**step 3**, see section 5). This model will determine the level of service for each network component. Subsequently a more detailed assessment of the selected networks with respect to various sustainability measures can be performed. In this part of the research project the main focus will be on correct modeling of multimodal trips. The results of this detailed assessment can be presented to decision makers, so they can come to a grounded decision. Because of computational constraints, in step 1b a static version of the dynamic assignment model in step 3 will be used.

The explicit multimodal approach in this research implies multimodality for the static model as well.

FINDING PARETO OPTIMAL SOLUTIONS

We adopt a multi-objective approach in this research. Several existing methods take multiple objectives into account. Some methods translate multiple objectives to a single objective, by using weights for each objective. This method leads to two main problems: the weights as well as the normalization of the different objectives are arbitrary. So we choose a method which results in a set of solutions, with different values of the different objective functions: the so called Pareto Optimal Front is constructed. The basic rule in this method is that a solution is excluded from the set when it scores worse than another solution on all objectives and is included otherwise.

The network optimization problem is a discrete problem which is hard to solve. However, in the literature different techniques exist to approximate the multi-objective optimization problem by using a heuristic (see Deb, 2001 for theory and Fan, 2004 for a practical application in transportation science). Examples of these are different forms of Genetic algorithms, Simulated Annealing or Tabu Search. A proper balance needs to be found between the number of decision variables and the computational complexity.

SELECTION OF SOLUTIONS

A problem that may rise when using a Pareto front, especially when the number of objective functions is increasing, is that the number of solutions in the optimal front is too big to get a concise overview of the possibilities. In the available literature some pruning and clustering techniques have been found to reduce the front to an acceptable number of solutions (e.g. Taboada et al, 2007). In that case, a policy maker can get a complete and clear overview of the main possibilities for multimodal network development.

ASSESSMENT OF PROMISING SOLUTIONS

Assignment of travelers to the network is an essential step in assessing transport networks. From the resulting (equilibrium) network state nearly all relevant objective values can be derived. In the coming years developments such as road pricing, improved information provision and introduction of the chip card will contribute to a better coordination and integration of private and public transport services. An integrated multimodal transport system offers opportunities to benefit from the strengths of the various modes while avoiding their weaknesses. The share of multimodal trips is already relatively large (20%) for medium and long distance trips to and from large cities (see Van Nes, 2002). As travelers in the Randstad use a variety of modes and modal combinations a proper analysis requires a truly multimodal approach, which does not really exist yet. Furthermore the dynamic character of transport itself and the combination of non-scheduled (car) and scheduled (public transport) modes sets extra emphasis on correct modeling of variation over time.

In traditional four-stage transportation models (production and attraction, distribution, mode choice and assignment) mode choice results from a dedicated mode choice model at O-D level, whereas route choice results from traffic assignment, completely separated from the mode choice model. These models are not capable of dealing with the full complexity of multimodal trips. To deal with the possibility of combining modes in a trip the model set up in figure 2 is proposed. Mode and route choice are integrated into a simultaneous choice process.

To this end, a single integrated multimodal network is constructed, also called supernetwork. In the supernetwork several unimodal networks are connected by transfer links which represent the possibility of making a transfer and the related time and cost components. A route in a multimodal supernetwork will therefore not only determine which links are used, but also which modes are chosen and, in case of a multimodal trip, the transfer location as well. The rigid separation between mode choice and route choice disappears.

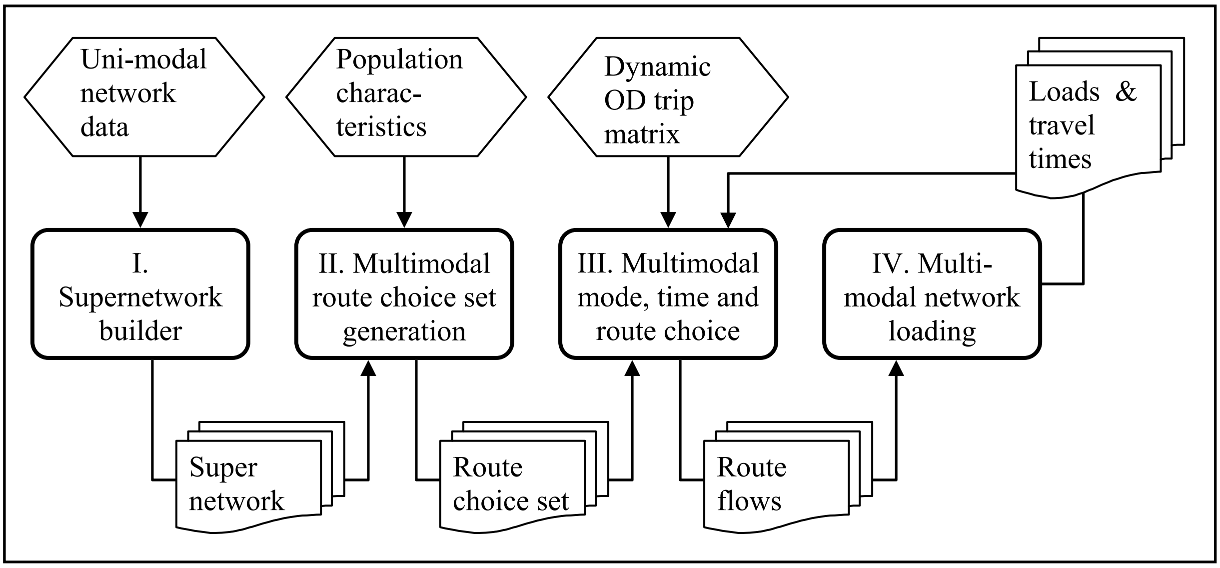

Figure 2: Proposed dynamic assignment model

After the construction of a supernetwork a route-based approach will be applied where (uni- and multimodal) routes will be generated a priori, which allows maximum freedom when modeling travel behavior while limiting computation time during the iterative assignment process. The basic assumption is that travelers have a set of possible alternatives available from which he or she chooses the alternative that is most suited to him or her. Next the time, mode and route choice and network loading components will iteratively distribute transport flows among these routes. In complex transport networks, such as multimodal networks, alternatives are likely to partly overlap. This overlap causes correlations among alternatives in a choice set, which will influence choice behavior and should thus be accounted for in modeling choices. The macroscopic dynamic assessment will be based on equilibrium principles while considering capacity constraints (roads, parking facilities, and public transport) and pricing strategies. Some components of the proposed model have been discussed in earlier studies such as choice set generation (Fiorenzo-Catalano, 2007), modeling travelers behavior in multimodal networks (Hoogendoorn-Lanser, 2005) and dynamic assignment of public transport (Nuzzolo, 1994). However a coherent model that combines these and new components to a dynamic truly multimodal assignment model is lacking.

CONCLUSIONS

The main goal of this research is to develop an optimization framework for the design of multimodal transport networks considering multiple objectives. Application of the proposed method should provide policy makers with the required information to make a well supported decision on network design. First a set of Pareto optimal solutions is constructed. After a selection procedure a dynamic multimodal assignment model is developed and applied to assess the remaining promising solutions with respect to multiple sustainability objectives.

From previous research some useful multi-objective optimization techniques and multimodal transport modeling components are available. However further elaboration and integration of these building blocks is needed to come to a coherent framework. Some challenges that have to be taken up are to search efficiently in the solution space, handle the large variety of multimodal travel alternatives in an efficient way, considering capacity constraints in public transport and parking facilities and taking into account variation over time. The proposed modeling framework will be translated into operational design and assessment models, which will be applied to the Randstad area, whose size and complexity set extra challenges.

ACKNOWLEDGEMENTS

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