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# Multimodal transportation plan adjustment with passengers behaviour constraints

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## 1 Introduction

For the last decades, the growth of population in high density areas pressed the need to enhance mobility services. Nowadays, most of the biggest cities have settled public transportation infrastructures to fluidize traffic and ease local mobility. Nevertheless, these infrastructures are likely to meet their saturation limits during rush hours, making the management of such a system a crucial point. This led to consider Transportation Network Optimization Problems (TNOP).

One can divide TNOPs into two main parts, each part corresponding to a different aspect of the problem.

### 1.1 Network flows and user equilibrium

It is usually more convenient to model passengers as flows. The practical interest of flows lies in its ability to aggregate each individual while still capturing the movements on the network. Network flows have been introduced long ago (see, e.g., [4], enhanced later by [2]). Since then, these models have been generalized for multiple “commodities” [10] and grouped under the label of “multi-commodity” flow models. A lot of optimization problems aim at deciding the best routing solution of flows –by minimizing a cost function for instance (see e.g. [1]), whereas in transportation models these flows are used to describe a user equilibrium, namely a Wardrop’s equilibrium. [11] sums up equilibrium models by describing its two competitive mechanisms: a “selfish” disutility minimization for each individual on one hand (the objective), and the increase of disutility generated by confronting the strategies of those individuals on the other hand (the constraints). Hence, he shows how to reformulate it with mathematical programming. This will become the base principle from which every other passengers behaviour model will derive.

### 1.2 Network design and Bi-level Programming

Whereas network flows problems consists in using the network, the network design problem consists in deciding how the network should be. The latter can be the case when it comes to choose whether we want to install a network component or not, considering a cost function (see e.g. [5]). More generally the impact of such decisions (in terms of cost and/or feasibility) is not always easily computed, which is typically the case in TNOPs. It is typically the case in TNOPs, where we have to solve a network flows problem (as [11]) to know what are the consequences in our transportation plan decisions. These two embedded problems (network flows problem and network design problem) can be seen as hierarchical in the sense that the

decisions of the transportation plan will set the available itineraries of passengers, but the other way around is not true. From the game theory point of view, this can be seen as Stackelberg competition, as the transport operator decides the transport plan first (and hence is the so-called “leader”), and given that decision, the passengers will decide how to react (they represent the so-called “followers”). However, the leader have insights about the way the follower will react to develop a relevant strategy. To model it as an optimization problem, Bi-level Programming is often used. Bi-level Programming means that two level of decisions exist: one that becomes parameters for the second. [9] proposed a large survey of different transportation Bi-level models and algorithm techniques to solve them, completed later by [3]. [8] then [7] tackles the stochastic versions of user equilibrium, especially for road networks.

### 1.3 Multimodal transportation plan adjustment with passengers behaviour constraints

With the rise of digital technology and telecommunications, transportation operators can simultaneously be closer to the real time state of transportation infrastructure and have larger vision of the whole (even multimodal) transportation system. This allows transport operators to react at a disturbance dynamically and disseminate quickly a recourse strategy to face it off. This is what we call multimodal supervision. From this point of view, we propose to address a problem of transportation plan readjustment. Readjustment differs from classical optimization by four main points. Firstly, the problem has a variable spatial and temporal perimeter, as we do not necessarily know in advance how long and how far the issue will propagate along the network(s). In other words, the space and time needed to go back to a nominal state is unknown. Secondly, for the previous reason (propagation avoidance), the adjustment model must be as accurate as possible during the horizon it is deployed. It includes passengers strategies and problems caused by their overloads (delays, door blocking...). This can induce interdependency between different transportation systems. Thus, the multimodal network must be considered. Thirdly, the optimization horizon starts with a given infrastructure state. This includes the positions of vehicles and passengers, and whole infrastructure state. Finally, adjustment implies that the solution is a differential plan from the nominal one. In terms of optimizing process, it can induce a set of specific constraints related to the distance with the proposed plan (adjustment) and the nominal one.

Moreover, as the situation is extremely dynamical, to ensure the strategy to be deployed at the time it is provided, the adjustment must be made in a short time-window. This problem can be formalized as a particular TNOP and modelled using (Time-Expanded or Time-Dependent) graphs (see e.g. [6, 12]). We discuss here a first mathematical formulation to tackle this problem in one single Mixed Integer Linear Program, and future methods to achieve these operational objectives.

## References

- [1] R. K. Ahuja, T. L. Magnanti, and J. B. Orlin. *Network flows: theory, algorithms, and applications*. Prentice Hall Inc., 1993.
- [2] J. Edmonds and R. M. Karp. Theoretical improvements in algorithmic efficiency for network flow problems. *Journal of the ACM*, **19**(2):248–264, 1972.
- [3] R. Z. Farahani, E. Miandoabchi, W. Y. Szeto, and H. Rashidi. A review of urban transportation network design problems. *European Journal of Operational Research*, **229**(2):281–302, 2013.
- [4] L. R. Ford and D. R. Fulkerson. Maximal flow through a network. *Canadian Journal of Mathematics*, 8:399–404, 1956.

- [5] E. Gourdin, M. Labbé, and H. Yaman. Telecommunication and location. In Z. Drezner and H.W. Hamacher, editors, *Facility Location: Applications and Theory*, pages 275–305. Springer, 2002.
- [6] C. Liebchen and L. Peeters. Some practical aspects of periodic timetabling. In *Operations Research Proceedings 2001*, pages 25–32, Berlin, Heidelberg, 2002. Springer Berlin Heidelberg.
- [7] H. Liu and D. Z. W. Wang. Global optimization method for network design problem with stochastic user equilibrium. *Transportation Research Part B: Methodological*, 72:20–39, 2015.
- [8] Q. Meng, D. H. Lee, H. Yang, and H. J. Huang. Transportation network optimization problems with stochastic user equilibrium constraints. *Transportation Research Record: Journal of the Transportation Research Board*, 1882:113–119, 2004.
- [9] A. Migdalas. Bilevel programming in traffic planning: Models, methods and challenge. *Journal of Global Optimization*, 7(4):381–405, 1995.
- [10] F. Shahrokhi and D. W. Matula. The maximum concurrent flow problem. *Journal of the ACM*, 37(2):318–334, 1990.
- [11] Y. Sheffi. *Urban Transportation networks: Equilibrium Analysis with Mathematical Programming Methods*. Prentice Hall Inc., 1985.
- [12] M. Skutella. *An Introduction to Network Flows over Time*, pages 451–482. Springer Berlin Heidelberg, Berlin, Heidelberg, 2009.