A Mixed Integer Linear Program for the Rapid Transit Network Design Problem with Static Modal Competition

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Abstract

In recent years, several models and algorithms have been put forward for the design of metro networks (see e.g. [1], [7], [2], and [6]). Here we extend the rapid transit network design problem (RTNDP) of [4] by introducing modal competition and by enriching its multi-objective framework. In that reference an origin-destination flow is considered as captured by rapid transit if some stations are sufficiently close to both the origin and the destination of the flow. We observe that by maximizing the captured traffic using this criterion results in improving *access*, i.e. the number of commuters who could benefit from the rapid transit network for their daily trips. This is indeed a relevant goal in urban transit, but on its own it does not adequately reflect modal choices. In this talk we consider a traffic flow as captured if the travel time (or equivalently the generalized cost) by rapid transit is less than by car, i.e. an "all or nothing" criterion. This feature has been neglected in most previous discrete mathematical programs because considering origin-destination flows results in models that are too large for realistic instances. As observed by [8], considering traffic flows requires a multi-commodity formulation, where each flow is considered as a distinct commodity. This was the approach taken by [5], but it only allowed the solution of very small instances. We introduce a methodology that overcomes this difficulty by exploiting a pre-assigned topological configuration. As explained by [1], a pre-assigned topological configuration is in itself a positive feature for planners since it incorporates their knowledge of the traffic flows in cities and corresponds to what is often done in practice. We note that a metro network is typically built incrementally starting from a simple layout. Very often planners identify a few major corridors that should be privileged for an initial metro configuration or for later extensions. Geographical constraints may also limit the number options. We remark that, despite the simple layouts, the high number of location choices for each layout renders the problem hard. The precise alignment of metro lines within these corridors can be optimized by using a methodology such as the one we propose. The basic topological configurations we consider are not limitative in the sense that our approach will work with any basic layout. We note, however, that simple layouts such as stars and triangles exist in several networks (e.g. Minsk and Prague). With time the basic networks evolve into more complex, but still common configurations. [10] find that metro networks converge to a shape characterized by a core from which quasi-one-dimensional branches grow and reach out to areas of the city further from it. We discuss relevant goals of rapid transit planning, and we propose a multi-objective model conducive to a post-optimization

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analysis for effectiveness, efficiency, and equity concerns. The multi-objective framework works with two alternative measure of effectiveness under a budget constraint, and a post-optimization phase is suggested to assess efficiency and equity trade-offs, an issue rarely considered in transit planning (see for example [3] for a review of equity in location problems, and [9] for a discussion of equity in urban transit). We show that our approach can be applied to realistic situations and we illustrate it on data from Concepción, Chile.

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