Developing a Strategic Network Optimization Model for Freight Transportation

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1 Introduction

Freight transportation is an activity that plays a crucial role in the everyday life of any modern society, having a great economic importance. Due to that, it is important to think of it as a separate part of the transportation spectrum (instead of being grouped with passenger transportation, as it frequently happens), and to plan for future network improvements specifically with freight transportation in mind. This is justified not only because of the importance of freight in itself, but also because the needs of freight transportation are different from those of passenger transportation, which means that the network investments needed to improve freight transportation can be considerably different from those aimed at improving passenger transportation. In order to address this problem, the authors are developing a strategic network optimization model made for freight transportation, where the specific needs of this kind of transportation are taken into account.

2 Network structure and traffic assignment technique

The traffic assignment model that is used in this work was developed in the scope of a larger task [1], and is designed to model macro networks with a high aggregation level, namely national or international networks, being a strategic planning model [2]. As such, it will not require very detailed data inputs, and the outcome of its application is the estimation of the movement of freight at a national scale. It is therefore intended to be a useful tool for a variety of planning and policy decisions, which are the kind of tasks for which this type of models are more suited for [3]. The model is intended to simulate land freight transportation, considering both road and rail transportation modes. It considers two different types of cargo (general cargo and intermodal cargo) and uses different assignment techniques for each type, with its main innovative feature being the fact that it takes into account both capacity constraints and a variable perception of costs by users. In the case of intermodal cargo, more than one mode of transport may be used in each trip, and an all or nothing assignment technique is used. As for general cargo, the model considers that it may be transported by only one mode per trip (no intermodality), and the traffic is distributed between the least costly road and rail alternatives using a Logit function, simulating a variable perception of costs. The fact that this assignment model takes into account both capacity constraints and a variable perception of costs by users distinguishes it from the traditionally used all or nothing, equilibrium or stochastic (multi-flow) models, none of which considers these two factors simultaneously, making it a new and innovative strategic freight traffic assignment model.

3 Network optimization process

The first step in the development of a network optimization model is the creation of a base network improvement scenario, considering a number of investments in the transportation infrastructure, which may contain both upgrades in the quality of the links and the construction of a new links. In order to quantify the improvements, the authors opted to divide network into several possible link levels, in which level zero corresponds to just the mere possibility of building a new link [4], which allows the model to consider both the improvement of existing links and the construction of new ones. Each of these network improvement operations (from one level to another) have an associated cost, in order to quantify the money spent in the improvement scenario, so that the creation of a network improvement scenario respects a defined budget limit. In the presented model, the tool that is used to create the base network improvement scenarios is based on a greedy algorithm, in which the links with the biggest improvement benefit (using a criterion defined by the authors, based on the traffic that uses each link) are improved first.

In order to optimize the base network improvement scenario, the first thing that has to be defined is the optimization criterion that is going to be adopted. Although there is a wide range of quantitative parameters that can be used to assess the quality of the network solution, namely the total generalized cost, the robustness of the network, the environmental impact caused and the equity of the territorial accessibility [5], the authors have used the most straightforward and more commonly used parameter, which is the total generalized cost. This parameter is widely used due to the fact that it reflects the total generalized cost that is supported by the freight carriers, and according to which they make their transportation decisions. In an improved network, this total generalized cost should be minimized, indicating that the same amount of freight is being transported in the network but generating less total generalized costs, incurring in benefits for the freight carriers and for the economy as a whole. In the near future, the authors plan to include other parameters to assess the quality of the network solutions, namely a parameter dedicated to the total environmental impact caused by freight transportation.

As for the optimization process in itself, due to the complexity of the transportation networks and to the discrete nature of the model, there is no practical analytical solution for this problem, which leads to the adoption of heuristic techniques. Several techniques have been successfully used to address this kind of problems, predominantly metaheuristics such as tabu search, simulated annealing and genetic algorithms [6]. In the developed model, and after having studied various alternatives and having consulted with specialists in the area, the authors decided to use a local search heuristic which, being a relatively straightforward heuristic, delivers very good results for this type of problem.

References

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