Supply and demand models in intermodal transport: how to bridge the gap?

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Modal shift from road to rail or water freight transport is a key objective of the European Green New Deal to move toward sustainable mobility (European Environment Agency 2021, European Commission 2019). In order to take appropriate actions, it is crucial to accurately represent and understand the intermodal transport market, its actors and their interactions. On the supply side, the carriers are using the existing infrastructure to propose shipping services that are requested by the demand side (including mostly shippers and forwarders) to deliver cargo.

Many freight transport demand models have been developed over the last decades. Most of them are based on the 4-step model (generation, distribution, modal split, assignment), coming from passenger transport. In particular, mode choice models have received a lot of attention and numerous variations have been developed, where mode choice is sometimes coupled with other decisions, e.g. shipment size (de Jong 2013). These models can also include attributes specific to the carriers (e.g., service frequency, price charged) in order to consider the supply side into the decision-making.

On the supply side, models can be classified according to the length of their time horizon. They range from long-term, strategic decisions (e.g. hub location) to short-term, operational problems (typically vehicle routing) with an intermediate, tactical time horizon (SteadieSeifi, et al. 2014). The latter category includes Service Network Design problems. They consist in determining several key attributes of the services to be offered, among others (Crainic 2000):

- The itineraries and the frequency at which they are served;
- The terminals allocated to the routes;
- The general plan about empty vehicles repositioning.

These are typically determined by solving an optimization model, whose goal is to minimize the costs (or maximize the profits) of the carrier. Some existing Service Network Design models also include the shippers characteristics into their formulations. Most of the time, this is done indirectly through pricing or revenue management considerations, or by including levels of service (e.g. in terms of punctuality). A more advanced formulation introduces the value of time and value of reliability of 2 different classes of shippers into the cost minimization: the heterogenous preferences of shippers in terms of transport durations and delays are then directly considered (Duan, Tavasszy and Rezaei 2019).

But there are still too few models considering supply and demand simultaneously and, most importantly the interactions between both sides of the market. In the existing models, interactions are limited to the services characteristics proposed by the carriers (typically the routes and frequencies, and optionally the prices and levels of services) based on prior information on the demand. However, there is little consideration of the shippers response to the proposed services. Moreover, the nature and amount of information exchanged between the parties should also be considered: for example, the proposed services may differ if they are based on raw estimations made by carriers themselves or on detailed forecasts provided by shippers. The present research aims at bridging these gaps by including (a combination of) several aspects in the existing Service Network Design models.

1. Shippers decisions, especially regarding mode choice, can be directly included using choice-based optimization techniques.
2. A two-stage stochastic formulation can be introduced: the first stage includes the planning decisions, while the second consists in various recourse actions that can be taken in case of disruptions. The choice of the adequate recourse action can be done by minimizing its repercussions on the shippers.
3. The first two aspects can be combined by modeling the learning process of carriers. The idea is that a carrier updates its services according to the level of information provided by shippers, its previous decisions/actions and their effects on the mode choice decisions of shippers.

The final goal is to develop a simulation of the iterative shipper-carrier interactions with an explicit modeling of the information sharing (for example through Agent-Based Modeling) to get insights about the choice behavior of the shippers and the service development of the carriers on the long-run. This simulation will then enable to assess future policies and innovations by analyzing the impact of these developments on the intermodal transport system and its actors in a realistic and comprehensive way.

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