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Opportunities of sectoral freight transport demand modelling

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ABSTRACT

This paper discusses the opportunities of sectoral freight transport demand models. The work is based on literature and insights from interdisciplinary research in the field of production, logistics and transport. First, current and future factors influencing freight transport are discussed. Next, a brief summary of the traditional transport modelling approach and recent extensions and adaptations of freight transport models is given. As interdisciplinary research has shown, the impact of the identified factors on the development of freight transport is strongly dependent on the sector under investigation. As a consequence, this paper proposes the application of a sectoral modelling approach. The automotive and food sectors in Germany are used as examples to further examine the opportunities of sectoral freight transport demand models.

1. Introduction

The transport system plays a key role in national and international economic prosperity. To begin with, it offers mobility to people. It also bridges the spatial gap between locations of production and consumption for materials and goods. With today's multi-tier, minimum-inventory supply chains, the reliability of the transport system has become a competitive advantage for national economies. Given the budgets and strict environmental regulations, public authorities have limited options for creating and maintaining sustainable transport systems that fulfil the arising requirements. In order to cope with this challenge, reliable prognoses and policy assessments are needed. These are the key areas for the application of transport models. The question then arises: what are the most important factors governing freight transport demand?

Since freight transport demand is a derived demand resulting from the systems of production, logistics and trade, we will extend our view and also address potential influences from these systems in the following sections.

The paper is organized as follows: First, trends influencing the development of freight transport demand are described. Next, existing approaches and recent developments in freight transport modelling are discussed. Building upon these two sections, the concept of sectoral freight transport modelling is introduced and exemplified by referring to the German food and automotive industry. In the end, a brief conclusion is drawn.

2. Trends influencing future freight transport demand

Trends influencing future freight transport might originate from the demand side for transport, e.g. trade and production, the supply side for transport, e.g. logistics and transport systems, as well as regulation.

Trade and production are responsible for fulfilling the demand of households as well as companies. Here, the development is closely connected to innovations in products and production technology as well as trade patterns. For example, affordable small- to mid-scale automation solutions make it possible to establish smaller production facilities in close proximity to demand locations instead of operating single centralised production plants, thereby reshaping the spatial flow of intermediates and final products.

The transport system itself also faces changes. Especially in developing countries, there are plans for massive investments in new infrastructure. These new connections will foster accessibility, in many cases especially that of remote regions, and therefore directly impact national as well as international freight flows.

Advances in information technology are another source of change. For example, real-time analytics in combination with big data will allow for better traffic control and better information for transport system users, e.g. freight carriers. In addition to this, the broad application of new technology on the user side, e.g. automated guided vehicles, may lead to radical changes in the transport system. The impact of navigation systems on infrastructure usage can already be observed today.

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Last but not least, regulation will have an increasingly strong influence on freight transport. After focussing on passenger mobility, public authorities are beginning to put more effort into freight transport demand management in order to balance the requirements of businesses with traffic-oriented objectives. This trend is intensified by the need for measures that help achieve sustainability targets, especially those related to environmental protection, since existing agreements require major reductions in greenhouse gas emissions. Another focus of governmental action will have to be on the security of supply chains and risk prevention since international supply chains are increasingly vulnerable to disruptions caused by political instabilities or extreme events caused by nature, epidemics or technical failure.

3. Freight transport modelling

New freight transport demand models, attempting to forecast freight transport, should explain the impact of trends, like the ones described in the previous section, on freight transport. In practice, however, the traditional four-step-approach is used most frequently. This approach was originally developed to explain passenger transport demand (Martin et al., 1965; Hutchinson, 1974). Directly applied to freight transport modelling, the steps are as follows:

1. Generation: How much freight is generated where?
   ⇨ freight volume per zone (O_i and D_j)
2. Distribution: Where does this freight go?
   ⇨ freight volume per zonal relation (X_{ij})
3. Modal Choice: Which means of transport are chosen?
   ⇨ trips per relation ij and mode v (T_{ijv})
4. Assignment: Which route is chosen?
   ⇨ vehicles per network section

Emphasizing how the interaction between activity system and transport system leads to flows, Marvin Manheim made a major contribution to the development of transport models (Manheim, 1980). In the very same work, he already described several limitations of the four-step-approach. In our opinion, the most severe restraints are the absence of decisions of actors, especially those related to logistics (e.g. transport lot size, distribution structures), the absence of interaction between modelling steps due to sequential modelling (e.g. increased costs caused by congestion, synergies from bundling transports) and information loss caused by aggregation (supply chains/networks, transport markets).

Since then, the freight transport modelling research community has put a large amount of effort into overcoming these shortcomings of the traditional approach. As a consequence, there have been advances, in particular in the following areas of modelling:

- Large (extended) trade models (multi-regional input-output, e.g. Cascetta et al., 2008; spatial computable general equilibrium, e.g. Bröcker et al., 2010).
- Elaborate discrete-choice models (total logistics costs, latent classes, e.g. Park, 1995).
- Additional logistics steps within the traditional aggregate sequential model framework (tours in trip-based models, e.g. FRETURB, Routhier and Toilier, 2007; lot sizes and transport chains, e.g. ADA, de Jong and Ben-Akiva, 2007; logistics locations, e.g. Davydenko and Tavasszy, 2013).
- (Micro) simulation of logistics decisions / interactions (multi-agent frameworks, e.g. Roorda et al., 2010; interaction of shippers and carriers, e.g. INTERLOG, Liedtke, 2006 integration with passenger transport model, e.g. MATSim, Schröder et al., 2012; simulation of warehouse structures for food retailers, e.g. SYNTRADE, Friedrich, 2010).

All these different approaches have contributed significantly to the improvement of freight transport modelling with regard to the wide variety of modelling or evaluation purposes. From our interdisciplinary point of view and corresponding research questions, we developed a sectoral modelling approach that attempts to combine developments from the areas depicted above. Sectoral modelling offers significant advantages during the model creation and data collection phases as well as new areas of model application. We will explain this approach in the following section.

4. Sectoral freight transport modelling

The idea of limiting a freight transport model's scope to a single industry has its origin in the main challenges of transport modelling, i.e. data availability, homogenous groups of actors and decisions, and complexity. We propose to define sectoral models as follows:

> Sectoral models limit their scope to one sector. Their objective is the analysis of a sector's system behaviour. For this purpose, they focus on a single sector's characteristics, i.e. system elements, interrelations and especially actors and their decisions.

The general development process of sectoral freight transport models starts with choosing the sector that is going to be captured in the model. The process is also outlined in Fig. 1. The next step then will be to conduct a system analysis for the sector of interest. This can be done based on literature and explorative expert interviews. The system analysis will foster an understanding of the actors in the sector, their interrelations, and their planning scopes.

Based upon this knowledge, it must be decided which aspects of the sector should be analysed. After the relevant aspects have been chosen, the required data can be identified. Structural data, like detailed spatial employment statistics, can often be provided by federal statistics offices. For the economic integration of the sector, it is often necessary to join different sectoral production and consumption statistics, published for example by organisations like industry associations, in order to capture the physical flows in form of enhanced sectoral physical input-output-matrices. Behavioural data can be found in sector studies and accompanying

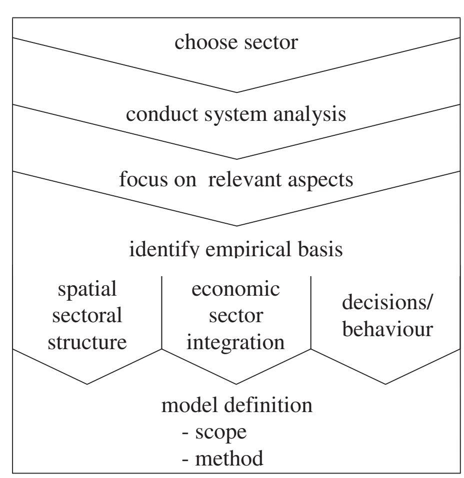

Fig. 1. Design process for sectoral freight transport demand models.