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RESEARCH ARTICLE

Transport chain choice modelling in freight transport demand models

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Abstract

Modelling (intermodal) transport chains is of major relevance in order to support public sector decision-making regarding transport planning and policy measures assessment. However, the systematic and comprehensive analysis of freight transport models shows that only few existing models integrate transport chain choice in their modelling framework. These models, furthermore, differ in consideration of relevant aspects – such as actors, processes, transport market interactions or shipment and system related characteristics. The analysis reveals that there are several gaps in integrating transport chains in modelling in today's modelling approaches and that there is no model that integrates all relevant aspects of transport chain choice properly. Future research and model development should therefore focus on closing the revealed gaps.

Keywords: freight transport, demand modelling, transport chain choice, mode choice

Introduction

Freight transport – as a derived demand from trade – is of major importance to the economy. Especially since manufacturers spread their production and assembly facilities around the globe, freight transportation becomes an ever more important issue (Rodrigue et al., 2006). Within freight transport many shipments are moved via transport chains. The French ECHO survey, for instance, reveals that nearly 47% of shipped tons are transported via transport chains, while around 46% are transported using one mode only (7% other) (Guilbault, 2008). The reason why many shipments are transported in chains is that transporting goods directly or by using one mode only it is mostly inefficient and sometimes even impossible to transport goods directly or by using one mode only. Transport chains are used in these cases because the specific advantages of particular modes (intermodal chains) or vehicles (monomodal chains) can be utilized in the most productive manner (Konings et al., 2008). Thus, transport chains contribute to enhance the economic and ecological performance of transport (Rodrigue et al., 2006).

Beside the positive effects of freight transport, such as economic welfare, there are also numerous negative ones, which become apparent in existing key issues in freight policy (Eastman, 1980; Tavasszy 2006). These key issues mainly refer to the negative impact of freight transport on environment, society, landscape and ecosystems (Dora & Phillips, 2000; Chapman, 2007; van Essen, 2008). Referring to that, there is an ongoing political discussion on these issues, which increase the need for effective decision making (de Jong et al., 2012). In the European Union, for instance, road transport is still increasing, which puts pressure on governments to push intermodal transport and to assess the potential of intermodal mode shift (Tsamboulas et al., 2007). Therefore, intermodal transport and transport chains are a big and important issue – both in practise and science (see e.g. Bontekoning et al., 2004).

In order to cope with these key issues the estimation of freight transport is important for transport planning as well as for measuring the influence of transport policies on transport and, thus, predicting desired and undesired effects (Eastman, 1980). The ongoing increase in freight transport (Woodburn et al., 2008) induces the need for accurate estimation of these movements and the underlying commodity flows – especially for future (Chow et al., 2010). Although the importance of suitable transport modelling tools is not a new issue (see e.g. Eastman, 1980) and considerable efforts have been conducted to progress in that field (see e.g. Winston 1982, Ben-Akiva et al., 2013), there is still a major need for effective and more accurate tools to support public sector decision making. Freight transport demand models are such tools that enable decision makers to evaluate transport policies and correlated effects (de Jong et al., 2012; Tavasszy & de Jong, 2013) and, therefore, they are an important basis for transportation planning (Chung & Kang, 2013).

There are several challenges freight modelling has to cope with (see e.g. Turnquist, 2008; Liedtke, 2009; Samimi et al., 2014). One major recent issue is the introduction of logistics aspects because logistics is a major driver of freight transport (see e.g. Tavasszy et al., 2010). Nevertheless, scientific literature shows that most existing models lack logistic aspects, in general, which is not adequate according to map freight transport in realistic ways (Tavasszy et al., 2010).

Although transport chains are of major importance within transport and logistics, there is only little information regarding their consideration in modelling. There are some articles that refer to the topic briefly but there is no comprehensive overview that allows assessing the current state of transport chain integration in models and, thus, to identify major needs and challenges. The paper will close that gap of knowledge. In chapter 2 we present the systematic analysis approach that has been used. In the subsequent chapter we a) present major aspects that need to be considered for transport chain integration and b) reveal models that integrate transport chains and cross-check considered aspects with the requirements from a). Finally, major needs and future research endeavours are discussed.

Materials and Methods

Different quantitative and qualitative approaches can be used to conduct a scientific literature review and investigate the current state of knowledge (see e.g. Cooper, 1989). Their individual advantages and disadvantages can be found in Li & Cavusgil (1995), Whittemore & Knafl (2005) or Cronin et al. (2008). In order to reveal most studies we used two complementary approaches to review the topic: the quantitative systematic content analysis and the inheritance principle as more qualitative approach.

The systematic content analysis has been used successfully within studies across different disciplines in science (see e.g. Li & Cavusgil, 1995 or Bontekoning et al., 2004) and appears an adequate method to cover most of relevant studies. We used computerised literature research to find significant literature, since it is fast, easy and efficient and allows accessing to a huge database referring transport research articles. Although there is some limitation towards accessing all articles (e.g. articles published before the 80s, if not digitalised) most articles dealing with the topic were found because the most relevant ones have been published in last two decades, primarily. The selection of proper search keys (key words) is a main factor of success towards identifying relevant articles/studies. The following search keys were used in different combinations for the computerized literature research: freight, transport, chain, demand, model/modelling, choice, logistics. In order to evaluate the relevance of sources different selection criteria were applied. A pre-selection of the contribution was applied in the first round if the search keys were found in the title, abstract and the key word section of the articles. Secondly, a further selection of articles was conducted regarding the search keys within the content section of the contribution.

To avoid deficiency of important information the content analysis was accompanied by a more qualitative procedure, which we call the “inheritance principle”. Following citations in articles across several generations of articles in time but also thematically leads to new studies and references that may be of major relevance for a topic. This classic/conventional method of investigation also contributed towards compiling a census of the most relevant information/literature.

The application of both methods, which complement each other in a sound way, resulted in a comprehensive picture of freight transport demand models their integration of transport chains.

Different types of scientific sources were used within the process: articles from scientific journals present the most profound and verified information due to easy access and the peer-review process. Articles and presentations from scientific conferences have been reviewed as well as dissertations and presentations from scientific workshops and seminars. Scientific reports and handbooks are another important reference that has been used because they often present models in application. Using all contributions, 126 freight models were identified and reviewed.

Finally, a multi-level analytical process was carried out: first, a census of freight transport demand models, which have been developed and used (or still are in use) has been compiled. In a second step, all models that consider logistics aspect in any regard (transport chains as one major aspect in considering logistics) were culled from the census. A further filtering process was conducted within a third step: filtering the models that integrate transport chains and/or transport chain choice.

Results and Discussion

Freight transport chains

Compared to passenger transport, freight transport chains are, by far, more complex. Actors are very heterogeneous, have a different focus and deal with different challenges (e.g. shipment building, tour and route planning, vehicle choice). Moreover, the objects – the goods – are less homogeneous (de Jong et al., 2004; Liedtke, 2009; de Jong et al., 2012). Although the high complexity of freight transport chains – including various actors, their activities and interactions – generally hampers the ability to capture them comprehensively they can be indicated to some degree (Ramstedt & Woxenius, 2006).

The functional transport chain can be specified as a sequence of transports, intermediate warehousing or transhipment processes (Klaus & Krieger, 2008; Arnold et al., 2008). The ideal type of transport chain considers: a) forerun or collection leg, where freight is picked up and/or collected in tours within the origin area, b) the main run from the origin to the destination area, which is mostly long-distance transport, and c) the final leg or delivery tour in the destination area (Kille & Schmidt, 2008). Transport is often achieved using standardized loading units with several transport modes. This combined transport represents a special form, since the loading unit remains the same during the whole transport chain (Klaus & Krieger, 2008; Arnold et al., 2008; Rodrigue et al., 2006).

Transport chains hold high complexity and one reason can be found in the manifold possibilities to organise them. A multitude of actors (e.g. seller, buyer, transport service provider etc.) can organise and execute the transport and there can be complex interactions and interdependencies between them. There are, furthermore, several other factors such as shipment related or transport system related characteristics, which influence the choice of transport means/modes and, thus, the choice of transport chains overall (Davidsson et al., 2008).

Considering the relevant factors, the following categories can be identified towards determining freight transport chains:

Consideration of actors/roles which are important for transport chain organization and realization (sender, receiver, transport service provider etc.),

Incorporation of relevant processes (e.g. organizational processes, transport and transhipment, tour construction for consolidation and/or distribution etc.),

Integration of most important interactions on the transport market (e.g. negotiation between actors, formation of contracts, competition, etc.), Consideration of relevant shipment characteristics (e.g. shipment size, weight and value of shipments, delivery times, handling factors etc.) and

Integration of important characteristics of the transport system (e.g. network, integration of transport logistics hubs, access to modes etc.).

The formulation of this multifaceted structure helps to reflect and assess existing models and their consideration of transport chains.

Freight demand models considering transport chain choice

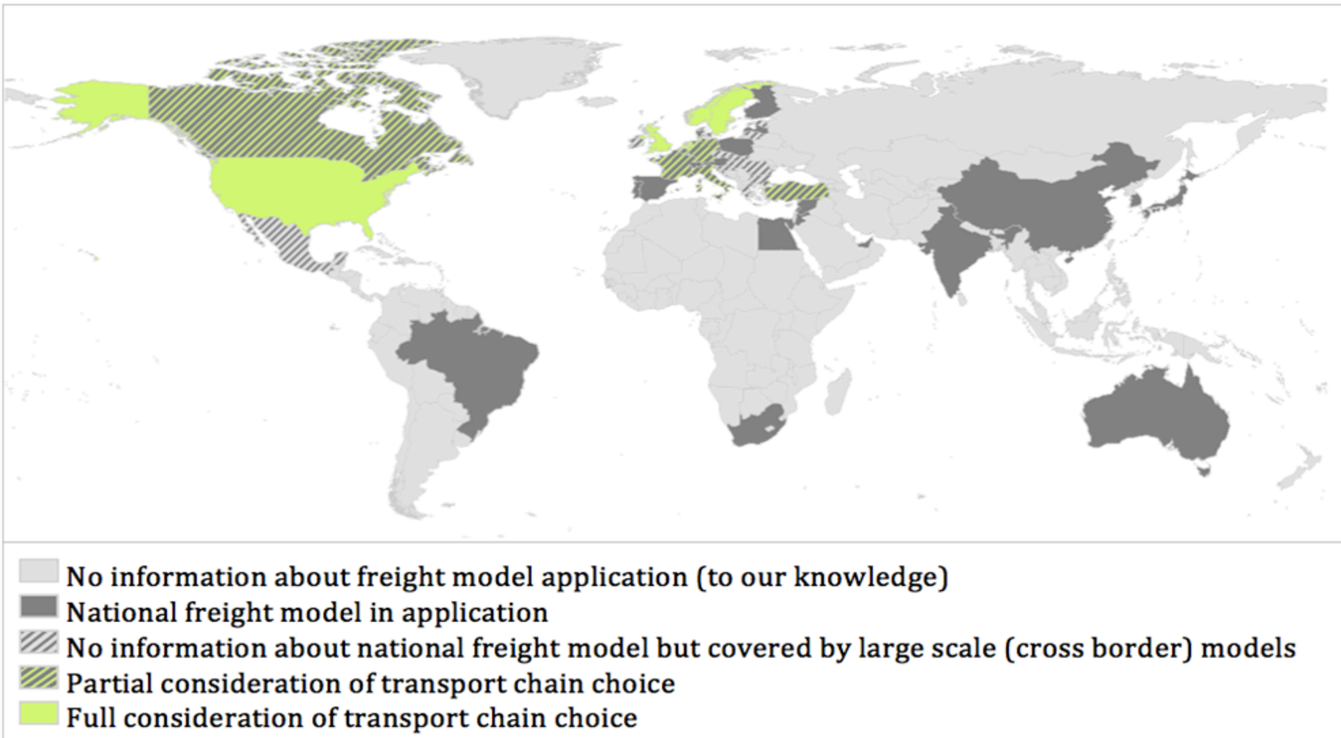
Although additional steps are necessary to comply with the requirements occurring from freight transport, most freight models are still based on the four-step modelling structure, which is well-known from passenger transport modelling (generation, distribution, mode split, assignment). A historic glance on freight models reveals that there has not been any consideration of logistics choices such as transport chain choice until the 1990s (de Jong et al., 2012).

The reviews of Eastman (1980) and Winston (1982), for example, present methods, models and their application until the early 1980s. Until then, only simplified models have been developed and applied, like macro forecasting models that work with aggregate values. Efforts to further develop models (e.g. spatial resolution, scale of analysis, level of aggre¬gation) mostly failed due to lack of adequate data or difficulties in estimation and computing capacities. In that manner, models have been developed and applied to assess mode competition, solely (Eastman, 1980; Winston, 1982).

Constraints have changed to some extent, until today. Especially regarding computational capacity but also regarding data availability. The state-of-the-art in freight transport modelling is well reported in several scientific articles, handbooks or meta-studies. Chow et al. (2010) and de Jong et al. (2012), for instance, present the state-of-the-art regarding freight transport demand modelling and provide a considerable overview over recent developments in national and international freight models. There are even more similar scientific articles (see e.g. de Jong et al. 2004; Tavasszy, 2006; Tavasszy et al., 2010; Tavasszy and de Jong, 2013; Ben-Akiva et al., 2013).

Reviewing international literature on freight models reveals that transport chain choice is still not considered widely in freight demand modelling. The spatial distribution and the degree of considering transport chains choice in national freight models is illustrated in Figure 1.

Figure 1: Distribution of freight models and their degree of considering transport chain choice



It reveals that the 126 models are widely spread over the world. Furthermore, there is a convergence of model development in North America and Europe because there are several models for some regions/countries with different scope – that is why there are not 126 countries marked in the map. 105 of the identified models deal with single mode competition. Only 21 of the 125 models do consider transport chains to some extend (but in different ways) and most of them are relatively young ones (developed since 2000). Four of these models consider transport chains "indirectly" which means, for instance, that mode choice for the main run is modelled but there is no direct transport chain construction, cost calculation and chain choice simulation. The remaining 17 models do consider transport chain choice "directly" (see also table 1). This means that these models construct and evaluate transport chains within demand estimation. The characteristics of models differ significantly due to model purpose. Differing in focus and scale of analysis, the majority of these models (n=14) have been in application. Five of them on national level (e.g. SMILE+ for the Netherlands or SAMGODS for Sweden) and the other models on urban level (e.g. GoodTrip for Groningen), regional and cross-border level (e.g. TAPAS for the Baltic States and England) or even international level (e.g. Trans-Tools for Europe). Depending on data availability and modelling method models also vary regarding depth of aggregation (aggregate vs. disaggregate), scale of analysis (micro, meso, macro) and modelling object (flows of goods, trips, tours, hybrid approaches).

At first glance, the analysis results seem to reveal that transport chain choice is considered sufficiently by plenty of models. However, going into detail shows that the integration of transport chains and the level of detail differ significantly. Analysing the freight models referring to the categories mentioned in the first section of this chapter reveals that models consider the mentioned aspects in different ways and to different degree (see table 1). Some models do cover most relevant actors in freight transport such as the TAPAS model, ANYLOGIC or the model presented by Windisch et al. (2010), whereas some models do capture actors to minimum extend. However, the mentioned models lack adequate consideration within other categories like the consideration of interactions that take place on the transport market, for instance. Within this category the model of Schröder et al. (2012) or the FREMIS model shows an adequate consideration. Table 1 summarizes the consideration of relevant aspects (categories) and gives a more general overview over the different models and their degree of considering transport chain choice.

Table 1: Freight transport models and their consideration of important aspects regarding transport chain choice

Model	Intermodality	Actors / roles	Processes	Transport market	Shipment related characteristics	System related characteristics	Source
GoodTrip	o	x	x	o	x	x	Boerkamps & Binsbergen (1999)
SAMGODS	x	o	x	o	xx	x	de Jong et al. (2005); de Jong & Ben-Akiva (2007); de Jong et al. (2012)
NEMO	x	o	x	o	xx	x	de Jong et al. (2005); de Jong & Ben-Akiva (2007); de Jong et al. (2012)
FAME	x	x	x	o	x	x	Samimi et al. (2010), Samimi et al. (2014)
FREMIS	o	x	x	xx	x	x	Cavalcante (2013), Cavalcante & Roorda (2013)
Schröder et al. (2012)	o	xx	x	xx	x	x	Schröder et al. (2012)
TAPAS	x	xx	xx	x	x	x	Davidson et al. (2008)
Toronto Model	x	xx	xx	x	x	x	Roorda et al. (2010)
ADA Model Flanders	x	x	x	o	xx	x	de Jong et al. (2010), de Jong et al. (2012)
SMILE+	x	x	x	o	x	x	Tavasszy et al. (1998), de Jong et al. (2004), Tavasszy (2006), de Jong et al. (2012)
Transtools	x	x	x	o	x	x	Newton & Smith (2011), Hansen (2011), Chen (2011), de Jong et al. (2012), Kiel et al. (2013)
Worldnet	x	o	x	o	x	x	Newton (2008), Newton (2009), Chen (2011), de Jong et al. (2012)
EUNET	x	x	x	o	o	x	Jin et al. (2005)
Habibi (2010)	x	x	x	o	x	x	Habibi (2010)
Windisch et al. (2010)	x	xx	x	o	x	x	Windisch et al. (2010)
ANYLOGIC	x	xx	x	xx	x	x	Baindur & Viegas (2011)
GBFM	x	x	x	o	x	x	Newton & Wright (2004), MDS (2008), Newton (2008), de Jong et al. (2012), Kiel et al. (2013)

Degree of consideration: o – no consideration, x – general consideration, xx – detailed representation

The analysis reveals that there is no single model that covers all important aspects within all the categories. Each model has its' strengths and weaknesses (see table 1). Not even all models cover intermodal transport – at least not in application cases reported in articles – although the model framework may work it out (e.g. Schröder et al. or the FREMIS model). Furthermore, only few models consider all relevant actors. A comprehensive consideration of relevant processes is also achieved by some models, only (e.g. organisational aspects and tour construction are often neglected). The analysis also shows that the consideration of the transport market and its' interactions is underrepresented in most of the models. Shipment and system related aspects are considered in models far more often.

Conclusion

Following the sections above, it becomes apparent that the integration of transport chains differs essentially corresponding to the relevant aspects that should be considered. Model improvements should, therefore, focus on the integration of important aspects that are neglected so far. Otherwise, a generic approach is needed to cover all aspects of intermodal transport chain choice in freight transport. This approach should consider all relevant actors in transport chain organization and realisation as well as their specific characteristics. Furthermore, all relevant processes should be considered and interactions between involved actors incorporated. Same applies to the characteristics of shipments and the transport system, since they exert a dominating influence on transport chain choice.

Although there is currently no model that considers all relevant aspects, each model can serve as one piece of the puzzle because every model considers different but important aspects. Thus, future research endeavours should focus on the following options: a) if there is any possibility to transfer models that consider most relevant aspect to countries that operate with less advanced models, for instance, this would be the way to cope with the challenge. The transfer and application of urban models to national level would be worthwhile step, in that manner, since urban models appear to be most advanced. Another worthwhile approach would be option b) the coupling or combination of different model types (e.g. integration of disaggregate micro models into aggregate macro models). If data availability is the reason for the identified gaps, the focus should be put, of course, on collecting new data or using methods new methods to extract data from new sources – option c).

Closing the gaps will help to improve the integration of transport chain choice and, therefore, increase model accuracy. This increase will enhance policy decision makers to come to more adequate decisions regarding transport planning and the implementation of transport policy measures, which is significant towards reducing negative impacts of freight transport on society and environment.

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