# CREATING AN INNOVATIVE ACTIVITY-BASED FREIGHT TRANSPORTATION FRAMEWORK

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## INTRODUCTION

In a growing globalised context and consumption economy freight transport is of crucial importance. Activities of firms are expanding, even across borders. This causes an increase in logistics activities of firms as they become more dynamic. Public and private decision makers need to take these trends into consideration with regard to their decisions and a better projection of freight traffic flows becomes necessary. Being able to understand the drivers of freight flows makes it possible to forecast freight flows in the future and to calculate the impact of different policies on freight traffic. It will put policymakers in the position to get a better insight in the way the transport of goods comes about. Still, freight demand modelling is lacking behind on the efforts made in passenger transport models.

Hence, there is a growing need for models that can predict freight flows more accurately. Here the category of activity-based models comes into play, as they are able to better represent the link with the economy, interactions between different actors and the logistic elements inherent of freight movement. The development of a comprehensive and reliable freight transport model is needed. This paper is structured as follows. First, the need of activity-based models in freight transport will be elaborated in the next section. The following two sections take a closer look at the main differences with passenger transport. Starting with the different actors involved and then the logistic elements, inherent at freight transport, are presented. Next an overview of the options for an innovative activity-based freight transportation framework is given. Finally, some conclusions will be drawn.

## ACTIVITY-BASED MODELLING IN FREIGHT TRANSPORT

To given an idea of the emerging trends in freight transportation modelling and the aspects of activity-based models, an overview of the main developments in literature is given.

Today, most state-of-the-practice models in freight transport are still four-step models, where the focus is on individual trips. These models have as main disadvantage, that they are looking at the aggregated flows between zones and cannot model flows at a more detailed level. For that, they are missing out on the behavioural aspects behind transport and are having errors due to aggregation. More importantly they are lacking elements of logistics decision making. The importance of incorporating logistics decisions and behavioural aspects in a freight transportation model is widely recognized (Tatineni and Demetsky (2005), Tavasszy et al. (1998), MOTOS (2006) and Liedtke (2009)). Some of the more recently developed four-step models are already incorporating logistic components (Tavasszy et al. (1998), SCENES Consortium (2000) and Yin et al. (2005)). However, these models are on an aggregated level and are not taken into account aspects of the different agents.

Recent trends in freight modelling are moving to agent-based models, which are part of the group of activity-based models and focus on each freight agent separately. Therefore they are better able to model their individual operational decisions and their interactions concerning logistics and transports. Furthermore a disaggregated approach is applied, by looking at trips and decisions on a microscopic scale and no longer to aggregate flows between different zones. This enables the understanding and representation of roles that each actor plays in the freight transportation system, as also the interactions between actors. Besides, it is possible to incorporate changes in actors and their interactions over time. These elements are of fundamental importance in the development of more behavioural models for the freight system (Roorda et al., 2010). The disaggregated approach of these models, together with the representation of the different actors, enables better modelling possibilities for logistics decisions.

One of the main differences between modelling freight and passenger transport is that there are more actors involved in the decision making process. First there are firms who are sending and receiving goods, shippers who are responsible for the organization of the consignment and modes and the last group are carriers who undertake the movement (Ortúzar and Willumsen, 2001). Next to this, there are several other firms responsible for the transhipment, storage and custom facilities. The transportation of goods may follow a network of shippers, carriers, forwarders, terminals, distribution centres and others to arrive at its destination. These logistics chains are typical for the movement of freight and need to be taken into account when it comes to modelling freight flows. The economic transactions between suppliers and consumers, and the logistics operations that actually deliver the goods, are the two main drivers behind the rapidly evolving patterns of freight movements (Yin et al., 2005). Therefore, more attention has to be paid to the different actors.

Another difference with passenger transport is the dynamic nature of the freight logistics system, therefore trends in industry supply chains need to be considered. Trends like just-in-time (JIT) logistics are having an impact on the modes used, and size and frequency of shipments. Two of the main trends stated in Hesse and Rodrigue (2004) are:

- Demand-side orientation of activities. While traditional delivery was primarily managed by the supply side, current supply chains are increasingly managed by demand.

- Logistics services are becoming complex and time-sensitive. This has led to the point that many firms are now sub-contracting parts of their supply chain management to third-party logistics providers. These providers benefit from economies of scale and scope.

This leads to the need for agent-based models at a microscopic level. Roorda et al. (2010) gives several reasons for implementing agent-based modelling. First of all, there are diverse actors involved in the production and distribution of goods, none of which may have full control or even knowledge of all decisions made throughout the supply chain. Secondly, the interactions between firms are diverse and finally business models are changing over time. So a close follow up of all these interactions is requested to have a more realistic image of freight transport flows. Due to the modelling at a micro level, it is possible to look at individual instead of aggregated flows. This gives the opportunity to include individual firm characteristics and detailed representation of commodity groups. When looking at single movements of goods, more information of a shipment may be represented that would go lost in aggregated data. As stated in Liedtke and Schepperle (2004), the activity-based approach can explain the effects of individual behaviour changes on the whole transport system. This allows improving the quality of forecasts for public and private planners.

The following two sections elaborated more on the freight actors involved in the process and the logistic elements that have to be included in a comprehensive model.

## THE FREIGHT ACTORS INVOLVED

In this section the role of the agents or actors is presented, hereby looking at which agent are defined and what their responsibilities are in the decision making process.

The groups of agents that are mostly used are shippers, receivers/customers, carriers/transporters and forwarders (Boerkamps et al., 1999; Liedtke, 2009; Wisetjindawat et al., 2007) and may be expanded to include politics as in the GoodTrip model. The role of these different actors is briefly discussed in the next paragraph.

The receiver or customer initiates the demand and chooses a supplier to deliver the required goods. After the shipper is chosen the receiver decides on the delivery moment, shipment size and whether he conducts the transport himself or not (Boerkamps et al., 2000). In Wisetjindawat et al. (2007) shippers play a major role in the selection of carrier and vehicle choice. Boerkamps et al. (2000) state that shippers are often responsible for transportation and therefore have to decide on mode choice, vehicle type and vehicle size. Furthermore, they decide on grouping of goods types, product range to offer, location of facilities, availability of distribution channels and whether or not to maintain own transport services. The carriers or transporter are responsible for the actual movement of the shipments and the tour planning problems. In Liedtke (2009) forwarders have the extra responsibility to build and coordinate transport chains. Freight movements are also indirectly influenced by politics (Boerkamps et al., 1999). Politics have an influence on the market structure, as they are responsible for an optimal spatial-economic organization. On the transport market they may make a difference by regulating the accessibility and mobility of the transport.

Many companies act as both shipper and receiver. Ultimately, a simple actor may fulfil all roles in the supply chain, that is, as receiver of goods deliveries, as shipper and/or as transporter of shipments. An actor may be active in different activity types, for example: consumer, supermarket, distribution centre, production factory, etc. (Boerkamps et al., 2000). At the same time, they may own a private fleet with which they deliver their own goods and may provide transportation services to other companies as well (Roorda et al., 2010).

The framework of Roorda et al. (2010) and the TAPAS model (Davidsson et al., 2008) differentiate themselves with regard to the choice of agents they have made. The models are working at an even more detailed level and are able to incorporate more of the interactions between, and the decisions of, the different agents.

Roorda et al. (2010) established a new set of agents in his framework. The main agents are business establishments, firms and facilities (commodity, business service and logistics service).

- Business establishment: an organization at a specific location that produces, processes, or stores commodities, or provides business or logistics services. A business establishment may include several different facilities.
- Firm: an organization that owns or operates one or more business establishments. Within a logistics firm, business establishments at different locations may be integrated into a logistics network.
- Commodity production facility: one of the internal resources of a business establishment. The function of a commodity production facility is to produce or process commodity inputs.
- Business service facilities: provide services instead of commodities.
- Logistics service facility: provides logistics services, including transportation and inventory.
- End consumers: initiates demand for commodities.

The TAPAS model uses six different agents (Davidsson et al., 2008): Customer, Transport Chain Coordinator (TCC), Product Buyer (PB), Production Planner (PP), Transport Buyer (TB), Transport Planner (TP). Many possible options are available for the location of the different decision making agents. The customer agent might be a retailer or a producer. The TCC might be a planner within a larger company or a third or fourth party logistics operator. The PB is often connected to the organization which hosts the TCC, but can be independent when the TCC is a third party logistics operator. The PP belongs to the producing company. The TB might belong to the same organization as the customer or as the TCC. The TP typically belongs to the organization owning and controlling the transport carriers (Bergkvist et al., 2005).

## LOGISTIC DECISIONS IN FREIGHT TRANSPORT

A disadvantage of many of the freight transportation models is that they are completely lacking elements of logistic organization (Ben-Akiva and de Jong, 2008). A better link with the freight distribution industry is required to overcome this weakness and some models have made progress in this respect by modelling logistic processes such as the number and location of distribution centres, the choice of shipment size and travel mode (Rand Europe, 2002). Furthermore, the choice of receiver or sender could also be modelled using disaggregate random utility models. This leads to the opportunity of simulating changes in the logistic chain, for example: these days many goods are delivered from distribution centres to the retailers, rather than from manufacturers (Kuzmyak, 2008). The delivery patterns that are optimal for distribution centres are different from when they were shipped directly by the producer. Those movements are often made by truck fleets whose travel is organized into tours with many stops.

One of the problems where firms are confronted with is the choice of an appropriate inventory level and transport mode. To make this decision most authors are referring to the inventory-theoretic model, which use the total logistic costs to determine which transport mode is most appropriate for the desired inventory level. This is done by taking into account all costs in the supply chain that are influenced by the mode choice. An integration of the inventory-theoretic concept may be found in the ADA model (Ben-Akiva and de Jong, 2008). Here the total logistic cost is used in the logistic module to make the 'transport chain choice', which is composed of shipment size and frequency, number of legs in the transport chain, transport mode and vehicle type. In Roorda et al. (2010) a similar approach to the ADA model is proposed.

In table 1 an overview is given of some of the main logistic decisions of the reviewed models. These models were examined whether they explicitly simulated shipment size, mode choice, vehicle type and the logistic distribution chain chosen. If one of these items is not represented in the model it is denoted with '0', if it is not know a '?' is inserted.

Table 1: Logistics Decisions

| Model | Shipment size | Mode choice | Vehicle type | Logistic chain |
|---|---|---|---|---|
| Tavasszy et al. (1998) | 0 | X | ? | X |
| SCENES Consortium (2000) | ? | X | X | X |
| Yin et al. (2005) | ? | X | X | X |
| Ben-Akiva and de Jong (2008) | X | X | X | X |
| Hunt and Stefan (2007) | ? | 0 | X | 0 |
| Fischer et al. (2005) | X | X | ? | X |
| Hunt (2003) | X | 0 | X | ? |
| Boerkamps et al. (1999) | X | X | X | X |
| Liedtke (2009) | X | 0 | 0 | 0 |
| Wisetjindawat et al. (2007) | X | 0 | X | ? |
| Davidsson et al. (2008) | X | X | X | 0 |
| Roorda et al. (2010) | X | X | X | X |

Looking at the different transport modes used in the models of table 1, a major distinction that may be made is between the urban or more regional models and the national and international models. Where urban or regional models focus more on road and rail transport, the national models are defining more transport modes. Besides rail and road national models mostly also include inland waterways and transport via sea. In some cases even air transport is considered. An exception to this is the INTERLOG model (Liedtke, 2009) that only considers road transport although it is a national wide freight transport model.

Although the first inventory-theoretic models date from 1970 (Baumol and Vinod, 1970) and were able to state the importance of integrated consideration of logistics and transportation in decision making, latter developed models are lacking this logistical insight (Liedtke, 2009). The more recent developed models are again taking the interaction of logistics decisions and transportation into their development. It is crucial to take logistics decisions into consideration while modelling freight transport to come to a more realistic image of freight movement today. Still work has to be done to fully grasp the logistic impact on freight transport. The options for a comprehensive activity-based freight transportation framework are further elaborated in the next section.

## OPTIONS FOR AN INNOVATIVE FREIGHT TRANSPORTATION FRAMEWORK

As stated earlier, there is a need for a more comprehensive model that includes logistical elements. The objective is to develop an activity-based micro simulated model, where the focus lies on the agents. Liedtke and Schepperle (2004) state that having a model for the transport of goods at a microscopic level, would be a significant improvement for transport forecasts and the assessment of policy measures at any point in process, due to its ability to map individual reactions.

First of all, the characteristics of freight transport have to be taken into account. The main characteristics are heterogeneity, physical factors, operational factors and dynamic factors (Ortúzar and Willumsen, 2001). When modelling at a micro level, it is possible to look at individual instead of aggregated flows. This gives the opportunity to include individual firm characteristics and detailed representation of commodity groups. When looking at single movements of goods, more information of a shipment may be represented that would go lost in aggregated data. Furthermore, production rates of firms may be included to take account for the changes in the demand pattern of customers, like in the TAPAS model (Davidsson et al., 2008).

As a starting point the relationship with the economy has to be included. Disaggregate models start from a detailed microeconomic background of the different commodity groups. The behaviour of shipper and carrier that is modelled helps to determine how much and in what way commodities will be moved. Transport can be considered as a part of the logistics process and a production factor. Companies consider their output as the arrival of finished goods at their destination. For this not only labour and capital is necessary, but also transport becomes important as production factor (Meersman and Van de Voorde, 2008). This allows the analysis of the relation between an economic activity and the resulting transport movement.

When developing an activity-based model great care has to be paid to the choice of agents involved in the model, as discussed earlier. The way these agents interact with each other and how they are involved in the decision making process is of key importance in developing a micro simulated activity-based model. This allows to include pricing mechanisms and to take into account long- or short-term contracts between agents. An opportunity exists to simulate market interactions and pricing negotiations. Furthermore, more attention has to be paid to logistic decision making. What are the responsibilities of each agent and on what may he have an influence?

By explicitly simulating the different agents involved in the decision making process of an activity-based model, the logistics decisions and chains may be represented. When it comes to logistical processes some main items have to be included, like modelling shipment size and an appropriate mode and vehicle type choice. It gives the opportunity to incorporate inventory management at the customer and vendor site, to include warehouse management at distribution centres and to simulate terminal operations. To optimize distribution chain flows the location of distribution centre may be included in the modelling process. A close follow up of all these interactions is requested to have a more realistic image of freight transport flows.

## CONCLUSIONS

There is a great need for better forecast models of freight transport. Some attempts to improve model results have already been made and freight modelling is moving to more activity-based models, like in passenger transport. In this paper a contribution to this process is been made, by exposing the main issues in freight transport modelling. First, the different agents that are involved in the decisions making process were given. These agents are necessary to construct distribution channels and supply chains, which may facilitate freight transport. Secondly, the many logistics elements and decisions that come with this entire process were discussed and have to be taken into account when modelling freight flows. Furthermore, some recommendations have been made to arrive at a more comprehensive activity-based freight model.

Further research has to be conducted to study the possible agents that may be introduced and how they interact with each other. Also the possibilities for incorporating the logistic elements have to be examined. Finally, research had to be done to collect the necessary data.

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