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# INTEGRATING CONSOLIDATION OPTIONS IN A NEW CONCEPTUAL FREIGHT TRANSPORTATION FRAMEWORK

Tabitha Maes<sup>1</sup>  
Katrien Ramaekers<sup>1</sup>  
An Caris<sup>1,2</sup>  
Gerrit K. Janssens<sup>1</sup>  
Tom Bellemans<sup>1</sup>

<sup>1</sup> Transportation Research Institute, Hasselt University  
Wetenschapspark 5 - Bus 6  
BE-3590 Diepenbeek, Belgium

<sup>2</sup> Research Foundation Flanders (FWO)  
Egmontstraat 5  
BE-1000 Brussels

E-mail: {tabitha.maes;katrien.ramaekers;an.caris;gerrit.janssens;tom.bellemans}@uhasselt.be

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## ABSTRACT

In a growing globalised context and consumption economy freight transport is of crucial importance. 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. This 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. For this the development of a comprehensive and reliable freight transport model is essential. In this paper a conceptual freight transportation framework is proposed. Special attention is paid to the different consolidation options of a forwarder.

## INTRODUCTION

When it comes to modelling transport flows most effort has been spent on passenger traffic. Only in the past decade freight transport is receiving more attention. This is due to the growing awareness that freight movements have an influence on general transport flows and it is hence crucial to integrate these flows into the transportation planning process. The reasons for this gap are diverse, but in general it is stated that the movements of goods are more complicated to model than those of persons (Ortúzar and Willumsen, 2001; Tatineni and Demetsky, 2005).

The most important aspect that is missing in almost every existing freight transportation model is a comprehensive integration of the logistic decisions made by the different actors. Today, most of the 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 producing errors due to aggregation.

The latest state-of-the-art freight transport models (e.g. Ben-Akiva and de Jong (2008); Liedtke (2009); Wisetjindawat et al. (2007)) are based on the activity-based concept. Within activity-based models a disaggregated approach is applied. Trips and decisions are considered on a microscopic scale as separate firm-to-firm flows and no longer as aggregate flows between different zones. These models are ideally suited to represent the relationship with the economy. The behaviour of shipper and carrier that is modelled helps to determine how much and in what way commodities will be moved. This allows the analysis of the relation between an economic activity and the resulting transport movements. For this activity-based models have several advantages compared to the traditional four-step method in freight transportation modelling. First of all, the **characteristics of the different actors** may be simulated. Within freight transport there is a wide variety of heterogeneous agents. By incorporating activity-based modelling the different actors in transport and logistics may be explicitly distinguished (Liedtke, 2009). Secondly, the **interactions between**

**the logistic players** may be included. This has an impact on freight demand characteristics such as the choice of modes, the shipment size, the ports to call, the time of day, frequency of shipments, ... (Beagan et al., 2007). With activity-based modelling it is possible to map a continuous interaction between shippers and carriers at a micro-economic level (Liedtke, 2009). Finally, the **trends in supply chain management and logistics** can be better represented. The disaggregated approach of activity-based models, together with the representation of the different actors, enables better modelling possibilities for logistics decisions. But still, most freight models do not address all relevant logistic decisions.

Several recent publications are taking into account the logistic decisions within freight transport and the different actors. In the ADA model of Ben-Akiva and de Jong (2008) the logistic component is modelled at a disaggregated level using total logistic cost. This 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. Liedtke (2009) develops a road transport model for Germany, making use of two main agent-types: the shipper and the carrier. In the 'Market interaction module' shippers determine the shipment size and choose a carrier. Carriers construct a tour making use of a vehicle routing heuristic. Both agents may interact with each other and learn from past iterations. In the conceptual framework of Roorda et al. (2010) a new set of actors is established. The main actors are business establishments, firms and facilities (commodity, business service and logistics service). These actors interact with each other to form commodity/business service contracts and logistics contracts. For the logistic decisions a similar approach to the ADA model is proposed. Wisetjindawat et al. (2007) present a micro-simulation model for modelling urban freight in the Tokyo Metropolitan Area. A modified traditional four-step model is proposed, in which the behaviour of freight actors is included. At each step the behaviour of the decision-maker with the highest influence on the logistic activities is mapped. Shippers choose a vehicle and carrier in order to minimize the total delivery cost. Also truck drivers set up delivery tours to transport goods at a lowest cost. In Davidsson et al. (2008) the Transport And Production Agent Based Simulator (TAPAS) is presented, which is a general tool for micro-level simulation of production and transportation of products. The TAPAS model uses six different agents: Customer, Transport Chain Coordinator (TCC), Product Buyer (PB), Production Planner (PP), Transport Buyer (TB), and Transport Planner (TP). Schroeder et al. (2012) present a multi-agent freight transport model with four freight agents: the shipper agent, the transport service provider

agent, the carrier agent and the driver agent. These freight agents are integrated into the MATSim traffic simulation originally used for passenger transport.

Also consolidation is often overlooked in freight transportation models, although it may lead to several advantages. One of the main advantages is the possible reduction in distribution costs, by consolidating several small shipments. This allows dividing the fixed costs between more shipments. Furthermore, social gains, including a reduction of air pollution, congestions and accidents, may be achieved from consolidation (Caris et al., 2010). For these reasons consolidation is an important part of our freight transportation framework.

In this paper an attempt is made to fill in part of the gap towards a comprehensive freight framework. This framework applies the principles of activity-based modelling, which allows us to predict future freight flows and the effect of certain policies. Also, the integration of logistic decisions made by the different actors involved in the creation of freight flows may be simulated. The key actors in our framework are firms, carriers and forwarders. Each actor as well as his logistic decisions is modelled separately. Especially the consolidation decisions of a forwarder are highlighted in this paper. The rest of the paper is organized as follows. First, the conceptual freight transportation model is presented, where the focus is on the Logistic module. In the following section options to integrated consolidation possibilities into the framework are considered. The paper ends with some conclusions.

## CONCEPTUAL 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 different actors. Liedtke and Schepperle (2004) state that having a model for the transport of goods at a microscopic level, would lead to 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.

In this section, the different steps of our conceptual framework are discussed. The main focus is on the Logistic module of the framework. In figure 1 the different steps of the framework are shown. First, the Generation module generates the different actors with their attributes and locates them in the modelling area. Secondly, in the Market module different firms interact with each other and create shipper/receiver relationships. This results in Production/Consumption flows (PC flows). Next, the Logistic module takes place and models the freight flows and interactions with the different logistic players. Within this mod-

ule also the “Transport chain generation module” is included. Finally, the resulting freight flows are assigned to the network. In the remaining part of this section the different steps are elaborated in more detail. It has to be stated that the framework is not yet implemented and hence no results can be shown.

The key objective of the framework is to have a model that includes the simulation of logistic decision making. This framework needs to be able to give a more realistic representation of freight flows in Flanders (Belgium) than existing models. As Flanders is located next to the sea, with some important harbours and an expanded inland waterway system, we opted for a multimodal network. The main transport modes considered are road, rail and inland waterways. For road transport a differentiation is made between light road and heavy road. Because Flanders is geographically small, air transport is not included, also transport by sea is only feasible for import or export.

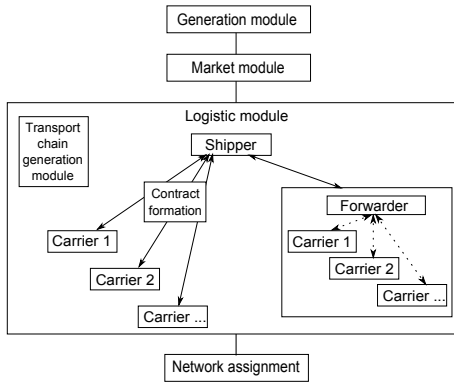


Figure 1: Conceptual framework

As stated by Holguin-Veras et al. (2011) it is important in freight transport to make a clear distinction between the generation of demand and the generation of traffic. The generation of freight demand is determined by the economics of production and consumption. Freight trips, on the other hand, are the output of logistic decisions. The greatest gap in many existing models is in the modelling of logistic decisions. Most frequently a rate is used to determine the link between freight demand and freight traffic flows. To improve this link, the focus of this research will be on the Logistic module. In our framework the generation of demand is included in the first two modules: Generation and Market module. The generation of traffic on the other hand is composed in the Logistic module. A general overview is given of each module.

**Generation module:** In this step the level of detail has to be determined. Firms are generated,

whereby location, economic activity, size and other attributes are assigned to a firm. Also the creation of multi-establishments firms may be considered in this step, to arrive at a better representation of reality. In these multi-establishments firms close interactions and co-operations between the establishments exist. Furthermore, firms’ annual demand and supply are simulated. This step allows creating a clear link with the economy.

**Market module:** The supply and demand of the different firms are matched with each other. This involves the choice of a supplier for each firm, as well as the quantity to be purchased. Firms may interact with each other to form contracts and negotiate the price of the goods. The result of this step is the annual commodity flow between pairs of firms and is represented by Production/Consumption (PC) matrices.

**Logistic module:** In this step the order quantity, frequency and transport mode are chosen. Also the decision of a firm whether or not to outsource the transport to carriers and forwarders is modelled. A carrier may select the requests that are the most profitable for him and generate a pickup and delivery tour. Within this module the consolidation options are simulated as a part of the forwarders decisions. In the next section this is discussed into more detail.

**Network assignment:** The scheduling and routing of individual shipments onto the network is modelled. In the network terminals and consolidation centres are included, to allow intermodal transport. Also empty trips are accounted for by tracking the different vehicles. This is often overlooked in freight transportation models. Also the impact of various constraints such as equipment and link capacities has to be looked into. Furthermore, different techniques to assign flows to the network may be considered.

For all these different steps, work has to be done in gathering data to be able to run the model. The process may also be made sensitive to policy changes like pricing, weight permitting, safety and travel time regulations. In the next section consolidation options for shipments by a forwarder are discussed.

## CONSOLIDATION OPTIONS

In this section a closer look at the operations of a forwarder is presented. Within the framework an option is inserted to rely on forwarders for the organization and execution of the transport orders. Forwarders have the responsibility to build and coordinate transport chains. They form the link between firms and carriers, when transport decisions are outsourced by firms. For each transport request, the forwarder determines

the optimal transport chain. This includes decisions about the use of terminals or consolidation centres, which transport mode to use for each transport leg and determining an optimal shipment size. For each transport leg the forwarder may contract the service of a different carrier, according to the transport mode chosen and the capacities of the carrier. A forwarder is ideally positioned to consider consolidation options, because he is responsible for multiple shipments and works for several clients.

The different steps of the decisions that are modelled for a forwarder are as follows. First, the forwarder determines the transport chain and shipment size. After that, he will consider the possibilities to consolidate different shipments to generate a lower total logistic cost. Next, the forwarder decides which carrier he will use for each leg in the transport chain. Due to the position of a forwarder and his probably larger demand, it may be assumed that he will receive different transport rates from carriers than firms will. The forwarder will negotiate transport rates with a carrier and make long term fixed contracts. Finally, the forwarder calculates the rate for the entire transport for each transport chain and responds to the call for offer. The transport solution that the forwarder considers as most profitable will be returned to the firm. This solution consists of an optimal shipment size/frequency of delivery, an optimal transport chain including the transfer points and the transport rate. In the remainder of this section the consolidation options of a forwarder are explored.

Hall (1987) defines three different ways of consolidation. The simplest form is inventory consolidation, where items that are produced are stored and transported in the same load. A second form is vehicle consolidation where items are consolidated over space, this occurs in classical “milk-runs”. The last form considered by Hall (1987) is terminal consolidation. Items from different locations are gathered at a terminal, where they are sorted and reloaded onto new vehicles. From the terminal they can be shipped to different destinations. In this paper only terminal consolidation is considered as part of the forwarders decisions within the freight framework presented in the previous section. Vehicle consolidation is applied in the decisions of a carrier but will not be further explained in this paper.

Woxenius (2007) gives six different transport options form an origin (O) to a destination (D), see figure 2. In these transport chains terminal consolidation, as defined by Hall (1987), may take place at each hub. As the purpose of our freight transportation framework is to simulate large networks with multiple shipments and multiple actors, only three options are considered. This limitation is necessary to keep calculation efforts within bounds. The first option is the direct link,

which transport the goods direct from the sender to the receiver without terminal consolidation. Secondly, the corridor is considered whereby shipments may be consolidated between two common terminals. The last option that is taken into account is the connected hubs, where the main haul of a shipment may be consolidated.

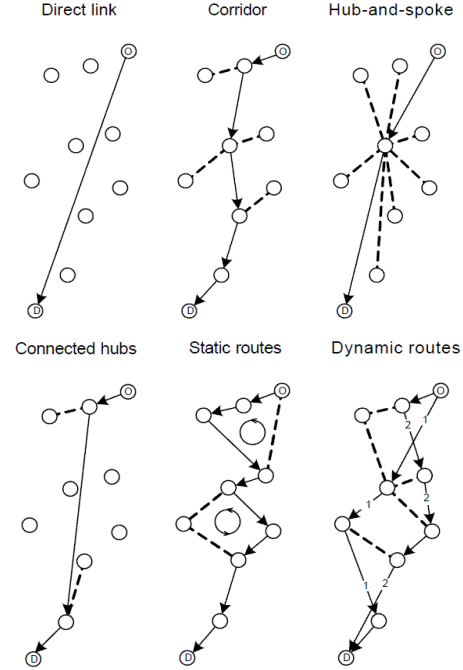


Figure 2: Consolidation options (Woxenius, 2007)

After a forwarder has determined which transport chains are the most profitable to operate a certain shipment, the previous discussed consolidation options are considered. As a forwarder has several clients and multiple shipments he is ideally positioned to consolidate different shipments. To start the shipments are ranked based on their begin and end terminal, if more than one shipment share the same begin and end terminal it is checked whether they may be consolidated. This is done according to the connected hubs system of Woxenius (2007). Another option is to build a corridor with several shipments heading in the same directions and which may have the same begin terminal or end terminal but not necessarily both. The shipments are consolidated for the parts of the corridor that they share with other shipments, the remainder of the transport is unconsolidated.

Consolidation options are calculated for the three transport chains with the lowest total logistic cost without consolidation. By consolidating several shipments the transport price per shipment may go down and could stimulate a modal shift. Furthermore it allows a more efficient use of transportation resources.

## CONCLUSIONS

Integrating consolidation options into a new freight transportation framework is the main focus of this paper. If policy makers want to fully grasp freight flows, a detailed freight transportation model is essential. Consolidation plays an essential role in intermodal transport and may have an effect on modal shifts. Within the framework that is proposed in this paper the decisions of a freight forwarder are highlighted and more specifically their consolidation options. This leads to a more realistic representation of transport cost and shows that direct transport is not always the most advantageous.

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