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A micro-simulation model of shipment size and transport chain choice

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Abstract

Practically every international, national or regional freight transport model system in the world lacks explicit treatment of logistics choices (such as shipment size considerations or the use of distribution centres). This paper deals with the development of a new logistics model and its application within the national freight model systems of Norway and Sweden. This logistics model operates at the level of individual firm-to-firm (sender-to-receiver) relations and simulates the choice of shipment size and transport chain for all (several millions) these relations within the country, export and import. A logistics model with deterministic cost minimisation has been constructed for both Norway and Sweden. The full random utility logistics model has not yet been estimated on disaggregate data, but this is planned for both countries. For Sweden, more limited disaggregate models for the choice of mode and shipment size have been estimated.

Keywords: Freight transport; Logistics; Shipment size; Mode choice; Micro-simulation

1. Introduction

Many existing model systems for freight transport at the international, national or regional level use the conventional four step (production/attraction, distribution, modal split and assignment) approach, originally developed for passenger transport. Often, value-to-weight transformations and vehicle load factors are added as additional sub-steps (see de Jong et al., 2004). Usually, all steps are handled at the aggregate (zonal) level. Practically all these models (in Section 2 we discuss exceptions to this rule) are lacking logistics elements, even though in recent decades logistic changes, such as the adoption of just-in-time delivery, have been (re-)shaping freight transport significantly. Logistics elements include the determination of shipment size and its influence on mode choice, or the use of consolidation and distribution centres. Here we define consolidation centres as locations where goods are transshipped (and possibly stored), with small loads getting in and larger loads getting out. Distribution centres are locations where goods are transhipped (and possibly stored), with large loads

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getting in and small loads getting out. Both consolidation and distribution centres exist not only in road transport, but can also be ports, airports or rail terminals.

In this paper, we put forward a model that includes the determination of shipment size and the use of consolidation/distribution centres, within a behavioural framework, that can be estimated on disaggregate data and applied in micro-simulation. This model can be regarded as the logistics module within a larger freight forecasting and policy simulation system for a country, group of countries or large region within a country.

The other parts – besides the logistics module – of the freight transport model system would be:

- Production-consumption (PC) matrices that give flows of goods by commodity type between two zones (municipalities for domestic zones, more aggregate zones abroad). Wholesalers can be included both at the production and the consumption end. In this case we call these matrices 'PWC matrices'. These matrices can for instance be generated by spatial input–output models (either multi-regional or regionalised national input–output models, see Marzano and Papola, 2004; Hunt and Abraham, 2005) or by spatial computable general equilibrium (SCGE) models.
- Assignment to the networks.

The PWC flows are input for the logistics module, after disaggregation of the zone-to-zone flows to the level of firm-to-firm (sender-to-receiver) flows. The outputs of the logistics model consist of origin-destination (OD) vehicle flows, which are used in aggregate network assignment. OD flows differ from PWC flows in that a PWC flow can consists of multiple legs, each with a different mode and with transshipments between the modes (e.g. a truck–ship–truck transport chain). At the transshipment points there can not only be changes of mode, but also consolidation of shipments together with other shipments, and de-consolidation. More information about the model as a whole can be found in Ben-Akiva and de Jong (2007). This paper focuses on the choices that are modelled in the logistics module:

- Frequency/shipment size (so inventory decisions are endogenous).
- The number of legs in the transport chain (direct transport, two legs, etc.).
- Use (and location) of consolidation and distribution centres for road and rail transport, but also including ports and airports.
- Mode (road, rail, sea, and air) used for each leg, including choice of vehicle/vessel type and loading unit (unitised or not).

The latter three choices together are called 'transport chain choice'.

The focus of the paper is on the presentation of the general structure of the logistics model; there are no estimation results for the full transport chain choice on disaggregate data as of yet (this work is planned for 2007 and later). We restrict out attention to the pure transport of goods; vehicle movements for the delivery of services are not included.

In Section 3, we present the inventory logistics part of the proposed logistics model, which focuses on the determination of shipment size. In Section 4, the transport logistics part (choice of transport chain, including the number of legs and the modes for each leg) is discussed. Both inventory logistics and transport logistics are based on a minimisation of a full logistics cost function. This could be regarded as the behaviour of integrated shipper–carrier operations (there are no conflicts of interests between shipper and carrier in the model, as can occur when interaction is made explicit, as in Holguin-Veras et al., 2007). The treatment of empty vehicles is described in Section 5 and in Section 6 we discuss the required data for model estimation. Section 7 deals with an application of this framework to Norway and Sweden and describes the available data in these countries as well as our ideas on how to estimate the logistics model for each of the two countries, whereas Section 8 deals with progress made so far (development of prototype or 'version 0' and a 'version 1') in Norway and Sweden. Related work concerns the estimation of a model for mode and shipment size on disaggregate data from the Swedish 2001 Commodity Flow Survey, starting from the same cost function. This is reported in Section 9. This model is more limited in scope than the proposed logistics model, because it does not explain the use and location of consolidation and distribution centres. Finally, in Section 10 conclusions are drawn and directions for future work are discussed.