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APPROACHES TO LOGISTICS CHOICE MODELLING IN AGGREGATE GOODS FLOW

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ABSTRACT

This paper outlines main approaches to logistics choice modelling in aggregate goods flow. It briefly gives background information over transport models and the place of logistics choice models in them. The paper further discusses 3 main modelling concepts on the way of implementation. Independently from the chosen model concept, logistics choice models rely heavily on data such as quantification of trade flow, transport flow and costs. We provide a short discussion on the main sources of data available in the Netherlands and data bottlenecks. We conclude that a survey of shippers and further research in official statistics and raw observational data are to fill in the data gap.

INTRODUCTION

Transport and logistics plays a tremendous role in life of any contemporary society. It moves products from production places to consumers, allows exorbitant choices of products in shops and on the internet, provides jobs to hundreds of thousands of people in the Netherlands, but it also contributes to congestion, pollution, noise and accidents. The essence of logistics operations is to bring products to the customers within acceptable time and cost, which in reality manifests in complex distribution structures. Individual companies optimize their logistics structures to satisfy the criteria of time and cost, i.e. finding a balance between different cost components such as transport costs, warehousing costs and stock keeping costs. While optimization of a company's logistics is a well studied subject, mainly through operations research, there are huge gaps in understanding of logistics choices at the regional level, namely when the scope of the system contains many or all companies located in a particular region.

This work intends to close a gap which exists between the micro level logistics models (i.e. optimization of a company's logistics operations) and the macro level transport models (i.e. models that describe transport and goods flow at the regional, national and international levels). It means building a bridge between descriptive macro level transport models and optimization micro level transport models: the descriptive macro level transport models do not consider processes that take place in distribution structures, while optimization micro level models is the tool used by companies to control their processes and are not extended to the regional level.

There have been a few attempts to model logistics choices, namely the location of stocks at the regional level. The first and pioneering model, which took into account spatial allocation of stocks, was the SMILE model (Tavasszy, 1998), which was further extended with a whole lineage of derivatives (SLAM, SCENES, TRANS-TOOLS). The second approach to deal with the problem is addressed through simulation of logistics choices. The SYNTRADE model (under development at the Karlsruhe Institute of Technology) looks at the food retail sector in Germany (Liedtke, 2005 and Friedrich, 2010). The model uses data over location, type and size of the retail outlets and generates population of actors. It further simulates the behaviour of actors such that location of distribution centres, lot sizes of shipments and pallet-kilometres are determined. Lidtke 2009, argues for studying of meso-structures as a way to close the gap between micro and macro models. In the context of emissions estimation from freight transport in Great Britain, an application of supply chain optimization software was used to model spatial stock allocations and transport needs they entail at the regional level, Maurer 2008. Given known production / consumption tables for one commodity "Food, drinks and agricultural products", supply chain cost minimization models have been tried to determine allocation of stocks in supply chains.

In the United States there is an on-going work to bring logistics considerations into the freight transport models. Fischer (2005) proposes logistics chain modelling and tour-based truck modelling to support decision makers at the Los Angeles County Metropolitan Transportation Authority. The authors argue that the logistics chain model alone cannot model freight transport, it needs to be coupled with a tour-based model. The model choice depends on commodity type leading to a conclusion that commodities transported in big batches are more suitable for the logistics model, thus defining the application scope of the logistics model. Nagurney (2002) proposes a multilevel network perspective for the conceptualization of the dynamics underlying supply chains in the presence of competition. The authors combine logistical, informational, and financial networks in one framework to conceptualize dynamic supply chain processes and problems.

There are two main research challenges in development of logistics choice models. The first one is attributed to the model itself, and the second one is related to data, because such a model has quite extensive data requirements.

CLASSES OF MODEL

The extension of the classical 4-layer transport models with the 5th one, logistics choice layer, was first incorporated into the SMILE model (Tavasszy, 1998). The logistics choice model takes Production / Consumption (P/C) trade matrix from the

distribution model as the input and converts it into a transport Origin / Destination (O/D) matrix. The difference between the P/C and O/D matrixes is that the P/C matrix shows goods flow between production and consumption regions, without any further information about paths taken by the goods between these regions. The O/D matrix takes into account intermediate steps taken in transportation of goods from producing region to the destination region. The SMILE lineage of models performs logistics choice in a very complicated and rather ad-hoc way, such that choices made by the model are very hard to trace back. The approach of Lidtke (Liedtke, 2005) relies heavily on generation of a population of agents and simulation of their behaviour.

Tavasszy 2009 describes three modelling approaches that can be tried to model the logistics choice. The first one, gravity method, equals P/C trade flow to the flow from P to DC plus from DC to C plus direct from P to C. Cost components from the Generalized Logistics Cost (GLC) concept define the level of attraction between the regions, and in the end, determine the fraction of flow which will go directly or via a DC, see figure 1, where on the left side of the “equation” is the P/C matrix and on the right side is the O/D matrix composed of a sum of O/D matrixes related to direct shipments (directly from P to C) and indirect shipments (from P to DC plus from DC to D).

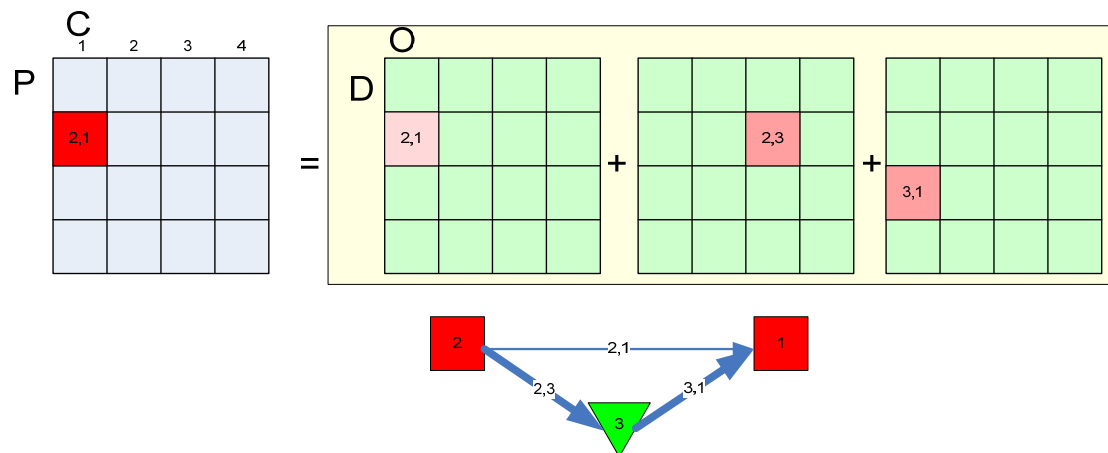


Figure 1: An example of a single trade relationship translated into transport flow

The second modelling approach, the multinomial logit method, uses the concept of GLC as the factor determining fraction of flow that is transported via a certain structure. It captures the logic of logistics design: where low replenishment frequency is possible or volumes are high (normally upstream in supply chains), high-volume shipments such as FTL are more likely. In this case the unit transport costs and unit depot / handling costs are low. On the other hand, when frequent replenishments required or volume is small, a costlier logistics solution is used, such as direct shipment or small shipment (LTL) via a distribution centre. From the stocks point of view, high stock keeping costs may be bigger than cost difference between a cheap and expensive transport options. A logit function will be used to determine probability of a certain logistics design suitable for specific situation.

The third modelling approach is to present supply chains in the form of hypernetworks. In this method different layers of the network represent segments of the chain upstream and downstream from distribution centres, for example Full Truck

Load (FTL) network and Less than Truck Load (LTL) network. The distribution centres function as the switch points between these two networks. The route choice process can be carried out using deterministic or probabilistic network choice methods, where determining parameters are the costs associated with the specific routes, see figure 2, where Route I represents a direct flow and Route II represents a flow via distribution centres.

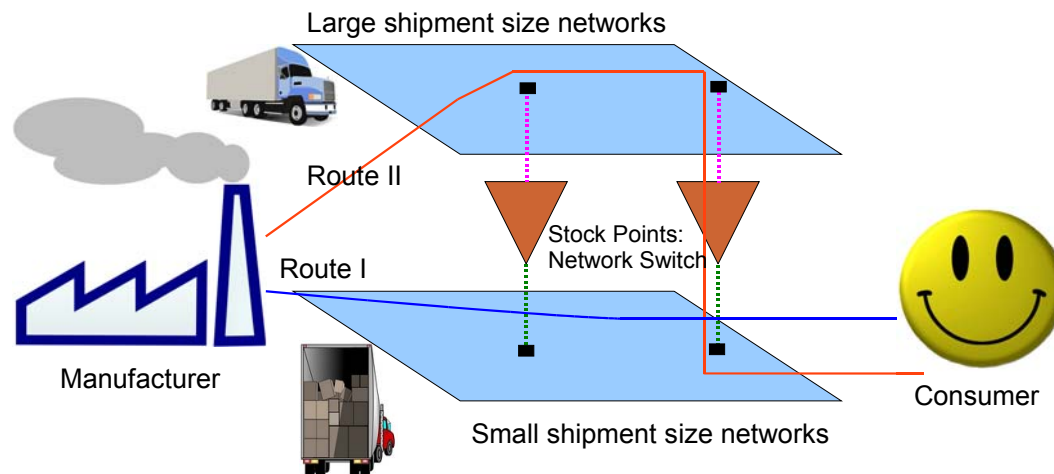


Figure 2: A hypernetwork model for inventory location choice

DATA NEEDS AND BOTTLENECKS

In addition to the modelling challenge, the three approaches described earlier in this paper rely heavily on data. The minimum data required is structured into the following data components.

1. Data over trade flow (P/C matrixes)
2. Data over transport flow (O/D matrixes).
3. Data on costs, which are included into the Generalized Logistics Cost (GLC) concept
4. Data on prevalent distribution structures

1. The search for the data over trade flow came to a conclusion that there is no observational data available over interregional flow of goods. Moreover, since 1992 the European Union does not require statistics bureaus to collect import-export data within the union, since it has been functioning as the common market. Therefore, all estimations of interregional trade are based on computations and not on observed values. The CGEEurope model generates information about interregional trade, but the output is in the form of Euro term values and it does not distinguish commodities. In general, the EU models such as TRANS-TOOLS, SASI, and CGE produce P/C matrixes at NUTS3 level for Europe, however the data is not directly observational, and there insufficient details available over commodity types. The SMILE model uses Input-Output tables and local employment and population figures to produce Production and Attraction tables. The Production / Attraction tables are not in the form of P/C flow tables, because it does not show interregional flow, but only values for produced and consumed goods per region. An application of other methods, for instance a gravity model, must be used to produce a P/C table.

2. The Dutch Statistics Bureau (CBS) publishes annual reports over transport flow in the Netherlands in the form of a matrix, which indicates loading and unloading points at NUT3 level for the country, type of commodity transported, modality of transport and tonnages transported. Similar statistics are also available at Eurostat, which cover shore Europe. However, the bureau does not distinguish between types of flow, namely there is no indication whether goods transported for the purpose of distribution, production / consumption or it is a transit flow via a terminal. The logistics choice model requires such a division of transport flow, because the transit flow is not related to distribution activities. However, we expect that the transport statistics can be reworked such that some conclusions over the locations of distribution centres can be drawn, therefore some more in-depth research and analysis of raw observational data is needed.

3. Logistics choice model uses the concept of Generalized Logistics Costs (GLC) (Tavasszy, 2009) to calculate flow over certain distribution structures. However, there is no information collected in principle over the components of the GLC. The GLC takes into account all major drivers and apply for product i out of the set of all products:

$$C_i = I_i + H_i + T_i, \quad i = 1, \dots, I.$$

Where I_i is the stock keeping costs, defined as the sum of pipeline inventory and safety stock costs; H_i is the handling cost and depends on the packaging density; T_i is the transport cost and depends on distance, shipment (lot size), frequency, mode, value density, speed and transport reliability. The survey method described in the following section will be used to collect information over GLC components.

4. Individual companies organize their supply chains according to company needs, mainly balancing costs and service level in a trade-off. In practice, companies choose a certain design of the supply chains: it can be a centralized network, where the customers are supplied from one central warehouse. It can also be a multi-echelon supply chain, where the regions have smaller regional distribution centres, which in turn are supplied from an upper stream country level distribution centre or even from a European one. However, currently there is no good empirical information over prevalence of each of the designs, especially split down to the commodity types. We claim that the survey method can be used to determine prevalence of each of the supply chain designs as the way to obtain empirical data on dominant supply chain structures.

REQUIRED DATA COLLECTION

The data on generalized logistics costs and over the main supply chain designs cannot be obtained through statistics bureaus or other official bodies. Therefore, we claim that the only practical way to obtain up-to-date empirical data is to conduct a broad survey among producers, importers and exporters of palletizable cargo. The survey method will underline the cost values that are attributed to transport cost per distance and shipment unit; value of time, which determines the trade-off between batch size and mode used; costs attributed to warehouse-related processes; interest rates values intrinsic to stock keeping.

The second component of the survey will deal with the discovering of the main supply chain designs. Supply chains have evolved from a decentralized form, when production and consumption were mainly local affairs to a centralized form, which came along with globalization and decreasing transport costs, Tavasszy 2003. The current pressure from fuel costs, pollution and congestion as well as demand for customized products and short lead times may tip the balance back towards decentralized supply chain structures, or complex mixed ones. However, the degree to which this phenomenon manifests itself in real logistics chains is not known. Figure 3 presents some of the most used supply chain designs; the survey will bring empirical data on what conditions influence each of these designs and how often they are met in reality.

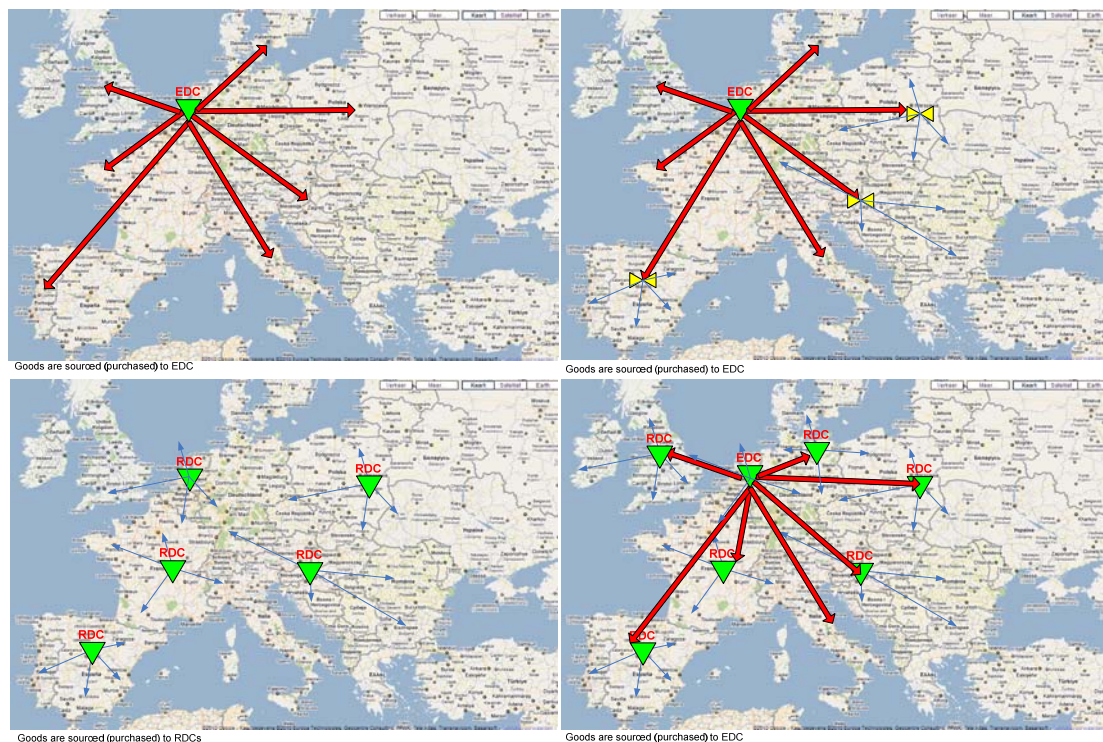


Figure 3: An example of dominant supply chain structures in Europe

CONCLUSIONS

The logistics choice models are intended to fit into the classical 4-step transport modelling framework with the aim of refinement of the transport models by the means of splitting trade flow into transport segments. Distribution centres serve as the connecting points in transport segments such that production and consumption points can be linked together via a series of transport legs. The logistics choice models can also be seen as the models determining where the stocks of products are kept; consequently stock keeping strategies determine replenishment policies, which trigger transport movements.

There are 3 main modelling concepts to implement logistics choice models: the most aggregate one in the gravity method, which determines whether goods will travel directly from production points to consumption points, or via a (series of) distribution centre. The second approach is the multinomial logit method, which assesses the costs

of (possibly quite numerous) alternatives, and in combination with discrete choice methods, defines fractions of flow that realize themselves over each of the alternatives. The third, hypernetworks approach, is closer to network modelling and uses distribution centres as the switch points between network types. All three approaches rely heavily on trade and transport statistics as well as on cost and supply chain design data.

The data on transport and trade flow can be obtained at such agencies as Eurostat and CBS, from other models such as TRANS-TOOLS, SASI, SMILE, CGErope, however not directly usable, the data needs to be reworked, possibly using raw survey data. The data on logistics costs and dominant supply chain structures must be collected; a survey of shippers, importers and exporters is deemed to be a practical way of obtaining empirical data.

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