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A Freight Energy Model Specification

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Abstract

Transportation modeling is a tool used to assess the impact of different improvement measures and improve planning. Traditionally, freight modeling has been emphasized less than passenger travel. Given the growth of the importance of freight in the global economy and indications that traditional energy sources are becoming scarce, a better understanding of the status-quo and alternative mitigation interventions is needed. The paper describes a comprehensive guide for the design and implementation of a freight energy model. This document includes the outline of the final paper. Some paragraphs will only be available in the final version of the paper, as research is ongoing.

Background

The world has become a global economy that cannot exist without the movement of people and goods. Unfortunately, negative impacts, such as global warming, oil depletion, air- and noise pollution and congestion are encountered due to the drive to increase economic activity. Transportation accounts for over 60% of all oil consumed globally, and the world's transportation systems are over 90% dependent on oil and oil by-products.

Freight transport forms the backbone of most market-driven economies. The cost of freight transportation impacts on inflation and consumer price indices. To sustain the global village way of life, it is of extreme importance that freight operations and planning are as streamlined and sustainable as possible.

To mitigate the negative impacts of transportation systems and move towards a more sustainable situation, appropriate future planning and a full understanding of the impact of alternative mitigation interventions, is needed.

Transportation modeling is one of the tools used to assess the impact of different measures. 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 (de Jong et al., 2004). Usually all steps are handled at the aggregate (zonal) level. Practically all these models 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 centers (Jong and Ben-Akiva, 2007).

Within the arena of freight movement modeling, several types of models have been developed in the past. Originally developed to model inter-industry relationships, input–output analysis has been extended to analyze inter-regional relationships, including the "pure inter-regional input–output model" by Isard (1951), the "column coefficient input–output model" by Moses (1955), and the "multi-regional input–output model" by Leontief and Strout (1963).

Comodity flow models in many variations have been applied by Samuelson (1952), Paelinck (Paelinck et al, 1983), and more recently by Celik and Guldmann (2007).

As indicated, practically every international, national or regional freight transport model system in the world is lacking logistics elements (Jong and Ben-Akiva, 2007). Exceptions are the SMILE and SMILE+ model in The Netherlands (Tavasszy et al., 1998; Bovenkerk, 2005), the SLAM model for Europe (SCENES Consortium, 2000), the EUNET 2.0 model for the Pennine Region in the UK (Yin et al., 2005) and the model for Oregon (Hunt, 2003; Hunt et al., 2001). The first three model systems are based on aggregate (zonal) data, but unlike other freight transport models, include the use of consolidation and/or distribution centers, so that routes between a production zone and a consumption zone can be either direct (one leg) or indirect (multi-leg; these models can distinguish various types of multi-leg transport chains). A more aggregate specification of a logistics model for Sweden, following the SMILE model in several respects, can be found in Östlund et al. (2002). Recently, de Jong and Ben-Akiva (2007) put forward a model that includes the determination of shipment size and the use of consolidation/distribution centers, within a behavioral framework, that can be estimated on disaggregate data and applied in micro-simulation. Furthermore, the application of Neural Nerwork (NN) theory has entered the transportation modeling field, including freight modeling (Reggianni et al, 1998; Nijkamp et al, 1997).

Internationally transport energy requirements are increasing continuously. Recently sustainability issues such as the recognition of global warming and oil constraints started changing transport modeling requirements. The current status-quo in terms of freight modeling is not sufficient anymore. A need exists to gain more insight into the magnitude of and the mechanisms responsible for energy demand in the transportation system, in particular in freight movement. Knowledge gained could assist decision making in terms of sustainability criteria and highlight some of the hidden costs of freight transport. The end-product of this paper is a comprehensive guide for the design and implementation of a freight energy model.

Modeling levels

Transportation modeling traditionally focuses on person travel; middle- to long-term decision making was required. Based on that planning horizon, the four-step model (the traditional macroscopic model) was developed as a tool to assist decision makers. Over the years, the planning horizon of decision makers changed; more strategic decisions (like changing fuel levies) were required. Tailor-made sketch planning models have been developed for that purpose. On the other hand, there has been an increasing awareness that the predict-and-provide philosophy is not sustainable.

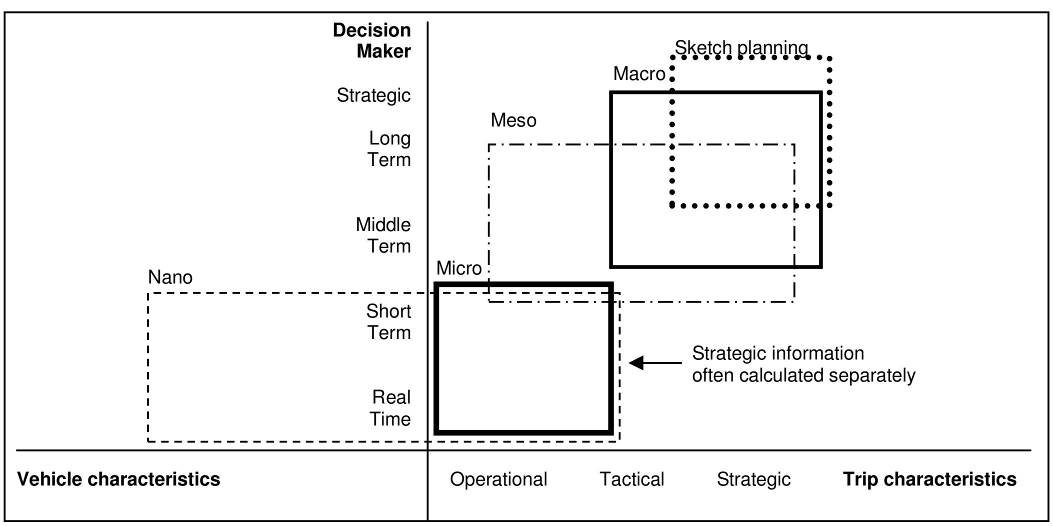

Figure 1. Trade-offs between the decision horizon and model characteristics
Source: Vanderschuren, 2006

Users make choices (strategic, tactical and operational) at various moments in time. Strategic choices, such as purchasing a vehicle or making a trip, are made (long) before the road user enters the public space. Tactical decisions, such as the departure time or route choice, are generally made as the trip starts. Some tactical decisions, such as the route choice, may be changed during the trip due to information that becomes available (i.e. congestion). Operational choices, such as accelerating, decelerating, lane changes etc., are constantly made during the trip.

Based on the flow and traffic dynamics representation, transport models can be divided into five types:

- **Sketch planning models** are, although based on the four-step transport model theory, tailor made for specific questions. In general, a higher aggregation level is chosen. Moreover, often one or more (traditional) steps are eliminated.
- **Macroscopic models** are based on the four-step transport model. Individual vehicles are not recognized. The network representation is based on links, nodes and attributes. Aspects, such as traffic controllers, are included as a node delay.
- **Mesoscopic models** include a representation of individual vehicles (or small 'packages' of vehicles with similar characteristics). Traffic dynamics are based on fluid approximation and queuing theories. The network representation is link and lane based (often for a corridor). Traffic control systems are detailed models based on aggregated capacity equivalents.
- **Microscopic models** include a representation of individual vehicles and traffic dynamics through vehicle interaction and movement. Driver behavior is included in a more detailed way (often via driver classes). Departure times of vehicles are available for every one to five minutes. During every calculation time step (e.g. 0.1 sec), the position of all vehicles in the network is calculated.
- **Nanoscopic models** are micro-simulation models that also include vehicle dynamics, such as turning radius and acceleration power. Nanoscopic models are developed for situations where microscopic models are not detailed enough. Many nanoscopic models are tailor made by car manufacturers. Nanoscopic models are also dynamic.

Freight models and related public policy tools have lagged behind logistics and technological advances. The structure of supply chains and freight systems have rapidly evolved in the last few decades and their complexity cannot be accurately captured by existing freight transport models at the international, national or regional level using the conventional four step approach, originally developed for passengers. Freight models simply based on the four-step modeling paradigm cannot provide adequate answers in the 21st century global customer-driven economy (Hensher and Figliozzi, 2007).

The need for energy modeling

Important answers required include: what the status of energy demand in terms of freight transportation is, what the driving forces behind this demand are and where the opportunities for improvement lie. Freight is the end use sector with the strongest relative growth (80%) in energy demand in International Energy Agency Member countries since 1973 (IEA, 2004).

The amount of energy consumed in transport is mainly affected by the average mileage of a vehicle, the fuel economy of a vehicle (which in turn is affected by vehicle maintenance and driving behavior) and the number of vehicles in the network. Other relevant factors include vehicle age and the fuel type used. Different modes of freight transport have different energy demand characteristics, but are not all equally well-suited to every type of commodity. There is reason to believe that an optimal modal distribution exists for every freight network. All of these elements need to be added to traditional freight models to constitute a freight energy model.

Presently, due to a lack of good, comprehensive and reliable data, it is more important to obtain a high level understanding of the energy consumption in freight transportation. The guidelines set out in this paper are aimed at sketch planning level. Such a model would form part of an energy management tool, assisting decision makers and planners in keeping track of the energy consumption of the industry, enabling benchmarking and allowing the introduction and tracking of sustainability improvement targets.

Freight attributes and application level

In modeling, it is very important to understand exactly what data is used as input, how the calculations in the transformation phase work and what information is produced as output. The aim of this research is to determine the key elements that need to be included or considered in a sketch planning freight energy model.

A first task is to establish the objective of the model. Based on this objective and the available data, the appropriate measuring units need to be chosen. For example: the growth in freight energy demand was accompanied by a generally modest overall decline in fuel intensities. It is likely that whilst individual truck intensities per truck-km have declined, but that this was offset by a move towards smaller trucks or lower load factors. This lead to an increase in fuel use per ton-km shipped (IEA, 2004). Hence there is a great difference between using truck-km and ton-km as a measuring unit.

In general a model is only as good as the input data used. This research identifies the minimum amount of data and the format of the data required to construct a reliable freight energy model. Typical data that is required includes data on the type of commodities transported, classification of the commodities (e.g. fast-moving consumer goods, mineral ore), fleet specifications, commodity quantities, modal split data, the network lay-out and many more.

The typical constraints, model parameters, calibration requirements and potential pitfalls are established.

Freight energy modeling in SA: A case study

To be added in the final paper

Conclusions and Recommendations

To be added in the final paper

References

Bovenkerk, M. (2005), SMILE+, the new and improved Dutch national freight model system. Paper Presented at the European Transport Conference 2005, Strasbourg

Celik H.M. and J.M. Guldmann (2007), Spatial interaction modelling of interregional commodity flows, Socio-Economic Planning Sciences 41, pages 147-162

De Jong, G.C., H.F. Gunn and W. Walker (2004), National and international freight transport models: overview and ideas for further development. Transport Reviews 24, Issue 1, Pages 103–124

De Jong G. and M. Ben-Akiva (2007), A micro-simulation model of shipment size and transport chain choice, Transportation Research Part B 41, Pages 950–965

Hensher D. and M.A. Figliozzi (2007), Behavioural insights into the modelling of freight transportation and distribution systems, Transportation Research Part B, Volume 41, Issue 9, Pages 921-923

Hunt, J.D., R. Donnelly, J.E. Abraham, C. Batten, J. Freedman, J. Hicks, P.J. Costinett and W.J. Upton, (2001), Design of a statewide land use transport interaction model for Oregon, In: Proceedings of the 9th World Conference for Transport Research, Seoul, South Korea

Hunt, J.D. (2003), Agent behaviour issues arising with urban system micro-simulation. European Journal of Transport Infrastructure and Research 2, issue 3/4, Pages 233–254

International Energy Agency (IEA, 2004), Oil crises and climate challenges: 30 years of energy use in IEA countries, OECD/IEA, page 18

Isard W. (1951), Interregional and regional input–output analysis: a model of a space-economy. The Review of Economics and Statistics 33, pages 157–69

Leontief W and A. Strout (1963), Multiregional input–output analysis. In: Barna T, editor. Structural dependence and economic development. New York: St. Martin's Press; pages 119–50

Moses LN. (1955), The stability of interregional trading patterns and input–output analysis. American Economic Review 45, pages 803–26

Nijkamp, P., A. Reggiani and S. Bolis (1997), European Freight Transport and the Environment; Empirical Applications and Scenarios, Transportation Research Part D, Volume 2, Issue 4, Pages 233-244

Östlund, B., G. Janson, A. Burgess, C. Ruijgrok, L. Tavasszy and M.S. Petersen, (2002), A Logistics Module for SAMGODS. TFK – Institute for transportforskning, Stockholm

Paelinck J.H.P., J.P. Ancot and J.H. Kuiper JH (1983), Formal spatial economic analysis. Aldershot, UK: Gower Publishing

Reggiani A., P. Nijkamp and W.F. Tsang (1998), European Freight Transport analysis using Neural Networks and Logit models, In: Reggiani A. (Ed), Accessibility, Trade and Locational Behaviour, Ashgate, Aldershot

Samuelson PA. (1952), Spatial price equilibrium arid linear programming, American Economic Review, Volume 42, Pages 283–303

SCENES Consortium (2000), SCENES European transport forecasting model and appended module, technical description. SCENES deliverable 4 for the European Commission DG-TREN, ME&P, Cambridge

Tavasszy, L.A., M. van der Vlist, C. Ruijgrok and J. van de Rest, J. van de (1998), Scenario-wise analysis of transport and logistics with a SMILE, Paper Presented at the 8th WCTR Conference, Antwerp

Vanderschuren M.J.W.A. (2006), Intelligent Transport Systems in South Africa, Impact assessment through microscopic simulation in the South African context**,** TRAIL Thesis Series T2006/4, ISBN number: 9055840777, August 2006 (Book)

Yin, Y., I. Williams and M. Shahkarami, (2005), Integrated regional economic and freight logistics modelling: results from a model for the Trans-Pennine Corridor - UK, Paper Presented at the European Transport Conference 2005, Strasbourg