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The issues in modelling freight transport at the national level

1. INTRODUCTION

In Europe, a number of countries have developed national freight transport models to assist national governments in decision-making on future transport infrastructure and transport policies[1]. The same is true for some other small to medium-sized countries elsewhere. In large countries like the US or China, regional models (e.g. state-wide models in the US) will be more comparable to the European national models, in terms of issues covered and detail provided, though many of the same issues are also relevant for national freight models for such countries.

In recent years, many national freight transport models have changed considerably, moving away from the four-stage model that was originally developed for passenger transport, especially by including more aspects of transport logistics and sometimes even inventory logistics.

However, new types of models lead to new issues to be solved. Transferring concepts from operations research developed for the individual firm level, from behavioural economics, from computer sciences or elsewhere raises all kinds of new questions, both in terms of model specification and data. Model teams in various countries have encountered such issues and between countries there appears to be a large degree of agreement on the current issues for modelling freight transport at the national (state-wide) level .

Nonetheless, there are a number of challenges that clients face in commissioning a national model. Which specific questions should the model address? Does the client want to "run" the model or is he happy to contract out the development and operation? Does the client intend to make the model available to other users? How will the model be maintained, both in the sense of enhancements/updates and of ensuring that it can still be operated?

There are also questions of model specification and, critically, whether data is available (or can be collected) to support the level of detail required. This in turn affects the level of confidence which can be placed in the model output.

Thus, there are many issues to discuss, and they are quite varied. Based on the experiences of the authors from national freight transport modelling mainly in Norway, Sweden, Denmark, the Netherlands, Belgium, Germany and the UK, this paper will provide a review of these issues. For the purpose of the discussion, we have classified them under four main headings, as illustrated in the following Figure:

[1] National freight transport models are usually not restricted to domestic flows, but also include import and export flows and sometimes transit flows.

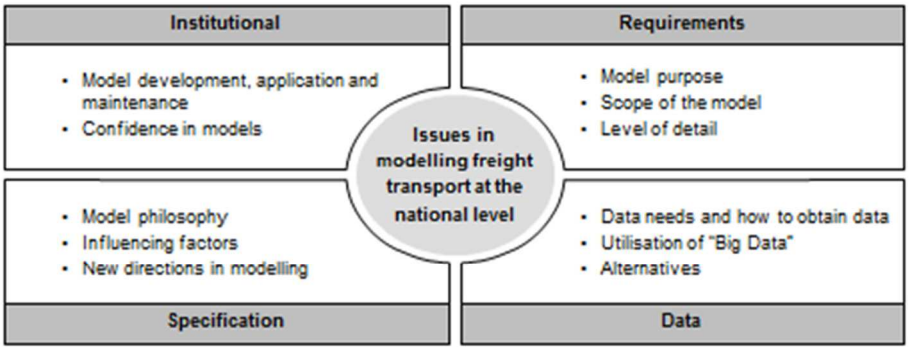

Figure 1. Overview of the issues in modelling freight transport at the national level

In a little more detail, the key questions are as follows:

- Institutional:
    a. Organisation: how do we structure the work on model development, application and maintenance?
    b. Confidence: What can be done to determine the level of confidence we can have in the model outputs? And what can be done to increase confidence?
- Requirements:
    a. What is being asked from the models?
    b. What are the appropriate scope and level of detail of the model?
- Specification:
    a. which model philosophy do we choose? Which additional influencing factors of freight transport could be incorporated in the model?
    b. New directions: what are the new model components (modules) that could be added to the existing frameworks?
- Data:
    a. Data wish-list: what kind of data is ideally needed for the new types of models? How can we obtain these data? How can we make the best of "Big Data"?
    b. Data use in practice: what can we do if these data are not available? What can we do with the data that we have?

These issues are discussed in more detail in the sections 2-5 respectively. Finally, section 6 contains a summary and conclusions.

2. INSTITUTIONAL ASPECTS

2.1 Organisation

Two main approaches for the organisation of modelling can be distinguished. Firstly, the conventional approach involves the creation of a broad model platform of the national transport system for general policy support to the government. In the organisation of modelling efforts, continuity is of prime importance. The development, maintenance and use of national freight transport models are matters that span many years and during this period a stable environment that commits to the model is important for success. Secondly, a complementary and increasingly popular approach is to develop case-based models around a single policy issue of national importance that does not allow broader usage. Besides national government, other stakeholders such as private parties, NGOs and other governmental bodies are grouped around a single issue. Critical success factors for both approaches include involving the users of the models as early as possible, clear ownership of the model by one organisation or a group of organisations that can act as a single body, transparency about the model (including use of the model by third parties, consultants as well as academics) and using different tracks for daily model application and further innovation.

In the Norwegian National Freight Model (in short NGM), the first approach has been chosen, developing it as a broad model covering all freight transport (domestic and for export and import) in one model. The model is using a fairly detailed network (the network from the long distance passenger model) for all modes, detailed freight flows (before mode distribution) on a zone to zone level, detailed cost models for 11 modes (some modes are divided into sub-modes for modelling reasons), with close to a hundred different transport units for road vehicles, vessel types, train types etc. The philosophy has been that by simulating optimal transport choices from the point of view of transport users – minimising logistical costs – the various micro-economics-based decisions will on an aggregate level give good predictions for transport flows. The model has been developed over nine years in various versions through a cooperation between Significance, Institute for transport economics in Norway (TØI) and SITMA AS. The commissioner for the development and the management of the project has been a joint group from the Road Authorities (head of project), the Rail Authorities, the Coastal Administration and Aviation (the air traffic authorities). The results achieved actually support the hypothesis of getting a good fit with statistics, also on detailed levels like terminals and ports, as well as though the networks, from this aggregated micro-simulation approach. This has also made the model quite suitable for project and policy analysis. The detailed level of the model is especially useful in this context. The logistical costs are treated at a very detailed level, which enables the users to simulate the effect of a broad variety of parameter changes, both exogenously given, and policy driven. The detailed level of the output information – down to individual transport chains and shipments, also enables more detailed analysis for specific projects (de Jong, Ben-Akiva, Baak, Grønland, 2013).

When a model-based analysis is required for specific projects or policy studies, the broad model approach has proved to be sufficient for most cases, so development of more limited models for special purposes has not been deemed necessary. One of the advantages of using a broader model is also that effects of special projects can be seen not only on a local level, but also on the national level for freight transport (Hovi, Madslien, Grønland 2013).

Examples of applications of the model over the last five years cover for example analysis of new rail freight terminals and their location, port planning projects, policy analysis of different policy measures as background studies to the Norwegian national Transport Plan, forecasting of future freight flows and terminal volumes (NTP – 2015).

2.2 Confidence

Confidence in the models not only rests on proper statistical estimation and calibration using accurately measured data, but also on other methods used in a broader context of quality management. This includes performing backcasting exercises, comparing model predictions to realisations and asking industry experts and regional planners for their opinion on whether the model behaviour and the model results look reasonable (so-called face validity testing).

While there are a lot of quality management tools like these mentioned above, an important question is which one can provide useful information to improve the model quality and how much effort has to be invested. Depending on the aim the right tool has to be chosen.

One of the most laborious and much discussed tools is the backcasting method. The idea of this method is to calculate a forecast for a year in the past. By comparing the model results with real data it is possible to check the quality of the forecast. Work conducted work at the German Aerospace Center (Lange and Huber, 2015) has shown that applying the backcasting method can lead to problems that reduce the value of this tool. As the backcasting method is based on data of the past, limited data availability and lack of continuity complicate the work. The change of the commodity classification in 2007 from NST/R to NST 2007 makes it even more complicated. On a higher level both classifications are not comparable to each other. If this affects the forecast and the calibration year a useful backcasting is not possible. In addition a lot of data of freight transportation are only available at a very aggregate level so that more detailed model results cannot be checked.

A big question is how to use the information obtained by backcasting to improve the model. By using the backcasting method it is only possible to state the deviation from the measured data but not the cause. This is why further tools have to be used. One step is to check the most important input data concerning their chronological continuity. It could happen that data, which are needed for a forecast (i.e. gross domestic product, gross value added) are not compatible with the trend of the forecasted value (i.e. traffic volume). Another useful tool is a sensitivity analysis whose theoretical background is comparable to the backcasting method. The difference is that only a single input parameter is changed. This puts one in the position to know the reason for the change in the results. Thus, it is possible to derive information about the models behaviour, but not about the quality of the forecast.

Summarising the previous passages, there is no tool that is able to test all quality aspects at once. In order to get a broad quality management it is necessary to use a combination of several methods. However, a combination of different methods requires a lot of work and time. This leads to a second problem of quality management: the frequency of utilisation.

The quality test is, especially in commercial use, an often neglected step. Furthermore, there are just a few countries in which required quality methods are defined in a guideline. In combination with a rising cost pressure this results in a shrinking attention to the model's quality (Sammer et al, 2012).

All in all, confidence in the models is a difficult topic. Available quality management methods are often time-consuming so that many modellers do not use them for the model's calibration and validation. An important and necessary step to improve the current situation is to create a consistent guideline that defines the calibration and validation quality and that gives advice which methods are helpful to fulfil the quality requirements.

3. REQUIREMENTS

3.1 Questions asked

National freight transport models are used for investigating what might happen to transport (and transport-related indicators, such as emissions or tax revenues) in the medium to long run (using one or more scenarios as input) and to simulate the impact of transport policy measures (e.g. pricing for a certain mode) and infrastructure investment projects, assuming fixed or adaptive model coefficients. Not all these questions require the use of a full-fledged transport model; sometimes a subset of the modules or a simplified model will be sufficient. Furthermore, not all questions for which one uses a model have the same time horizon. Questions on toll revenues for private financers may focus on the time path of the model outcomes in the first years of operation, whereas scenario studies may look 20 or 30 years ahead (e.g. the Mobility Masterplan Study Flanders and the Dutch new WLO study, that uses the Dutch national freight transport model BasGoed, use future years up to 2040 or even 2050). There also is a need for models that can give the impacts of large exogenous shocks, both in terms of economic development and in terms of natural disasters.

The required model scope and level of detail depend strongly on the issues under investigation. For instance, policy studies require mostly aggregated outputs either at the national or the regional level, sometimes it is not even needed to relate the results to transport networks. This commonly is the case of national studies for the medium or long run related for instance to emissions forecast, tax revenues or the impact assessment of policy measures. On the other hand infrastructure planning needs normally speaking, more detailed and network-linked outputs. The level of detail is directly related to the time horizon of the investments and the step in the planning process. Long term planning within feasibility studies require much less detailed information and a longer run forecasts than the planning of infrastructure after the decision about the solution has been made.

The table below shows an overview of questions that can addressed by means of modelling.

Table 1. Questions that freight transport models can answer

Themes	Main questions	Applications	Required modules
General	Forecast freight transport (tonnes and trips) for different time horizons on the basis of socio-economic scenarios	• Studies for policy making. Geographical detail depends on the scope of the study (national-regional-local) • Infrastructural planning. Forecast at network level, (frequently at link level)	Travel demand model to forecast growth in OD flows by mode and commodity and uni-modal assignment
Vehicle/ vessel/ wagon types	Factors influencing vehicle type choice (vehicle/train wagon/vessel) and their effect	• Studies for policy making on reducing emissions • Infrastructure design and maintenance schemes • Emissions forecast	Models of development of vehicle/vessel/rail wagons stocks and choice of vehicle type
Spatial and economic effects	Influence of accessibility on the economic and spatial development of a region.	• Spatial planning • Land use forecast and policy making • Macro-economic effects of changes in the transport costs	Iterative link between spatial models and transport models
International trade and ports	• Factors defining port choice • Impact of trade barriers on freight transport • How can transit flows be influenced by policy measures?	Studies for national and regional level and policy making on main ports	Consistent port and trade models Models for choice of port and the impact on maritime transport route choice. Trade models linking trade to freight transport flows
Logistics and intermodality	• (Potential) intermodal choices for different types of goods between each PC and how to influence the choices made. • Optimal location of logistics centres for overall minimisation of tonne-km	Intersectoral transport policies	Multimodal (logistics/transport) chain model

	• Consolidation of goods, empty transports, load factor, influence of shipment size/inventory logistics		
Reliability	Effect of travel time reliability on the route choice and logistics behaviour	Costs-benefit analysis of infrastructure and policy measures	Reliability model
Air and pipeline freight	Forecast for freight transport by air and pipeline in tonnes	Studies for policy making.	Basic demand models including data on air and/or pipeline transport
Effect on congestion	• Effect of route choice on length and location of congestion • Effect of congestion on route and mode choice	Policy making (i.e. regulations on time slots)	Iterative feedback linking the level of services to the mode choice and assignment modules
Hazardous materials	Forecast of both internal and external risks of transportation of hazardous materials on dedicated routes	• Infrastructure planning • Regulations on hazardous materials transportation	Risk models in combination with travel demand model

There are additional requirements for models directed at 'living-lab-type' environments that justify a one-off model development based on data of all stakeholders involved. Here, for example, face validity, i.e. the realistic representation of present day behaviour at the operational level, is an important criterion. Before discussing requirements for models in such situations we will first describe the model use environment in more detail.

The commonly held conception of policy and innovation processes is that policy measures or major innovations are implemented after a policy preparation and decision making stage. More and more, however, stakeholders in freight transport and logistics are realising that policy implementation and deployment of innovations are part of a lengthier evolutionary process (Nevens et al., 2013). It is not uncommon that freight policies or innovations do not make it beyond a first trial stage or fail completely (van Binsbergen et al., 2013). Often, there are unwanted side-effects or rebound effects which prevent innovations to reach their full impact. The causes of such failed changes can be manifold but are rooted in the fact that supply chains are complex systems. Many measures affect the business of different stakeholders at the same time, making changes difficult. Changes may require actors to collaborate in new ways, or require a change in business models of firms and

government. In order to cope with this complexity, also the policy and innovation processes are changing. These new processes build on systems-of-systems thinking and revolve around an integration of planning and deployment processes. We call them here “living labs”.

Living labs are multi-stakeholder experimentation environments aimed at realising a system-wide innovation in a step-by-step manner. Stakeholders who participate in a living lab often share a roadmap based on a common objective, which guides them towards developing and deploying measures. Contrary to the policy analysis environment, with years-long linear decision processes, the context here is one of high-frequency cyclical decision making and co-makership among practitioners. Examples may be a region in which the government, the logistics community, shippers and citizen groups decide together to change the regime under which logistics operate (see e.g. Lindholm and Browne, 2013). This may involve electric vehicles, night time distribution, or concessioning of freight transport services. Another example is a port where container terminals, sea carriers and hinterland service providers work together to reduce port emissions (see e.g. Giuliano and Linder, 2014). A more recent example are the EU corridors for the TEN-T, where corridor managers have to supervise the consistent development of infrastructure, services and new governance approaches (see e.g. Abastante et al., 2014). Several measures of a different nature are needed, well aligned between public and private authorities, to make such living labs work. We should note that even though living labs do not always operate at a national scale, their impacts are often of national significance, be it in the way they affect freight flows, or the scale of their economic or environmental impacts.

In living labs, data and models have the same basic function as in policy analysis: to allow ex ante predictions and ex post analysis of the impacts of measures. Their role, however, is different than in the conventional public arena, due to three particular characteristics of living labs. Firstly, data and models need to be inclusive in the sense of the relevant stakeholders, and need to address everyone’s particular perspective. In many models, nowadays, individual stakeholders cannot be recognised. Secondly, models and data need to be experienced as valid, by all stakeholders. From a practitioner perspective, this implies that ontological completeness, conceptual richness and face validity will often be more important than statistical validity – this holds for industry as well as for policy makers. Thirdly, as forecasting, deployment and measurement of effects are more tightly coupled, the models need to be able to process data obtained from operations and be able to predict effects at the same level as they are measured. The emphasis in the function of the model will shift away from the conventional function of providing supporting proof for single policy decisions, towards being a tool for continuous and collective learning (Anand et al., 2012; Joys, 2014). Moreover, the above characteristics of the user environment also place different demands on the subject of modelling itself. Particular aspects of the freight and logistics system suddenly become manifest within living labs and need to be modelled explicitly. These include:

- Different types of stakeholder and their business models,
- Tactical and operational characteristics of freight transport operations, including the main decision variables of actors and their performance metrics,
- Individual adoption process and emerging patterns of collective adoption,
- Processes of social and business interaction that determine cooperation outcomes,
- Dynamic characteristics of behaviour to determine response times and payback periods

These characteristics will become more and more important in national level freight modelling, especially as the policy agendas for freight transport at the national level are increasingly dominated by “living lab” type innovation programs.

3.2 Consequences for scoping

Models are simplified representations of reality. Generally, this simplification is achieved by omitting details. Real life systems do not contain explicit hints whether certain entities or relations are of optional or essential nature. Hence, the model designer needs to develop an own interpretation based on the model’s purpose, respectively potential applications. Building upon such a system analysis, the borders for the intended model can be defined. In most cases, there are additional constraints, e.g. coming from data availability, manageable complexity or computability. The entirety of all boundaries is called scope. It defines which elements and relations are to be integrated into the model and which are to be left out. Accordingly, the scope definition is an essential part of the model description.

In the area of freight transport modelling, the scope definition usually incorporates remarks on the model’s boundaries regarding space and time as well as objects, relations and activities. For each of these dimensions range and resolution need to be defined for their representation in the model, thereby determining scale and level of detail.

This work addresses models that spatially focus on the national level. Nevertheless, the modelling of national freight transport often requires an extended spatial scope, e.g. by linking to international or regional models. Traditionally, national models make use of zoning systems to represent space. The zoning system’s resolution depends on considerations regarding data availability, model complexity and objective. Its resolution can vary within the model, e.g. using small zones within the national borders and large zones for the international parts.

Most national freight transport models apply static concepts of time, e.g. by calculating freight transport for isolated points in time. In contrast, new developments in freight transport research focus on the continuous representation of time by using dynamic simulation. Hence, the temporal scope either defines certain points in time or beginning and end of the analysis together with information on the temporal resolution in between.

Another part of the scope definition deals with the model representation of transport modes and intermodal transport chains. First, it must be defined which transport modes and combinations thereof are available in the model. Next, the level of detail per mode needs to be decided upon. The Swedish national freight model SAMGODS has 82 different transport chains (distinguishing modes and vehicle/vessel type for each OD leg of the chain) and the Norwegian national model has 79. The models for The Netherlands (BasGoed), Flanders, France and Germany are in this respect much simpler in that they only distinguish modes (road, rail, inland waterways) with no or only a few distinctions within each mode. The Norwegian and Swedish models however do not include chains with inland waterway transport, which is clearly less important in Scandinavia than in The Netherlands, Belgium, Germany and France.

For road transport, an issue could be whether one models tour patterns (e.g. collection rounds with multiple senders followed by main hauls and finally distribution tours with multiple receivers) or

simple direct trips between origins and destinations. Especially for the assignment of resulting vehicle flows to the infrastructure, the model scope must define whether and how the interaction with passenger transport is captured, e.g. one solution being the linkage to passenger models.

Freight transport behaviour strongly depends on the type of commodity transported. Often influenced by data availability, one strains to identify homogenous groups of commodities and integrate these into the model. As freight transport is a derived demand, it is often helpful also to integrate or link economic or spatial planning models. Here, the economic models' granularity might match the different categories of homogenous commodities considered. In order to capture the economic systems, some freight transport models incorporate economic activities and trade relations on the level of business establishments. Sectoral freight transport models, which focus on freight transport demand arising from single industry sectors (e.g. food retailing), are based on the idea of identifiable homogenous groups of actors. By limiting their scope, they are able to behaviourally capture the interaction between economic activities and freight transport per sector, and then build up a full national model from the sectoral ones. In some cases, however, national freight policy could also be well served by a partial model for one sector, or around a very specific policy measure. This leads to important questions about model transferability between cases, sectors and countries.

Finally, as indicated above in the living lab discussion, explicit treatment of individual stakeholders and their operational processes is becoming more important. National models will need to be operationalised in such a way that connections can be made with sector-specific or industry-specific models.

4. SPECIFICATION

4.1 Model philosophy

An important question in terms of model philosophy concerns the level of detail of potentially useful data. The challenge here is to decide whether to use aggregate or disaggregate data with all its advantages and disadvantages. Aggregate data – mainly surveyed, edited and published by public authorities – provide only little detail but are, at least, published periodically. Therefore, they represent a relatively reliable data source that can be used to estimate, calibrate and validate for example freight distribution of freight models. The level of aggregation of these data is crucial because very often aggregate data are not sufficient. Thus, many underlying behavioural assumptions have to be applied, for example on shipments, to run models using aggregate data (de Jong et al., 2012, Ben-Akiva et al., 2013). Even most macroscopic models that work with aggregate data claim high data requirements today. However, aggregate data do not offer detailed information about e.g. single shipments or actors. In order to model detailed decisions disaggregate data are necessary (Tavasszy and de Jong, 2014; Friedrich et al., 2003).

Disaggregate data allow a detailed insight in selected problems and are very helpful to follow and model decision processes realistically. Examples can be found for instance in choice of shipment size or mode choice models, which are often based on disaggregate data from SP or RP surveys (see for instance the work carried out to base the Swedish logistics model on stochastic formulations

estimated on RP data instead of the current deterministic rules reported in Abate et al. (2014)). The focus is, however, mostly on single sectors (e.g. automotive industry or food retailing), actors (e.g. freight forwarder or carrier) or specific spatial units (e.g. regions or urban areas). Therefore, disaggregate data are very useful e.g. for microscopic models in urban areas or for specific industry sectors, but they are not transferable and, thus, do not enable modellers to draw a complete picture of decisions processes in freight transport. New upcoming empirical methods tackle this challenge and the increasing availability of disaggregate data (e.g. on firm-level) has led to a shift towards more disaggregated and behavioural analyses (Ben-Akiva et al., 2013, Friedrich, 2012). Nevertheless, disaggregate data are commonly not available – neither nationwide nor for all sectors and actors – and it is mostly singular surveys for a certain year. In this manner, the limited availability of disaggregate data is a major constraint on the development of sophisticated demand models (de Jong et al., 2012).

There are plenty of models around the world that work with aggregate data (e.g. the Dutch national freight transport model Basgoed or the strategic freight model for Flanders) and also some whose input is more disaggregate (see e.g. de Jong et al., 2012, de Jong et al., 2004). The accuracy and possible uses of models but also their development costs vary depending on the aggregation level of the data. A well-balanced combination of both aggregate and disaggregate data could be a possible way to deal with the current data situation.

In freight transport there is a variety of significant influencing factors that have a major impact on transport processes. Travel times, costs for loading and unloading, transport cost as well as handling cost (all distinguishing different modes but also for different commodity types) are some examples. Enhanced by costs for warehousing etc., these costs constitute total logistics cost and can be integrated in modelling via specific logistics cost functions. However, there are supplementary factors that are not commonly integrated in demand models. Reliability and delay, for example, have received considerable attention in last years. There are still few studies on the valuation of reliability (see e.g. Halse et al., 2010; Significance et al., 2013) but the integration of proper cost functions considering reliability should be among the research objectives in the near future. A similar case may be made for including factors like flexibility of transports as well as damages possibly occurring during the transport process. There is still not enough information on that and, therefore, cost functions used in practice are a rather incomplete representation of the actual factors influencing decision-making. The same applies to technological change like the utilization of information and communication technologies (ICT), which is an important topic in freight transport. ICT refers to all actors and its utilisation can vary significantly (see e.g. Ruijgrok, 2008). However, the effects of ICT are poorly investigated and, therefore, not integrated properly in most models. All the mentioned influencing factors can affect the models considerably. Their integration would increase the explanatory power and enable new scenario calculations etc. However, different and detailed cost functions are needed to integrate the different factors in modelling adequately.

In order to reproduce decision making processes a key decision in terms of model philosophy is to choose a proper model type. An important question is whether to use a deterministic or a stochastic model. In deterministic models relations are clearly determinable because decisions are made assuming complete information. This model type is easy to calculate and provides discrete values which can be used by deterministic optimization tools (e.g. the logistics models in the current

national freight models of Norway and Sweden). However, using statistical values (e.g. averages) does scarcely reflect reality. In contrast to that, in stochastic models relations are determined statistically, as representing imperfect information, for instance by adding a random utility component. This enables the models to capture intrinsic variability, which underlie most transport processes. Nevertheless, both model types can assume cost minimisation behaviour on the side of agents. Furthermore, a probabilistic model (e.g. of the logit family) can be estimated on micro-data and may probably lead to smoother response functions. The choice of the proper model type should, therefore, be made thoroughly and with the purpose of the model in mind. Work on probabilistic models of mode and shipment size choice is currently going in Sweden, Norway and for the new European transport model Transtools3.

4.2 New directions

There is an increasing interest in freight transport modelling research, and new directions for modelling are developing quickly. Directions of change are determined by several developments, including an increasing importance of logistics processes in supply chains, ever-increasing computing capabilities, a tendency towards more collaboration between stakeholders in the freight and logistics sector, an increasing integration of operational, tactical and strategic management systems, automation of freight and logistics processes, increased availability of data and so on. Here we discuss some of the dominant directions of innovation that can be found in the literature nowadays.

An important source of inspiration for new models is the recognition that freight transport demand is derived from trade and logistics activities. The desire to more explicitly model these underlying processes results in a complete research agenda for freight models (Tavasszy et al., 2012). Typical new model components, some of which have already been implemented and tested, and some of which are still in the experimentation stage, deal with (intermediate) warehouse location, local and regional logistics centres, supply chain structures, the emergence of logistical networks and time period choice (Tavasszy and de Jong, 2014). A key challenge is to populate the freight modelling frameworks with descriptive models of logistics decision making behaviour, where models from the logistics literature are usually normative in nature. In recent years, this agenda has led to new research, supported to a large extent by urban level initiatives but also within national model environments.

The worlds of logistics innovations and that of freight transport policy are converging. As sketched in 3.2, change in freight systems is more and more brought about in collaboration between various types of stakeholders, public and private, around new logistics concepts that require public and private support for their development, deployment and operation. These “living lab” environments require models that are stakeholder-inclusive, represent processes at the operational level, and allow anticipation into the future about possible effects of measures. Agent Based Modelling was signalled about a decade ago as a feasible modelling approach (Davidsson et al., 2005; Liedtke 2006, 2009) and is now gaining acceptance as a policy support tool (Donnelly and Wigan, 2012 and Gatta & Marcucci, 2014). Rooted in discrete event simulation, these models also allow a detailed description of reasoning agents, representing the stakeholders, and indicate which emergent behaviour is to be expected. Obviously, these models require more detailed data and a more detailed knowledge about individual behavioural preferences and patterns. Research challenges include the correct modelling of emergent structures (Murillo and Liedtke, 2013), the development of appropriate system

frameworks (Roorda et al., 2010, Anand et al., 2012) and behavioural research to populate such models (Stathopoulos et al., 2012).

An important development that is on the horizon, but has not yet reached the field of freight modelling, is big data. As operational systems in logistics become more developed and the management of processes becomes automated, everything that is measured creates data, and all data that is stored can be used for modelling (Witlox, 2015). The use of new sources for modelling freight transport activities is already clearly visible in the availability of GPS based analysis of trips for urban transport (Joubert and Meintjes, 2015) and maritime traffic (Shelmerdine, 2015). The data used here concerns observations of vehicle or vessel locations, including a time stamp and other information related to the shipper or carrier. As practice shows, however, such traffic counts and registrations of actually used routes often do not provide sufficient detail to estimate models, and additional surveying or data acquisition may be needed. As more and more operational data become available in freight supply chains, we are moving towards a situation where big data can be employed that covers the demand and supply side of transport markets and has sufficient repeated observations. . Possibly, in the future, one will rely less and less on theory for inferring relationships between independent and dependent variables, in order to allow management and design of freight transport systems. Recent data-driven modelling work (e.g. Petri et al., 2014) points in the direction that big data might allow predictions based on mere correlations and data mining. An idea, perhaps unattractive for freight modellers, is that this approach might be more effective than one built on sparse data and theory.

A fourth direction concerns the elimination of borders of systems that we have now in designing, governing and managing freight transport. Many trends in society (and trend breaks as well) cross borders between administrations, technological systems and regimes of governance and require new forms of cross-jurisdictional coordination of freight planning decisions (see e.g. Cambridge Systematics et al., 2009 and Monios & Lambert, 2013). Some examples: (1) freight transport policy is less and less constrained to domestic transport, as more and more policies are influenced by international agreements; (2) as supply chains are becoming increasingly integrated, it becomes interesting to study their dynamics, as shocks may have lasting effects; (3) Information and Communications Technologies will create self-organizing freight systems, which, according to some, will inevitably drive us towards a system called the “Physical Internet” (Mervis, 2014). Perhaps it is these changes that will be most compelling for the freight modelling research agenda, to the point where *national* freight transport models will lose their relevance.

5. DATA

5.1 Data wish-list

The following data are needed for a standard (that is without additional logistics components) freight transport model, distinguishing between data for estimation and application (see de Jong and Ben-Akiva, 2007):

Data needed for estimation of a standard model

- Data on GDP, value added or employment by zone and border, language and cultural resistance between zones as explanatory factors in the trade model.
- A base year OD matrix in tonnes by mode
- Time and distance between origins and destinations by mode from networks.
- Transport cost functions (transport cost, loading/unloading, order cost)

Data needed for application of a standard model

- Forecasts of the exogenous variables in the submodels for future years (in the form of scenarios) at the zonal level.

A model system that includes logistics choices (in this example: at the disaggregate level) requires more data:

Data needed for estimation of a model with logistics

- A base year PC matrix in tonnes
- Data on GDP, value added or employment by zone and border, language and cultural resistance between zones as explanatory factors in the trade model.
- Choice information for the logistics model (transport chains, modes per leg, transfer locations) at the individual shipment level.
- Time and distance between origins and destinations by mode from networks.
- Logistic cost functions (transport cost, loading/unloading, order cost, inventory cost, cost of goods in transit).
- Terminal locations for transhipment.

Data needed for application of a model with logistics

- Base year matrices at the OD level (by mode) for a pivot point procedure (recommended, but not necessary).
- Number of firms, turnover and/or employment by zone for disaggregation zone-to-zone PC flows to firm-to-firm flows
- Forecasts of the exogenous variables in the trade and logistics models for future years (in the form of scenarios) at the zonal level.

Difficulties between data requirements and data availability often arise with respect to the following items:

- Information on interregional trade flows.
- Shipment sizes.
- Transport and logistics cost functions (see section 4.1).
- the volumes of the goods (e.g. in m^3), which are needed to determine how many tonnes of a good can be transported by a vehicle of given capacity.
- A good link between sectors in national accounts data and commodities in transport data; and between old and new commodity classifications (e.g. the shift from the NST/R to the NST2007 commodity classification).
- Data that follow shipments all the way from the sender to the receiver (with information on all the modes and transhipments on the way).

Many of these require transfer of data from the private sector (or the customs office, tax office) or interviews with firms in freight transport (e.g. a commodity flow survey, see below). Getting such data is costly and it can also be commercially sensitive (though the sensitivity should decrease with the age of the data). There are also possibilities for simulating the behaviour of firms (e.g. assuming deterministic cost minimisation) and calibrating the model by comparing more aggregate outcomes of these simulations to available data.

Big data in transport, such as automatic traffic count data, RFID and GPS tracking data of shipments and vehicles, can provide some of the above information, especially on the choices actually made. Nevertheless, getting access to these data is not easy and existing big data in transport remains relatively poor with regards to measuring factors which influence these choices. This can be remedied by interviews (e.g. web-based) with firms or truck drivers that take the tracking data as starting point and ask for validation and background data (data fusion, see Cottrill et al., 2013). Again, for multi-stakeholder decision making situations, operational data is of primary importance, putting more pressure on accessing and reconciling different data sources.

5.2 Data use in practice

Whereas we would ideally wish to start from a complete base description of commodity flows as demanded by locations for consumption (including intermediate consumption) from locations of production, and then going on to consider the logistics of transport, in practice the trade and transport data that are traditionally available fall well short of this.

Customs data is a useful source (and unlike most sources, tends to a production-consumption definition) but is, of course, only available on a country-to-country basis. Usually the exact locations are not known in either the producing or the receiving country. However, a detailed breakdown by commodity is available, and figures are given by both weight and value. Some limited information on mode may also be available. Overall, this can act as a control on inter-country movements and also provide conversions between weight and value units.

A number of countries carry out surveys of lorries, which typically obtain data from a sample of movements (or lorries) on an origin-destination basis, with information on the loads carried (commodity, weight).[2] However, unless reasonable information about the land-use at both origin and destination is collected, it is not possible to convert the information directly to a production-consumption basis: typically it is not known, for example, whether the origin is a factory or an intermediate point (transhipment or warehouse).

For other modes (eg rail, air, maritime), surveys are not usually carried out, but depending on institutional arrangements, significant records may be kept, usually on a 100% basis. However, these are not normally made available to third parties – partly on grounds of commercial confidentiality, and even when they are, may require substantial effort in processing to a useful format.

Only a very small number of countries (e.g. US, Sweden) carry out “commodity flow” surveys, with the possibility of following individual shipments along their logistical “route”, and even here there are restrictions on how the “chains” are defined and how far they are followed. The Commodity Flow

[2] Abate and de Jong (2014) used micro-data from such a truck data base for Denmark to develop models of shipment size and truck size.

Survey (CFS) has been carried out in Sweden in 2001, 2004/2005 and 2009 (and there are plans for further rounds): a sample of Swedish production and wholesale companies is asked to record their shipments in a one to three week period. Information on both outgoing shipments (domestic and international) and incoming (international) shipments is collected, in terms of production and consumption location, industry, weight, value, commodity type and mode chain. The ongoing studies on mode and shipment size choice in both Sweden and Norway use the Swedish CFS (either 2004/2005 or 2009).

A more or less unique source is the French ECHO survey (2004), a sample of almost 3,000 French shippers who provided detailed information on their shipments in (up to three) last months. The researchers were able to reconstitute for almost 10,000 shipments the full transport chain (PC) by also interviewing 27,000 receivers, transport operators and logistic service providers, using the information provided on the parties involved in the transport of their shipments. The discrete choice models for mode and shipment size choice that are being developed for the European model Transtools3 use both CFS 2007 from Sweden and ECHO from France as database for estimation.

For the moment, therefore, data needs to be "fused" from a number of sources, using appropriate statistical techniques. While this is also the position with passenger data, freight data is both more complex and less available. However, as with passenger data, there are hopes that new "electronic" sources of data which track consignments can be increasingly used, after a suitable learning period.

6. SUMMARY AND CONCLUSIONS

Many national freight transport models have been developed, especially in Europe. In recent years some of these models have moved away from conventional four-stage transport models towards logistics models, that include more aspects of logistics decision-making as it takes place in individual firms (e.g. the use of logistics chains of several transport modes from producer to consumer, with a dependence on inventory planning). This has however led to increasing demands for input data for estimation and application of the models, whereas the data situation in freight transport already was far from ideal. Logistics models are ideally based on data that follow individual shipments all the way from the point of production to the point of consumption (including information on the transhipments and the logistics costs of all available choice alternatives). Moreover, we would also like to have information on reliability, the perceived probability of damage, flexibility and the use of ICT in transport. Some European countries have shipper surveys that contain a considerable part, but not all, of this information. Big (electronic) data on transport and vehicle flows can help to some degree, but to become really attractive for national freight transport modelling they have to be combined with surveys of truck drivers, carriers, senders and/or receiver (data fusion). There are however also possibilities to use simulated behaviour of agents in freight transport (e.g. cost minimising behaviour), the aggregate outcomes of which can be compared to available transport statistics by mode, from which one then can derive calibration constants to achieve a good match with the observed data.

While some countries have single issue models, most national freight transport models have a broad scope and relatively large degree of detail, so that they can be used for simulating the impact of many different developments in society, policy measures and infrastructure projects. National

models, however, still do not cater for “living lab” type, multi-stakeholder, operational level logistics analysis, which is needed for developing innovations in freight transport system through public-private collaboration. As innovation is more and more subject of national freight policies, new model types that do allow for such analysis, like agent based models (ABM), are emerging quickly. These new ABM are interesting tools to experiment with to understand linkages between disaggregate behaviour and aggregate (emergent) phenomena, as described above.

There is scope for both aggregate and disaggregate models, and certainly also for hybrid systems of aggregate and disaggregate modules, given the limited availability of disaggregate data in the public domain, computational complexity and the diversity of questions that need to be answered. Similarly (and for the same reasons) there is a place under the sun for both deterministic and stochastic models.

An important issue is confidence in models, both from private and public stakeholders. To increase confidence in the models, we recommend to go beyond statistical model estimation and calibration. Backcasting and sensitivity analysis are important quality management tools as well, though backcasting may be hindered by limited data availability in the past and changes in definitions, classifications and measurement methods over time. Face validity may be a more important criterion than statistical validity, in case of applications in “living lab” situations.

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