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A study on quantitative freight transport analysis models in Denmark and Sweden

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ABSTRACT

Purpose

The aim of this paper is to present a study on freight transport analysis models. The purpose is to identify different stakeholders' perceptions of existing models, e.g., strengths and weaknesses, and of their requirements and views on future models.

Design/methodology/approach

The study is based on a questionnaire and interviews with representatives of public authorities, consultancy companies, and universities in Sweden and Denmark.

Findings

The study shows that there is a need for freight analysis models for supporting the transport planning in public authorities, including impact assessment of actions and estimation of freight flows. The respondents work mainly with macro-level models, whose main strength is their large geographic scopes, which allow comparative studies on, e.g., the national level using one model. Weaknesses include poor quality, missing functionality, and inadequate user-friendliness. In order to achieve improved freight transport analysis, the respondents wish to include more detailed logistics aspects in their analyses, which could possibly be achieved by combining macro-level and agent-based models.

Research limitations/implications

The limitation of this study is that we only included Danish and Swedish respondents, who mainly work with macro-level models. Moreover, only one Danish person answered the questionnaire. However, the respondent group represent a wide knowledge on freight and passenger transport models, and the study concerns to a large extent model types, not only particular models. Therefore, we argue that our findings have a wider geographic applicability.

Practical implications

The outcome of our study might be used by researchers and public authorities in order to, e.g., guide the decision-making on future model development: the views of the model users and clients are important to consider in order to assure that the development and research efforts lead to fulfilling their needs.

Original/value

The presented work provides insight into the needs and attitudes of model users and clients involved in freight transport analysis. This knowledge is important, e.g., for researchers involved in model development. According to the best of our knowledge, there is no previous study like the one presented.

Keywords: Freight transport analysis, Macro-level model, Agent-based model, Needs analysis, Model requirements.

1. INTRODUCTION

Freight transport analysis models are often used to support the planning and decision-making in public authorities that operate on regional, national, and international levels. The models are used, e.g., to predict how various transport policy and infrastructural measures (or actions) are expected to influence how transport activities are chosen and executed, and to estimate current and future transport and freight flows. In order to highlight the desired and undesired environmental, economic, social, and logistics effects already in the analysis of possible actions, it is crucial that the models produce accurate and reliable results.

The predominant model type for supporting the decision-making in public authorities is the sequential and aggregate (macro-level) four-step approach (see, e.g., de Jong *et al.*, 2004), which include one or more of the following steps: trip generation, trip distribution, modal split, and traffic assignment. In addition, they adopt the so-called ADA (Aggregate-Disaggregate-Aggregate) approach: they start with aggregate data, which is disaggregated, in order to enable to generate detailed estimations of logistics choices (e.g., of vehicle types and consignment sizes), which are aggregated for further processing. Examples of four-step models are Samgods (Swahn, 2001; de Jong *et al.*, 2010) and TRANS-TOOLS (Rich *et al.*, 2009). Recently, also a number of agents-based freight transport analysis models have been developed, e.g., INTERLOG (Liedtke, 2009) and TAPAS (Holmgren *et al.*, 2012). There also exist several agent-based modelling frameworks that can be used to build agent-based analysis models (e.g., Chatfield *et al.*, 2007; Roorda *et al.*, 2010). Agent-based models belong to the class of micro-level models, where individual entities are represented and the relations between them are studied over time. In agent-based models, one or more of the entities, often decision-makers, are modelled as agents; an agent can be described as a system that is situated in some environment and that is capable of autonomous action in that environment in order to meet its design objectives (Wooldridge and Jennings, 1995). In particular, agent-based models enable to model the decision-making in freight transport, hence capturing causality. For overviews of existing freight transport analysis models, the reader is referred to (de Jong *et al.*, 2004; Tavasszy, 2006; Hensher and Figliozzi, 2007; Liedtke, 2009; Chow *et al.*, 2010; Holmgren *et al.*, 2012).

The on-going advances in computing, including improved methods for collecting and processing data, and faster (often multi-core) computers, enables using freight transport analysis models that take more detailed aspects into account than is possible using the macro-level models that is traditionally used for freight transport analysis. Examples of more detailed models are the agent-based models mentioned above. The trend of using more detailed models has been observed in other domains, e.g., the related domain of passenger transport modelling, where several micro-level (and agent-based) models are already in

extensive use. Examples are VISSIM¹, which is a commercial micro-level model used for detailed traffic analysis, and the agent-based transport simulation framework MATSim (see, e.g., Balmer *et al.*, 2006). Moreover, researchers have argued that the macro-level models currently in use are unable to fulfil the needs for freight transport analysis in public authorities, e.g., since they are not capable of capturing the logistics complexity in freight transport (Hensher and Figliozzi, 2007). This is another reason for considering models that are able to capture the more detailed aspects of freight transport.

Based on the above discussion, we claim that there is a need to reconsider some of the freight transport modelling that occurs in public authorities. When planning for future development of freight transport analysis models, regardless whether it concerns further development of existing models or developing new models, it is, however, important to take into account the needs for freight transport analysis, the strengths and weaknesses of already existing models, and the main stakeholders' (i.e., model users and clients) requirements on models.

The literature contains several studies focusing on the needs for freight transport analysis. For example, de Jong *et al.* (2004) present a freight transport analysis model review, focusing on the different options for each of the steps in the four-step approach. They also provide directions for future model development; in particular, they suggest developing an integrated set of models, including an easy-to-use low-resolution model and a detailed high-resolution analysis model. Ramstedt (2008) identify a number of model characteristics that are argued to be necessary for the ability to conduct different types of freight transport analyses. Using a model analysis framework, she discusses how different model types are able to capture the identified model characteristics. Chow *et al.* (2010) contribute an analysis on existing freight transport analysis models and future needs for data and model development. A number of basic model components are identified, and mapped both to a set of basic model types and to the identified analysis needs. They suggest developing detailed logistics models and hybrid models, where the latter represents more than one model type.

The studies discussed above provide important knowledge on the needs for freight transport analysis and how different model types are able to fulfil the needs. However, we argue that there is a need for a study focusing on the main stakeholders' views on existing and future freight transport analysis models, and the purpose of this article is to present a study that systematically collects the model users' and clients' needs for freight transport analysis, and their attitudes towards existing models and future development. According to the best of our knowledge, there exists no previous study like the one we present.

The outcome of our study is intended to be used as guidance for practitioners and researchers involved in the development of freight transport analysis models, and for the authorities with responsibility over regional, national, and international (freight) transport analysis models, regarding how to, e.g., direct future research and development efforts. In particular, the generated knowledge is important to take into account in order to obtain an acceptance (of the clients and model users) for new model approaches.

The article is organised in the following way. In section 2 we present the methodology used to conduct our study. In Section 3, we elaborate on the respondents, and present the outcome of the study. In Section 4, we briefly discuss the limitations and present a discussion on the validity of our study, and the article is concluded in Section 5.

¹ <http://vision-traffic.ptvgroup.com/en-uk/products/ptv-vissim/>

2. RESEARCH METHODOLOGY

We conducted our study on freight transport analysis models using a research methodology consisting of five sequential activities:

1. Design of questionnaire;
2. Initial analysis of questionnaire;
3. Follow-up;
4. Analysis;
5. Respondent feedback.

These steps are described in detail below; however, it is important to emphasize here that an important part of our analysis was to compile and summarize, in different ways, the answers of the questionnaire. For example, we summarized the answers for each of the questions in order to identify general trends among the respondents, and for each of the respondents, we studied the connections between different answers in order to identify reasons for attitudes and opinions.

2.1. Design of questionnaire

We identified two groups of professionals (or roles) that are directly or indirectly involved in different types of quantitative freight transport analyses: *model users* (work directly with the models) and *clients* (order freight transport analyses). We identified representatives of national and regional authorities, consultancy companies, and universities in Sweden and Denmark, who we asked to participate in our study. We chose to contact persons who, according to our judgement, have deep knowledge and experience either as model users or as clients. Model users are sometimes, but not always directly involved in the work with freight transport analyses, and they typically have deep model knowledge, which we considered important to capture in our study. In order to make sure that deep model knowledge was represented in the study, we asked persons who currently work with, or previously have worked with, development of freight transport analysis models, to participate. It should be emphasised that the process of using models often is an important part of the development of a model, e.g., for validation and calibration purposes. Hence, we consider model developers as users.

We formulated eight questions for model users (M1-M8) and seven questions for clients (C1-C7). The questions were formulated in order to fulfil the goals of the analysis, which are stated in Section 2.4. The respondents were asked to provide their names and organisational belongings, describe their roles in their respective organisation, and report whether they are model users, clients, or both model users and clients. The model users were asked to answer questions M1-M8, the clients were asked to answer questions C1-C7, and the respondents who considers themselves to be both model users and clients were asked to answer all of the questions. Moreover, all of the respondents were asked to suggest additional persons who might be relevant to include in the study.

The final version of the questionnaire is presented in the Appendix.

2.2. Initial analysis of questionnaire results

Before analysing the questionnaire answers, we carefully reviewed all of the received answers in order to:

- Exclude from the group of possible respondents those respondents who obviously do not belong to any of our two groups (i.e., model users and clients);

- Identify unclarities and interesting directions for further discussion, from which we defined a number of follow-up questions (see Section 2.3).

2.3. Follow-up interviews

We contacted several of the respondents over telephone, where we asked them to answer our follow-up questions (different questions for different respondents). The interviews were directed by the prepared questions; however, the interviewees were encouraged to freely express their thoughts, ideas, and opinions about freight transport analysis.

2.4. Analysis

We based our result analysis on the answers of the questionnaire combined with the complementing information that we gathered in the follow-up interviews.

The goals of the analysis were to:

1. Identify the needs for quantitative freight transport analysis;
2. Identify which freight transport analysis models are currently in use;
3. Identify strengths and weaknesses of the models in use, and requirements on existing and future models;
4. Identify possible directions for future development.

In the analysis, we considered these goals sequentially in four steps. In order to suggest possible ways forwards, we used (in step 4) the results of steps 1-3, the respondents' views on what a freight transport analysis model should be able to do, their suggestions for future development, and our own domain expertise. The four analysis steps were connected to the questionnaire as described in Table 2.1.

Table 2.1 Connection between analysis steps and questions

Step	Questions
1. Identify the needs for freight transport analysis	C1, C2, M1
2. Identify which models are currently in use	C3, M2 - M4
3. Identify strengths, weaknesses, and requirements	C3 - C6, M5 - M7
4. Identify possible directions for future development	C7, M8

2.5. Respondent feedback

We compiled the result of the analysis into a short report, which we sent to all of the respondents. In that way, they were given the possibility to once more complement their answers, as well as to identify incorrect interpretations of their answers. We adjusted the analysis based on the received suggestions for changes and clarifications.

3. SUMMARY OF THE STUDY

In this section, we describe the output of our study. We first elaborate on the respondents, and then we present the final analysis result, which takes into account the received feedback from the respondents (see Section 2.5).

3.1. Respondents

As mentioned above, we sent the questionnaire to representatives of national and regional authorities, consultancy companies, and universities in Sweden and Denmark, which we believed represent deep knowledge and experience as freight transport analysis model users and clients of analyses.

We contacted 23 persons, of which eleven chose to participate in the study, giving an answering frequency of 48 per cent. Of the twelve persons who did not participate, eight responded that they consider themselves to not belong to any of the two target groups, which gives an actual answering frequency of 74 per cent. From the eleven responses, we chose to remove one response from the study, since it was obvious from the questionnaire answer that the person's area of work is not within the scope of our study. From the remaining ten respondents (nine Swedish and one Danish), there were seven model users and six clients; three persons consider themselves to be both model users and clients. Based on the questionnaire answers, we contacted eight persons via telephone for follow-up questions. The summary of the analysis result was sent to the ten remaining respondents for feedback, and five of these provided suggestions for changes and clarifications.

3.2. Outcome of the study

3.2.1. Needs for analysis

In questions C1 and M1, the respondents were asked to list the types of freight transport analyses that they conduct (model users) and orders (clients). In the questionnaire answers, two main types of analysis needs appeared: action analysis and transport surveying. The answers indicate that the model users and clients agree on which analysis needs exist. We consider this to be rather expected, since the model users conduct those analyses that are ordered by the clients.

Examples of questionnaire answers (for C1 and M1) that covers the identified analysis needs are: impacts of policy changes, analysis of infrastructural projects, pricing, investigations, transport surveying in order to generate input for analyses and flow maps, and investigation of fees. In addition, the respondents provided some examples that do not directly connect to the identified analysis needs, i.e., analysing the willingness to pay, and theoretical and scientific model analyses. However, our opinion is that the two identified analysis needs, i.e., action analysis and transport surveying, accurately summarize the respondents' answers.

The purpose of *action analysis* is to analyse the effects of specific changes of, e.g., taxes and fees, and infrastructure investments. In order to enable the study of actions, it is necessary to be able to also estimate current and future transport flows, which is an important part of *transport surveying*. Transport surveys are based on, e.g., estimates of economic growth and already planned actions, which may impact the transport system. In that way, forecast work is typically an important part of transport surveying, and in the questionnaire, it was explicitly mentioned that models are used to generate forecasts of transport flows.

The purpose of question C2 was to encourage the clients to further elaborate on their answers in question C1, by providing examples of questions that are studied using those model analyses they ask for. We did not ask any equivalent question to the model users, since we believe that the clients in general use the model analyses in a wider context than the model users do, and that the model users' views on how the model analyses are used in a wider context would therefore not give any additional knowledge. The answers to C2 did not give much more knowledge than was already known from C1 and M1; however, the answers confirmed and exemplified the answers in C1. Examples of specific questions are: Which freight flows are generated by the businesses in a region? Which transport corridors are most

important? Do the proposed actions pay off? Which transport modes are used? In addition, the clients mentioned that questions regarding capacity, environment, and long-term planning are of interest to study.

3.2.2. Models and ways of working

In question M2, the model users were asked to report which models they use when conducting freight transport model analyses. All of the model users mentioned that they work with different macro-level models, i.e., the Swedish Samgods model, the EU-level model TRANS-TOOLS, and the Danish-Swedish model GORM (Swedish Road Administration, 2008); some of the model users work with more than one of these models. The Swedish travel demand forecasting model Sampers (Beser and Algiers, 2001) was also mentioned since it is often used as a complement in analyses focusing on traffic. The mentioned models are in principal the models that are available within the geographic area where the respondents are active. The (two) model users that are connected to universities report that they also use other models. One of the respondents works with a county-level model currently under development, and the other one works with models developed within their own organisation.

The purpose of questions M3 and M4 was to identify the model users' views on why they use the models mentioned in question M1, and identify how they work with the models. We found that an important reason for choosing to work with a particular model is that it has a geographical scope that matches the studied questions. The majority of the respondents also answer that there is often no alternative to the models they work with. Most of them work with one model at the time, but sometimes it is relevant to use multiple models in order to answer a particular question. Often, the model results are analysed together with different types of statistics.

From the follow-up interviews, we learned that it differs on case basis who decides which models (or model) should be used in a particular study: sometimes the model user decides, or at least have influence over the choice, and sometimes the client decides. As mentioned above, the university representatives mentioned that they use other models than the other respondents, and we are not surprised that the university representatives are given a larger freedom concerning the choice of models since universities typically are characterized by a large degree of independence.

3.2.3. Strengths and weaknesses

We here elaborate on the respondents' views on the strengths and weaknesses of the models they are using. The strengths and weaknesses discussed in the questionnaire concern the macro-level models Samgods, TRANS-TOOLS, and GORM. Even though some of the respondents mention that they also work with other models, they focused on the abovementioned models when discussing strengths and weaknesses. It should be mentioned that this section mainly concerns the Samgods model, since this is the model that most of the respondents discuss. Our discussion on TRANS-TOOLS and GORM is rather brief.

Question M5 concerns identifying the strengths of the discussed macro-level freight transport analysis models. A general strength, according to the model users, is that the models provide a fairly good view over all transport in their considered geographic regions, since they cover all of the three main modes of traffic, i.e., road, rail, and sea. Using the same model in the whole country, which was mentioned for Samgods, enables to conduct comparative analysis of actions. Important strengths that were mentioned (for Samgods) are that it has a "complete" transport network and data that covers the whole region of interest, and it includes infrastructure outside Sweden, advanced macro-logistics modelling, commodity types, and vehicle types. Another reported strength is that it operates on the strategic level. The

mentioned strengths for TRANS-TOOLS are that it includes both passenger traffic and freight transport, the whole of Europe is included, and its results visualization is good. The reported strength of GORM is that it is well calibrated.

Question C3 concerns the clients' requirements on models, and on the models' input and output data. Our interpretation of the questionnaire answers is that the most important model requirement is that the quality of the generated results should be high. In addition, it is important with an appropriate geographic scale, as well as logistics modelling. Requirements on the input data are that they should be accurate (i.e., credible) and the resolution should be on an appropriate level. Regarding the output data, it is important that the results are presented in a pedagogical way (easy to understand, graphically, easy to survey, standardised, and comparable over the whole region), and that it should be possible to validate the results, as much as possible, using existing statistics.

Question C5, M6, and M7 covers the weaknesses of the current freight transport analysis models and of their input and output data, and what is missing in the models. From the questionnaire answers, we identified five main areas of weaknesses, which are discussed below.

Quality and credibility. For Samgods, the main weakness pointed out by the respondents is poor quality of the generated results, and hence the ability to trust the model. According to several of the respondents, the reason for the quality problems is that the model has not been sufficiently validated and calibrated. A consequence of this is that there exists no "official" model version for which the Swedish Transport Administration (the Swedish public authority with overall responsibility over traffic and transport models) takes responsibility. According to several of the Samgods users, this is considered to be a problem. It is also reported that the quality problems are consequences of how the model is constructed and on the quality of the input data. Examples of reported problems are that the distribution of freight flows to ports does not work satisfactory (the output does not match the available port statistics), and the assignment of freight to different vehicle types is also considered to be problematic. The consequences of these problems are unrealistic transport costs.

The main problems in the input data for Samgods are that it is considered to be old (from 2006) and that some of the data is based on contradicting statistics. The cost data, and in particular the railway costs, are reported to be problematic. For example, the railway costs are not specific for each of the links, which, according to the respondents means that the model generates incorrect costs for new railway capacity. One of the model users point out that it is difficult to estimate the quality of Samgods, since it is complex and large amounts of input data is used. Regarding GORM, a weakness is that the base year used in the model is old (from 2003). In addition, it is no longer updated and maintained, which means that there is little use for the model. This is a pity, since several of the respondents consider it to perform well in Denmark and the southernmost part of Sweden (i.e., Scania).

Aggregation level. Most of the respondents point out that the aggregation level in the current (macro-level) models is too high, and there is a general wish to include more detailed modelling of logistics choices in order to, e.g., enable to study the potentials for multimodal transport. Basically all of the respondents want to be able to conduct regional analyses, since there is currently a knowledge gap on this level. However, one of the respondents point out that it is probably difficult to include more detailed aspects in the models considering the current availability of input data.

Functionality. The respondents report that there is missing functionality in the models, e.g., the ability to model congestion and capacity limitations. This, together with the fact that timetables are not supported (which was also pointed out), mainly influences the results for shipping and railway transport. In addition, it is mentioned that there is a need for a feedback-

loop for demand. However, it is not obvious whether the respondents wish to include these functionalities in Samgods. Several of the respondents mean that it is more important to develop a well-functioning Samgods model that is validated and calibrated, than adding more functionality. One of the respondents claims that timetables should not be included, since the model type is not suitable for this. Functional deficiencies mentioned for TRANS-TOOLS are: to simple modelling of logistics, no shipping assignment, and that only one train type is included. In GORM, wagonloads and shipping assignment is not included, and there is no railway capacity modelling, which might cause problems on some links, e.g., the Öresund Bridge between Denmark and Sweden.

Model delimitations. All types of transport are not included in Samgods, e.g., distribution transport and some market segments, such as transport of building material. For TRANS-TOOLS, it is mentioned that the zones in the Nordic countries are too large.

User-friendliness. Most of the model users indicate that the models, in particular Samgods, are difficult to use: its high complexity complicates the analysis and results validation, and its documentation is unclear. In addition, its revision management is unclear, which makes it difficult to repeat model runs with identical results. The model users also request more output data in order to enable to conduct interesting analyses. For example, there is a wish to being able to follow, in the output data, the different steps of the model on its way to the final results, i.e., that the model results are transparent and possible to explain. Several model users mentioned that they want to use a less complex model, which have, e.g., fewer commodity types, vehicle types and road links. For GORM, it is mentioned that it has an instable IT system.

Concerning question C6, i.e., how useful the generated model analyses are, one of the clients claims to be not comfortable with the generated model analyses, since the quality of the input and output data is difficult to understand. Other respondents said that on a general level, the model analyses give indications that are considered to be “ok”. However, in more specific studies, e.g., of railway transport in particular regions, the model output is difficult to use. Still, one of the respondents said that even though there are major uncertainties, it is better to use the models that exist today, than to not use them at all.

3.2.4. Possible ways forward

We here present a number of possible directions for future research and development, which might lead to improved freight transport analysis. When analysing the answers for question C7 and M8 (if there was a perfect analysis model, which freight transport analyses would you like to order/perform?), we found that the respondents essentially wish to conduct the same types of analyses as the do today; however, they want better quality. There is also a wish to conduct more detailed analyses, to conduct socioeconomic analyses, to study those types of investments abroad that may have national consequences, investments in terminals and marshalling yards, as well as railway capacity restrictions. There is a wish among the respondents to use a more detailed aggregation level; at the same time they want to be able to study large geographic regions. However, it is important here to emphasise that it is not necessarily possible to achieve both of these wishes by further developing the existing models: several of the respondents mean that Samgods already today is too complex. The model users pointed out that it is important to achieve higher user-friendliness and improved support for output data analysis, e.g., analysis on link level. The respondents also request to be able to connect the Samgods model to a passenger traffic model, and that it should be able to operate on both the macro-level and the micro-level. Several of the model users suggested that a possibility to achieve improved analysis is to combine models that operate on different levels of aggregation. This is also considered by us to be a possible way to capture the

detailed aspects of freight transport, at the same time as studying transport in large geographic areas.

The respondents expressed a wish to include additional functionality in the macro-level models they discussed; however, it is important to mention that this is perhaps not possible, or even desired in the foreseeable future. Regarding Samgods, several of the respondents expressed that it is important to finalise the model before adding more functionality. Some reasons that the macro-level models do not generate credible results, according to the respondents, is that macro-level models are not able to simulate transport over time, and the cost structures in the models do not reflect the actual costs. Models that simulate over time, e.g., agent-based models, are able to model the detailed aspects of time that are required in order to include, e.g., timetables.

Regional analyses and models for studying questions of regional interest are requested by most of the respondents, and it should be mentioned that there is an explicit goal within the Swedish Transport Administration to develop regional freight transport analysis models. Since there exists no regional freight transport analysis models in the focus area of this study, we mean that a possible direction for future research and development is to build such models. One of the respondents claimed that the technology used in GORM (i.e., pivot-point) could be relevant for the development of regional models.

As discussed above, the clients and model users are often limited regarding what types of analyses should be ordered and how the analyses should be conducted. Therefore, it is typically difficult for them to investigate the possibility to use other types of models than the ones traditionally used for freight transport analysis. In order to achieve long term improved freight transport analysis, we believe that it is important to also develop and use alternative model types, which may concern using a completely different type of model for certain types of studies, or to combine models. Our belief that improved freight transport analysis can be achieved using alternative modelling approaches is strengthened by the fact that the two university respondents reported their interest in alternative types of freight transport analysis models.

In the rest of this section, we briefly discuss six areas where our study indicates a need for future development in order to achieve long term improved freight transport analysis.

Further development. There is a need to finalise and further develop the existing macro-level freight transport analysis models, e.g., Samgods.

More detailed models. We suggest investigating the possibility to develop models that are able to include the more detailed aspects of freight transport, in order to enable studies that cannot be conducted using the traditional macro-level models. Agent-based modelling is a possible direction for future development; however, it should be mentioned that it is possible to include more detailed modelling also in ADA (aggregate-disaggregate-aggregate) models, by further developing the disaggregation logic. However, we believe it is difficult to use the current ADA-model type in order to include the important time-related effects. When developing and using more detailed models, it is important to carefully consider the calibration and results validation.

Regional models. Our study suggests that there is a need to investigate the possibility to develop regional models, which can be used to study regional freight flows and questions of regional interest regarding, e.g., city logistics in metropolitan regions. Since there is a need for analyses in smaller regions, we believe that agent-based models might be useful, which was also pointed out by some of the respondents. In addition, it might be suitable to use simpler models to study regional questions.

Combining detailed and aggregated model types. We believe that it is important to investigate how it is suitable and possible to combine models of different type, in order to benefit from their respective strengths. For example, combining macro-level and agent-based models would enable to both capture the detailed aspects of, e.g., logistics choices and time, and study large-scale transport systems. Combining macro-level and agent-based models were mentioned by several of the respondents as a possible way forward.

User friendliness. It is important to work with the user-friendliness of freight transport analysis models, e.g., by developing more pedagogical tools for results visualisation (see, e.g., Hajinasab *et al.*, 2013). The need to develop methods for increased user-friendliness concerns the current macro-level model, as well as the more detailed freight transport analysis models. We believe that, for micro-level models, the use of interactive tools for building and administrating scenarios would be very useful.

Input data. For both macro-level and agent-based freight transport analysis models, it is important to improve the input data. This requires development of methods for collecting and processing large amounts of data, and for using the data in existing and future models. It is important to emphasise, that in order to utilise on the opportunities provided by the detailed models, there is a need for more detailed, high quality input data. An initial step would be to make available, for model users and developers, all of the detailed data that already is being collected by various public authorities. An example of such data is the commodity flow surveys, which are conducted on a regular bases in, e.g., Sweden, and which provides micro-level data about shipments of companies (see, e.g., Trafikanalys, 2010).

4. LIMITATIONS AND VALIDITY ASSESSMENT

The limitation of our study is that we only involved Danish (one) and Swedish (nine) respondents. Hence, the focus was on the freight transport analysis models used in Denmark and Sweden (mainly Samgods, TRANS-TOOLS, and GORM), and the respondents' views on, e.g., strengths, weaknesses, and suggestions for future development mainly concern these models. However, as our results to a large extent are connected to model types, and that some of the suggested directions for future development concerns model development in general, we argue that the outcome of our study has a wider area of applicability than for the discussed models, and might be of interest also for other countries than Denmark and Sweden. It should be noted that the respondents represent experience in different types of models and model analyses for freight transport and passenger transport.

There is a risk that the set-up of the questionnaire might have introduced bias in our study since the formulation of the questions might have influenced the answers of the respondents. In order to reduce this bias, one person not involved in conducting the study reviewed a preliminary version of the questionnaire. Based on the received feedback, we updated the questionnaire. For some of the questions, we provided a supporting text, in the form of examples, in order to further explain the questions. The use of such supporting texts could lead to limiting the respondents' answers to the provided examples. However, as we received other answers than the supporting texts, we believe that they did not have any significant negative effects on our study. The context of the study was known by some of the respondents, and it cannot be excluded that their answers were biased by this knowledge. Similarly, most of the respondents were familiar with the background of the persons conducting the study, which is in agent-based freight transport modelling, and it is possible that this might have influenced those answers that points towards combining models and developing agent-based models. However, as one of the university-connected respondents are already involved in agent-based modelling, and since we also received answers pointing in

other directions, we believe that the study was not biased by the respondents' knowledge about the context of the study and of the background of the researchers conducting the study.

The researchers' interpretation of the received answers is another source of bias, and to reduce this risk, we made sure that more than one person was involved in each of the steps of the study (see Section 2). In addition, we involved the respondents as reviewers of the analysis output, as described in Section 2.5. This was an important step in order to reduce the risk for misinterpretations.

5. CONCLUDING REMARKS

We have presented a questionnaire- and interview-based study on freight transport analysis models, focusing on models used in Denmark and Sweden. The purpose was to identify different stakeholders' perceptions of existing freight transport analysis models, e.g., strengths and weaknesses, and on their requirements and views on future models. The study shows that there is a large need for computerized analysis models to support the transport planning in public authorities, e.g., for impact assessment of actions and estimation of current and future freight flows. The involved respondents reported that they work mainly with macro-level models, and an important strength of these models is their large geographic scopes, which allow performing comparative studies on, e.g., the national level using one model. Weaknesses are problems with the quality of results (leading to low model credibility), missing functionality (e.g., timetables), too coarse-grained results, and inadequate user-friendliness. The respondents report that it is important to finalise the already existing models, and they wish to model more detailed logistics aspects.

In the introduction of this article, we introduced the two main model types for freight transport analysis: macro-level and agent-based models. Models of these types typically have complementing advantages and disadvantages: macro-level models enable to study large geographic regions in low level of detail, whereas agent-based models enable to study entities in high level of detail, but typically only in smaller regions due to their large needs for micro-level input data and processing power.

From the analysis of our study it appeared that there is a wish to obtain the strengths of both macro-level and agent-based models in freight transport analyses, and several of the respondents mentioned that it might be relevant to combine the two types of models. Based on the outcome of our study, and that macro-level and agent-based models have complementing characteristics, we conclude that the combined use of macro-level and agent-based models may lead to improved freight transport analysis. This is also supported by the findings of de Jong *et al.* (2004) and Chow *et al.* (2010), who suggest integrating models and developing hybrid models, respectively. Combining macro-level and agent-based models for improved freight transport analysis is also discussed by Cambridge Systems, Inc. (2011) and Holmgren *et al.* (2013), and combining the two types of models in public transport analysis is discussed by Burghout and Koutsopoulos (2009) and Sewall *et al.* (2011).

We have in related work identified three approaches for combining macro-level and agent-based modelling, which might enable improved freight transport analysis (Holmgren *et al.*, 2014):

- Exchanging data between models;
- Conducting supplementary sub-studies;
- Integrating macro-level and agent-based modelling.

Exchanging data between models concerns running models of different type in sequence, and using the output generated by one model as input for one or more other models. It should be

noted that this is how the traditional four-step models operate. This approach could be used, e.g., when necessary data is missing or cannot be used due to poor quality. *Conducting supplementary sub-studies* concerns using different models in a study and combining the results in the analysis: this approach might be relevant to use when all of the aspects that need to be considered in a study cannot be analysed using one model. *Integrating macro-level and agent-based modelling* concerns incorporating features from both of the paradigms within one model.

The work presented in this article supports the relevance of the suggested approaches for combining macro-level and agent-based modelling, and future work includes analysing them in order to identify how they can be used to support the decision-making in public authorities.

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APPENDIX – SPECIFICATION OF QUESTIONNAIRE²

Questionnaire title

Questionnaire on needs and models for freight transport analysis

Initial description

The purposes of this study are to investigate how model users and clients of freight transport analyses experience how the freight transport analysis models currently in use perform, and to identify functional and non-functional requirements of freight transport models. The study is conducted within a research, development, and demonstration project, financed by the Swedish Transport Administration. Based on the results of, e.g., the answers of this questionnaire, we will compile a description of the identified needs for freight transport analysis, how existing models manage to fulfil these analysis needs, and give suggestions on future development within the domain. You will be given the opportunity to provide feedback on our description and analysis, and if necessary further explain your answers.

Initial questions

- Name?
- Organization?

General questions

- G1. Give a short description of your role, related to freight transport analysis, in the organisation you represent:
Supporting text: For example, development of models, making model runs, processing and analysing model output data, and making decisions and planning based on model analyses.
- G2. Specify whether you are a model user and/or a client of freight transport analyses.
 - Model user
 - Client
 - Model user and client

Questions to model users

- M1. Which types of freight transport analysis are you and your colleagues conducting?
Supporting text: For example, analyses within the action planning of the Swedish Transport Administration, surveying of regional flows, and forecasts of transport flows.
- M2. Which models are you using for conducting the freight transport analyses identified in the previous question?
- M3. Why are you using the models you work with?
- M4. Describe how you work, in your organisation, with freight transport analysis models.
- M5. What are the strengths of the models you work with?
Supporting text: Regarding, e.g., functionality, quality, and performance.
- M6a. Describe the shortcomings of the models you work with.
- M6b. Describe the shortcomings of the input data you are using.
- M6c. Describe the shortcomings of the output data that is generated.
- M7. What is missing in the analysis models you are using?

² Note that this is a translation from Swedish to English of the questionnaire that was used in our study.

Supporting text: Regarding, e.g., functionality, quality, the level of detail of the output, and performance.

- M8. If there was a perfect analysis model, which freight transport analyses would you like to perform with such a model? What functionality, which is missing in the current models, would be included in such a model?

Questions to clients

- C1. What types of analyses are you and your colleagues usually asking for?
Supporting text: For example, transport surveys, action analyses, and forecasts of future transport.
- C2. What types of questions do you want to answer using the analyses you ask for?
Supporting text: For example, how transport flows are distributed between different traffic modes, which transport corridors are used for freight transport given different conditions, and what is the environmental impact of an action.
- C3a. What are your requirements on the models that are used for freight transport analysis?
- C3b. What are your requirements on the input data used?
- C3c. What are your requirements on the generated output data?
- C4. What are you satisfied with concerning the freight transport analyses that the models currently in use are able to produce?
Supporting text: Regarding, e.g., the results and their level of detail, quality, and how easy it is to use the results.
- C5. What are you not satisfied with concerning the freight transport analyses that the models currently in use are able to produce.
Supporting text: Regarding, e.g., results, quality, and how easy it is to use the results.
- C6. How useful are freight transport analyses in your planning work? Do you feel comfortable to use the model analyses?
- C7. If there was a perfect analysis model, which freight transport analyses would you like to order?

Final question

- Do you have any suggestions for model users or clients to which we should send this questionnaire?