Combining macro-level and agent-based modeling for improved freight transport analysis

Johan Holmgren[1], Linda Ramstedt[2], Paul Davidsson[3], Henrik Edwards[2], Jan A. Persson[3]

[1] *School of Computing, Blekinge Institute of Technology, Karlshamn, Sweden*
[2] *Vectura, Solna, Sweden*
[3] *School of Technology, Malmö University, Malmö, Sweden*

Background and motivation

Most existing freight transport analysis models for supporting the decision-making in public authorities are built either as macro-level models or as agent-based models. Whereas macro-level models are the dominating model type for practitioners, agent-based models are getting increasing attention from the researchers. Agent-based models belong to the class of micro-level models, that is, models in which individual entities such as decision-makers are represented and in which the interaction between entities typically is studied over time. Macro-level and agent-based models have complementing characteristics; in particular, 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 in smaller geographic regions.

Due to the respective advantages and disadvantages of the two model types, we hypothesize that improved impact assessment of transport policy and infrastructural measures can be achieved through combined use of macro-level and agent-based modeling. In addition, development of new models typically requires considerable effort, and so it may, in many cases, be more time-efficient to combine existing models in a study rather than developing new models. Our focus is on how to combine macro-level and agent-based freight transport analysis models, even though it is possible to combine models of any type. Important reasons are that these model types in most cases represent the two extremes regarding the aggregation level used. In addition, agent-based models enable modeling of behavioral aspects (by modeling decision-makers) and causality in freight transport systems. These dimensions are difficult to capture in macro-level models, since such models are based on emulating rather than simulating freight transport in some geographic region. Even though there are several possible advantages of combining agent-based and macro-level modeling, it has so far been very uncommon to combine them in order to enable improved freight transport analysis.

There are several possibilities for how to combine macro-level and agent-based modeling. We suggest and discuss three approaches for combining them: exchanging data between models, conducting supplementary sub-studies, and integrating macro-level and agent-based modeling.

Suggested solutions

We suggest three approaches for how to combine macro-level and agent-based models.

Exchanging data between models. This approach involves using one model to generate input data for other models. Models are run in sequence, and output generated by one model is used as input for one or more other models, for example, if real data is missing or has low quality. Examples of input that can be generated with an agent-based model and then used in a macro-level model include elasticities, consignment sizes, and vehicle load utilization.

Conducting supplementary sub-studies. This approach involves using different models in a study and combining the results during the analysis phase. An important purpose for using this approach is that there is a need to use more than one model type, to be able to consider all aspects that need to be analyzed in a study. For instance, logistical choices can be studied with detailed modeling in an agent-based model, while general tendencies in the transport network can be studied with a macro-level model.

Integrating macro-level and agent-based modeling. This approach concerns developing models that contain features both from the macro-level modeling paradigm, and from the agent-based modeling paradigm. For instance, by using agent-based functionality in a macro-level model, it is possible to study more detailed and logistical aspects that otherwise would have been impossible.

The approaches *conducting supplementary sub-studies* and *integrating macro-level and agent-based modeling* were evaluated using two case studies; the East-West Transport Corridor (EWTC) and the Hallsberg-Mjölby (HM) studies. Each of which would have been difficult to conduct using only one type of modeling. The approach *exchanging data between models* was partially evaluated by discussing a freight transport analysis framework for the Chicago region, and by elaborating on how agent-based modeling may be incorporated in the four-step approach, which is based on the principles of running sub-models in sequence with exchange of data in between.

Summary of case studies

Case study 1. EastWest Transport Corridor (EWTC)

The EastWest Transport Corridor (EWTC) is a land-bridge for transport between China/Russia through the Southern Baltic Sea further towards the United Kingdom. In a simulation study, we have analyzed transports in the geographical area called the EWTC region. The purpose of the study was to estimate current and forecasted future transport volumes in the EWTC region, and to assess the possible impact of three transport policy and infrastructural measures, which may contribute to greener transport in the region.

In the study, the macro-level model TRANS-TOOLS was used to estimate the freight demand between a number of geographical zones in the EWTC region, and the agent-based model TAPAS-Z was used to estimate logistical choices. The output from the two models was analyzed in common in order to generate total transport flows differentiated on for instance transport mode and transport routes.

In the study, the approaches *conducting supplementary sub-studies* and *integrating macro-level and agent-based modeling* were used. TAPAS-Z is an agent-based model that integrates macro-level functionality. Separate studies with TRANS-TOOLS and TAPAS-Z were conducted in parallel, and the results from the two models were analyzed in common.

Case study 2. Railway capacity Hallsberg-Mjölby

Within a project referred to as “business economic consequences”, the Swedish Transport Administration recently decided to analyze a set of infrastructure investments for increasing the railway capacity between Hallsberg-Mjölby (Banverket, 2009; Trafikverket, 2011). Hallsberg-Mjölby is an important railway connection, especially for freight transport between southern and northern parts of Sweden. In a simulation-based study, referred to here as “the HM study”, we have analyzed the probable impact of an increased railway capacity between Hallsberg-Mjölby, by studying transport in the geographical region.

In the study, we used two versions of Samgods which have been developed in order to study railway capacity restrictions. The two versions were used to study total flows in the region with and without capacity restrictions in the railway network. The agent-based model TAPAS has been used study transports in detail in a specific relation in the region.

In this study, the suggested solution c*onducting supplementary sub-studies* was represented since the different models were used in parallel and in different ways contributed to analyze the benefits of increased railway capacity between Hallsberg and Mjölby.

Concluding remarks

The work presented in this abstract was conducted in a project called *Combination of macro-level and agent-based models for improved impact analysis on the transport system* financed by the Swedish Transport Administration. In the project we have identified three principles for how to combine macro-level and agent-based models, which mainly have been evaluated and applied in two case studies. Hence, we have shown that it is possible to combine macro-level and agent-based modeling in order to improve freight transport analysis.