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Long-distance and daily travel demand: integration of various travel markets and modelling approaches

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Abstract

Most travel demand models simplify the representation of trips from/to external zones. Despite the higher frequency of internal daily travel, long-distance travel cannot be neglected due to its high contribution to the travelled distance. In this paper we integrate two different models that represent those two travel segments. MITO is an agent-based model for travel demand implemented in the metropolitan area of Munich. DEMO is a macroscopic model that generates travel demand in Germany. DEMO is used to represent the external, long-distance travel from, to or through the MITO study area. DEMO demand is disaggregated and is jointly assigned with MITO trips using the transport model MATSim. The integration significantly improves the validation of the model against traffic counts and facilitates the simulation capabilities when the scenarios affect major roads.

Keywords: long-distance demand, agent-based model, model integration

1. Introduction

Most transport models provide incomplete demand, since trips from or to external zones are not included. If such external traffic is not discarded, there are different options to deal with it. One option is to extend the study area

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(adding a surrounding area to the core area) to include most of the relevant trips within the model. Alternatively, it is quite reasonable to count entering and exiting vehicles at cordon points at the boundaries of the study area. Extending the model study area is quite expensive in terms of runtime and adds large information that is not relevant. Counts or roadside interviews at cordon-points to generate external flows reveal very little background information about travellers, such as personal attributes, origin and destination or reasons of the trip. In this study, we propose to add the demand generated by a national macroscopic model to a regional agent-based one.

2. Literature review

Either with small or large study areas, the models have boundaries, for practical reasons. At microscopic models of small study areas (e.g. intersections) most (if not all) of traffic is external, since there is not any attraction or production of trips in the study area [1]. Researchers and practitioners often use traffic counts (manual or automated) to define origin/destination matrices. With this approach, the number of vehicles in the study area is predicted with high accuracy, although the users cannot be segmented by origin or trip purpose. On the contrary, at very large-scale models of Europe [2] or US [3] almost all the demand is internal. Between both extreme cases, most of transport models need to deal with the joint representation of internal and external travel demand.

The external travel demand includes a significant part of long-distance, non-recurrent and overnight trips, with travel patterns that differ from internal demand and that affect the amount of vehicle·km or passenger·km travelled [2,4,5]. However, most of travel demand data sources (and especially household travel surveys) do not represent long-distance demand with the same level of detail as local urban travel. For instance, the national household travel survey in Germany (Mobilität in Deutschland) [6] only informs about the number of overnight trips made in the last three months. The most recent US National Household Travel Survey in US (NHTS 2017) [7] does not include long-distance demand data. One exception to this lack of data is the Canadian survey for domestic travel [8].

The Ohio long-distance travel model or the Ontario passenger long-distance model [9,10] are examples that specifically forecast long-distance demand. Both long-distance models provide with the external travel demand (to/from outside of Ohio or Ontario, respectively) the corresponding Ohio and Ontario statewide models. The integration of different demand models involves a significant investment and high data processing costs [9,11,12]. The NCHRP Report 765 [11] warns about several issues during model integration, including the need of consistent network representations, consistency in input and outputs, the definition of points of connection between small and large scale models, etc.

There are not many examples for the integration of models of different scales in the literature, focused on the assessment of the benefits of adding external demand. This paper describes an offline integration of a national aggregated model and a regional agent-based model and discusses the benefits achieved with it.

3. Methodology

This section describes the two models that are integrated, and the process of integration.

3.1. DEMO model description

DEMO is an aggregated (macroscopic) national transport model for Germany, covering all types of traffic (passenger and freight). It has been developed to forecast transport scenarios under the influence of social trends, technological advances and policy measures. A more detailed presentation of the model can be found in [13]. DEMO consists of several modules, as shown in Figure 1. Two separate travel demand modules deal with short and long distance passenger traffic respectively. For commercial transport, travel demand is estimated separately for freight (goods) and service transport. These demand modules resemble traditional four-step models with trip generation, destination and mode choice. All resulting trip matrices are jointly assigned to the network model, which in turn provides the skim matrices required for the demand modules.

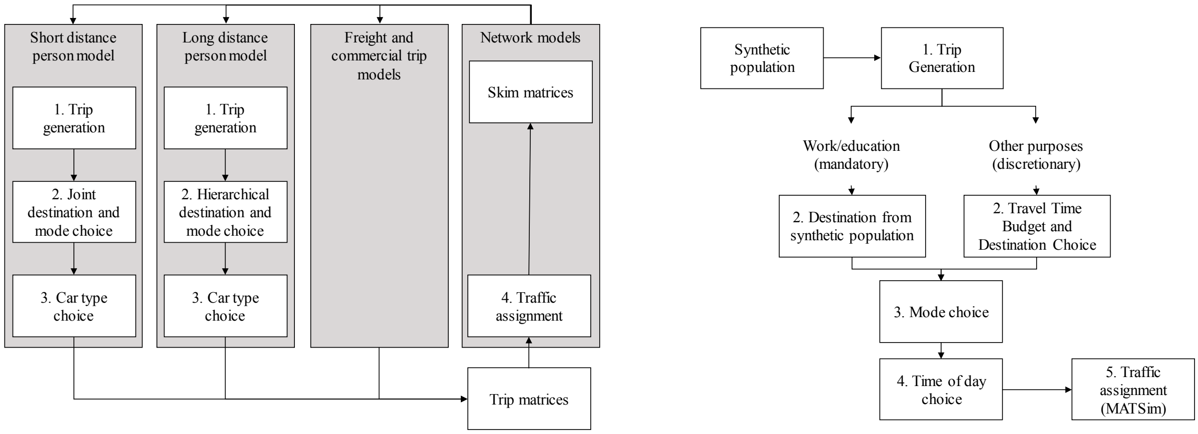


Figure 1. DEMO (left) and MITO (right) components

The long distance passenger and freight transport is estimated using 412 NUTS3-equivalent zones (Nomenclature of Territorial Units for Statistics) (Figure 2), short distance passenger transport is modelled on a zoning system consisting of ca. 6,500 zones. External zones are employed to model incoming, outgoing and through traffic, with the size of the zones increasing with the distance from Germany.

3.2. MITO model description

MITO generates the internal passenger travel demand at the metropolitan region of Munich (Figure 2b). It is a disaggregated (agent-based) trip-based model that simulates each household and person individually, as shown in Figure 1. After trip generation, the travel time budget in minutes is calculated for every household. This budget influences destination choice, i.e. people who spent a lot of time commuting are less likely to do much other travel, while people who telecommute might compensate by additional discretionary travel. Mode choice uses a nested logit model, and time-of-day choice in 1-minute interval. MITO ignores freight transport and commercial trips. The road traffic is assigned using MATSim [14].

3.3. Model integration

To integrate MITO and DEMO, the traffic flows generated by DEMO that cross the boundaries of the study area of MITO are added to the MITO travel demand and re-assigned jointly with it. The integration is implemented for private passenger trips by car, but adds DEMO freight transport and commercial trips. We propose an offline integration, where the models are not modified but run sequentially [11]. The boundaries of the study area of MITO are almost exactly overlapping with the DEMO zoning systems. The intersection results in 449 DEMO short and long distance zones (Figure 2). Cordon points are placed on the roads that cross the border of the MITO study area. All flows that do not pass by any of these 178 cordon points are either internal or external traffic, and are discarded since they either have already been generated by MITO or they do not affect the study area, respectively. MITO adds the DEMO traffic flows by reading the origin/destination matrices and disaggregating them into individual trips. According to this, we translate the aggregated data structure of DEMO (origin/destination) flows into agent-based trip data of MITO. MITO generates coordinates for the origin and the destination of the trips, depending on data about dwelling, schools and job locations (if trips start or end at home, school or work) or randomly within each MITO zone. Similarly, each one of the trips generated from DEMO origin/destination matrices is provided with origin or destination coordinates randomly distributed within the corresponding DEMO zone. After that, a departure time is assigned. DEMO origin/destination matrices are not provided with any time of day segmentation and contain all-day demand. We assumed departure time distributions from the US National Household Travel Survey [15] and randomly sample one value from these distributions to each individual trip.

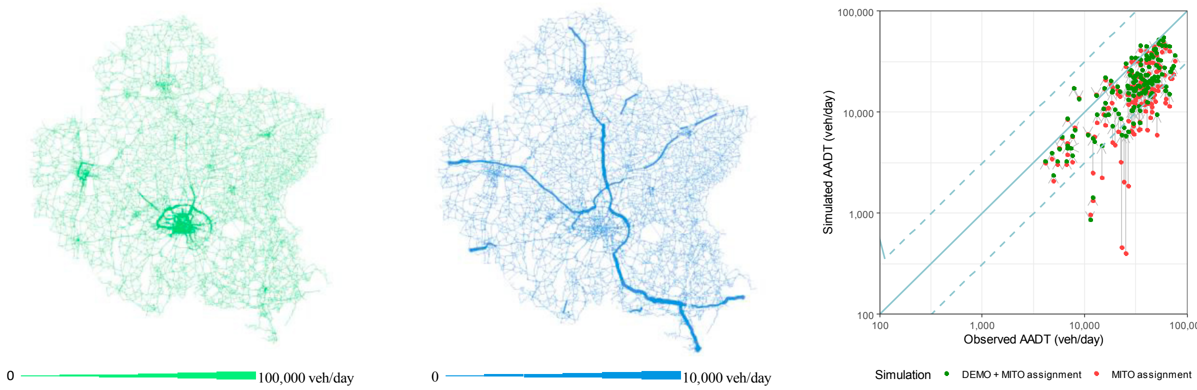
As a result, MITO models 8.7 million trips, 3.4 million of them made by car. DEMO adds around 179,000 trips, which corresponds to 5% of MITO car trips (The share of DEMO trips will be much higher on major roads, though, as seen later). Individual car trips generated by MITO and individual car trips generated from DEMO origin/destination matrices are jointly assigned to the road network using the MATSim transport model. Individual trips resulting from MITO and DEMO are scaled down using a sampling factor of 5%. MATSim link capacity is scaled down proportionally. The scaling process randomly selects and simulates 5% and it is required because of model runtime needs. We configured MATSim to run 50 iterations. The complete runtime of MITO, DEMO integration and MATSim joint assignment is 2 hours, using a Desktop PC with 64 GB RAM. Figure 3 shows the assignment results, divided by travel segment.

(a) DEMO long distance zones in Germany (blue) and MITO zones (green)

(b) subset of all DEMO zones matching MITO study area

(c) centroids on MITO study area boundaries

Figure 2. DEMO and MITO zoning systems



(a) internal MITO daily traffic

(b) external DEMO long-distance traffic

(c) Simulated vs. observed daily traffic volumes by model configuration

Figure 3. Joint traffic assignment results, segmented by travel market; and validation

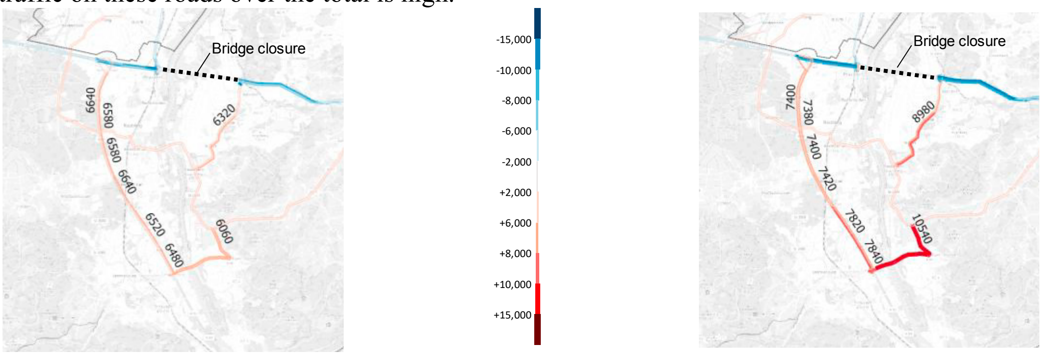
4. Results

4.1. Model validation

The integration of MITO and DEMO travel demand significantly improved the comparison between simulated and observed average traffic volumes, as seen in Figure 3c. Observed traffic volumes in 2011 were obtained from traffic counts [16]. In Figure 3c, each point is one link with a counting station. The gray arrows represent the change in the errors in veh/day between the MITO simulation and the integrated DEMO and MITO one.

4.2. Scenario analysis: Road closure

This scenario tests the effect of a motorway closure. The scenario is run before and after the integration of MITO and DEMO. The outcome of this scenario is the impact of the closed motorway on the rest of the network, measured by link volumes and travel times. Figure 4 compares the two model set ups: without and with external flows. The figure shows the increment of link counts due to diverged traffic volumes when a major motorway is closed. The differences of the increment of traffic flows on the most loaded links of the diverged routes are significant. These effects are relevant when analyzing scenarios that involve the modification of major roads, since the share of external traffic on these roads over the total is high.



(a) MITO (b) DEMO + MITO

Figure 4. Traffic volumes in the surroundings of the motorway closure. Differences with respect of base case (no closure) by model set up

5. Discussion

The model integration proposed in this paper has several limitations. Firstly, we do not characterize visitors by their socio-demographic characteristics, and they do not make additional trips at the destination. Secondly, we have not removed the residents that make long-distance trips outside of the study area. Thirdly, the integration discards the demand of modes other than road. This section proposes a framework to improve the integration (Figure 5).

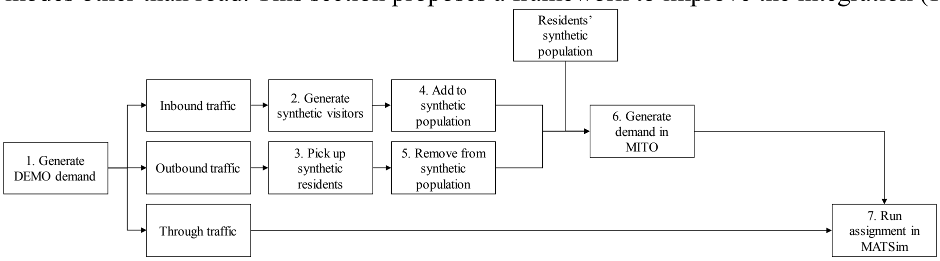


Figure 5. Framework for microscopic modeling of short- and long-distance travel demand

The following steps are proposed: (1) Multi modal study area border crossing demand is generated by DEMO. (2) For the amount of inbound trips in 1, we generate synthetic visitors that replicate border crossing travelers [17]. (3) The number of residents defined by DEMO number of outbound trips is picked up from the synthetic population of residents, for the simulated day. This selection is based on a random sampling, by weighting the individuals by their sociodemographic attributes, proportionally to their frequency in the synthetic visitors' dataset, defined in (2). (4) Synthetic visitors are added to the synthetic population of residents so they can be processed by MITO. (5) Selected synthetic residents in (3) are removed from the synthetic population since they do not travel the simulated day. The rest of the model components (6 and 7) run as usual. Specific trip generation, destination choice and mode choice parameters are required for visitors, as far as their behavior diverge from residents. The major challenge of this approach is, indeed, to generate the activities and trips of visitors at their destination (with limited data sources).

6. Conclusion

External travel demand is relevant for the validation of travel demand models, in order to better represent observed traffic counts at major roads. The addition of such flows is required to simulate scenarios involving the parts of the infrastructure that are used by both local- and non-local travelers, such as motorways. It helps with the validation of the models with traffic counts, too. An agent-based framework, such as MATSim, can be easily used to integrate the outputs of two different models with different scales (agent-based and aggregated), by jointly assigning the generated traffic flows.

Acknowledgements

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References

[1] Sultana MA, Tarko A, Romero M. Evaluating the Operational Footprint of Alternative Diamond Interchanges. J Transp Eng Part A Syst 2018;144:04018043. doi:10.1061/JTEPBS.0000166.

[2] Rich J, Mabbit SL. A long-distance travel demand model for Europe. Eur J Transp Infrastruct Res 2011;11:1–20.

[3] van Nostrand C, Sivaraman V, Pinjari AR. Analysis of long-distance vacation travel demand in the United States: A multiple discrete-continuous choice framework. Transportation (Amst) 2013;40:151–71. doi:10.1007/s11116-012-9397-6.

[4] Schiffer RG. Long-Distance and Rural Travel Transferable Parameters for Statewide Travel Forecasting Models. NCHRP Rep 735 2012. doi:10.17226/22661.

[5] Giamo GT, Schiffer RG. Statewide Travel Demand Modeling. A peer Exchange. Transp Res Circ 2005;E-C075:2–212.

[6] Deutschen Zentrums für Luft- und Raumfahrt (DLR). Mobilität in Deutschland 2017. http://www.mobilitaet-in-deutschland.de/ (accessed December 1, 2017).

[7] Federal Highway Administration. National Household Travel Survey 2017. https://nhts.ornl.gov/.

[8] Statistics Canada. Travel Survey for Residents in Canada 2014. http://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&Id=129083.

[9] Erhardt GD, Freedman J, Stryker A, Fujioka H, Anderson R. Ohio Long Distance Travel Model. Transp Res Rec J Transp Res Board 2007;2003:130–8. doi:10.3141/2003-16.

[10] Llorca C, Molloy J, Ji JY, Moeckel R. Estimation of a Long-Distance Travel Demand Model Using Trip Surveys, Location-Based Big Data, and Trip Planning Services. Transp Res Rec J Transp Res Board 2018;In Press.

[11] Horowitz A, Creasey T, Pendyala R, Chen M. Analytical Travel Forecasting Approaches for Project-Level Planning and Design - NCHRP Report 765. 2014. doi:10.17226/22366.

[12] Llorca C, Ji JY, Molloy J, Moeckel R. The usage of location based big data and trip planning services for the estimation of a long-distance travel demand model: predicting the impacts of a new high speed railway corridor. Res Transp Econ 2018;72:27–36.

[13] Winkler C, Mocanu T. Methodology and application of a German national passenger transport model for future transport scenarios. Eur. Transp. Conf., Barcelona: 2017.

[14] Horni A, Nagel K, Axhausen KW. The Multi-Agent Transport Simulation MATSim. London: Ubiquity Press; 2016. doi:http://dx.doi.org/10.5334/baw.

[15] Federal Highway Administration. National Household Travel Survey 2001. https://nhts.ornl.gov/.

[16] Bundesanstalt für Straßenwessen. Automatic traffic counts on motorways and Federal highways 2019. https://www.bast.de/BASt_2017/DE/Verkehrstechnik/Fachthemen/v2-verkehrszaehlung/zaehl_node.html.

[17] Llorca C, Moreno AT, Moeckel R. Synthetizing visitors for activity-based models. Transp. Res. Board Annu. Meet., Washington DC: 2019, p. 0–2.