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On the use of on-line services in transport simulation

Banafsheh Hajinasab[a*], Paul Davidsson[a], Johan Holmgren[a], Jan A. Persson[a]

[a]*Department of Computer Science and K2 – The Swedish Knowledge Centre for Public Transport, Malmö University, Malmö 205 06, Sweden*

Abstract

In this paper, we introduce a new approach for collecting data for transport simulation models that is using on-line services in order to outsource parts of the modeling and computation of simulation models. We describe our approach of using on-line services as part of a simulation model and we present our experiences of applying the approach to a case study using the ASIMUT model, where the travelers between two neighbour cities in Southern Sweden are modeled. The results from our case study shows that the use of on-line services for data collection in transport simulation can bring advantages to the simulation model, for example, in terms of reduced needs for modeling of the transport system as well as computation inside the simulation model and improved access to the most recent information. We also noticed some limitations, such as the inability to access to information regarding the future such as timetables and no control over data provided by third-party services. However, we argue that there are solutions for each of the identified limitations, and therefore we believe that the suggested approach might provide a unique opportunity for future transportation simulation models.

Keywords: Web Services; Data Collection; Simulation; Travel planning; APIs; Transport Network

1. Introduction

Transportation simulation is one of the most common approaches for supporting the decision making in transportation planning through, e.g., enabling to predict the impacts of new transportation policies and infrastructure investments. Based on the questions that a simulation model needs to answer, different types of data needs to be pro- vided to the simulation model. These data ranges from socio-demographic attributes of people to the transportation network data.

* Corresponding author. Tel.: +46-40-66 57636
E-mail address: banafsheh.hajinasab@mah.se

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The traditional approaches for preparing input for simulation models are usually about analyzing his- torical data, national surveys and censuses, and calculating origin-destination matrices. In traditional approaches, the data is either built into the model, or the data needs to be fed into the model manually by the modeler. The traditional data preparation approaches are complex and time-consuming since some of the data preparation work needs to be done manually. Furthermore, the data cannot be changed frequently due to the complex and long procedure of data preparation; therefore, these data are prepared and used as static data.

In this paper, we introduce a novel alternative approach to the traditional approaches for data collection and preparation. Since, in the suggested approach, most of the steps in the modeling and computation are done by third-party services, the input to the simulation can be changed dynamically. Moreover, on-line travel planner systems are becoming more popular these days. This means that people's travel behavior is most probably changing based on suggestions provided by these systems. Therefore, the use of on-line travel planners for estimating people's travel behavior can increase the accuracy of the travel behavior modeling in simulation systems. In this paper, we empirically investigate the advantages and limitations of our proposed approach for modeling, computation, and data preparation in an agent-based simulator for urban passenger transport (ASIMUT)[8].

2. Related work

The predominant type of passenger transport analysis models, which are used by public authorities on regional, national, and international levels in order to support their decision-making, is the so-called macro-level models. Macro- level models are based on highly aggregate data, and they are often described as top-down models as they are built with the purpose to reproduce known (aggregate) transport statistics, typically on national level. Examples of models of this type are the Swedish national passenger transport modeling system (Sampers)[1], and TRANS-TOOLS[9], which is an EU-level model for passenger and freight transport modeling[5,12]. Macro-level models are in general steady-state models, where time is not explicitly modeled, even though they might include components that are based on dynamic modeling. This means that, for example, bus and train departures in macro-level models are typically modeled using frequencies and average travel times instead of using timetables.

As macro-level models use aggregate data, it can be argued that the amount of data that needs to be collected, and included in the model, can be considered to be rather reasonable; at least when comparing with micro-level modes, which we discuss below. Moreover, in macro-level models, the data is in general included as a part of the model.

Micro-level models are those models where individual entities are studied over time, and they are therefore often referred to as dynamic models. Dynamic models are often used by public authorities, in order to study traffic in congested areas. Agent-based models are a special type of micro-level models, where some or more of the modeled entities are represented as agents. Agent-based models are often referred to as bottom-up models since the behavior of the modeled individuals, and the interactions between individuals are modeled and validated, and the outcome of the model is a consequence of how the individuals are modeled. An example of an agent-based passenger transport model is ASIMUT[8], which we use in this paper to show the proposed data collection approach. ASIMUT is discussed further in section 4.

From a data perspective, agent-based models (or micro-level models in general) are more data intensive, as they require data describing all the modeled entities (e.g. [13,10,2,6,7]). Obviously, it is possible to use statistical distributions in order to model the diverse behavior of the individuals, but such an approach still requires quite some effort on collecting micro-level data that represents the modeled population. As agent-based models are dynamic in nature, they also need data that allows to model entities over time, such as timetables for buses and trains. Obviously, this means that the amount of data that needs to be collected and included in the models can be quite large, in particular when studying large scenarios. Therefore, it is not always possible to build agent-based models where all of the required data is included as a part of the model, which is the case for the macro-level models discussed above.

Agent-based models are therefore sometimes modeling frameworks, which includes building blocks that can be used in order to build different analysis models. An example is the MATSim modeling framework [3], which can be used in order to construct different types of passenger and freight transport models.

Through the use of modeling frameworks, it is possible to develop models using a minimum amount of data, as it is possible to tailor the data collection to the specific needs of a model. In general, data can be collected for only the modeled entities and the part of the network that are modeled. However, as the number of entities and the size of the studied geographic region grow, it becomes more and more demanding to collect the data required by a model, regardless whether or not a framework is used.

Due to the large difficulties of collecting data for agent-based (passenger transport) models, we suggest an alternative to the traditional approaches to data collection. Instead of including all required data in the model, we propose to outsource model computations that require data that is difficult to collect to the third-party service providers who own the data. In that way, we argue that it is possible to save considerable amount of effort on data collection, which is of particular importance when developing large models.

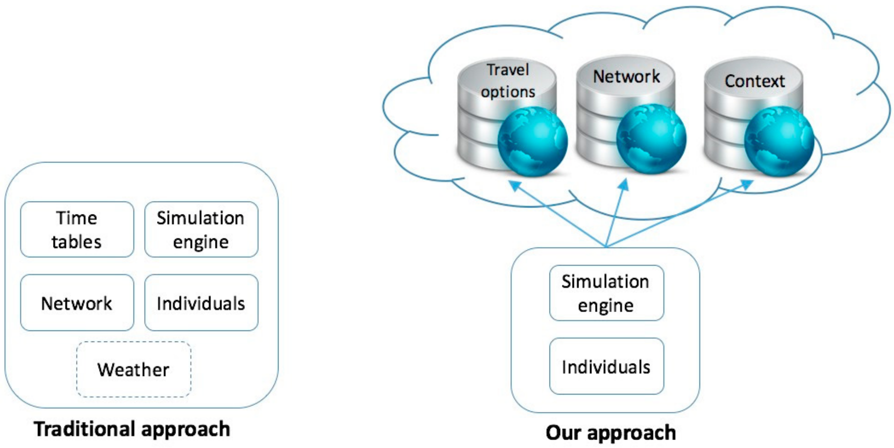

Fig. 1. The proposed approach for data collection and preparation vs traditional approaches.

3. The proposed approach

Our proposed approach is based on outsourcing some parts of the modeling and computation of transport simulation to external on-line services. We have identified three types of data that is typically used in transport simulation and is possible to be acquired from web services. In particular, we suggest using external services to:

- *Include the most promising travel options:* It is possible to use web services that provide timetables and network data. In this way, the simulation model does not need to include the network and timetables data and the algorithms needed to generate travel options from these data.
- *Extract data related to each travel option:* To extract the data such as, time, distance, price, and emissions embedded in each of the travel options generated by the on-line services.
- *Extract context data:* Information about the context of the travel can also be extracted from external services, such as data about weather and nearest parking place.

In Fig. 1, we demonstrate how our proposed approach compares to the traditional approaches of data collection. As illustrated in the figure, the simulation model consists of individuals, their socio-demographic data, and the simulation engine itself. Acquiring the rest of the data required for the simulation is outsourced to the external services. In fact, part of the model related to how to calculate and obtain timetables, network, and context information, i.e. weather is outsourced to external services. In traditional models, all these data are embedded in the model, which decreases the dynamic nature of the model and the model becomes specific for the data that is built into the model.

The process of outsourcing some parts of the simulation model to external services can be a solution to some of the challenges of traditional simulation models, where all the information about the network and the timetables needs to be implemented within the model. This process is time consuming and error-prone. In addition, it requires more computational resources from the modelers' side in order to run the model. Another important challenge in traditional models is that the transport network and timetables data become obsolete after each change in transport network or after each timetable update, for example, seasonal timetable updates or addition of a new bus line. In order to address these issues, we propose a new approach where we outsource elements of a simulation model to external services. In the next sections, we illustrate our approach by describing how we applied it in an agent-based simulator (i.e., ASIMUT).

4. ASIMUT: Agent-based simulator for urban passenger transport

ASIMUT is a multi-agent based simulation model that can be used as a decision support system for urban transportation planners in order to investigate the effects of different types of policy instruments and transport infrastructure investments on travel the choices of travelers[8], for example, how the travelers' choices of transport would change in case of introducing a new public transport fare.

In the ASIMUT model, the travelers are explicitly modeled as agents. This enables us to model the decisions of each individual and compute the consequences of their decisions on the transport system. The relevant travel options, for each specific traveler, from an origin (point) A to a destination (point) B are generated. The relevant information about all the travel options is extracted from the web services, and the travelers choose between the generated travel options according to their individual characteristics. As mentioned above, the generated information is used in the decision making model of the travelers in order to choose which travel option is the best option for each specific traveler. The modes of transport included in the model are driving, public transport, cycling, walking, and combinations of public transport, walking and cycling.

We assume that the choices between alternatives are based on four main factors: the cost of the travel option, the travel time of the alternative, the convenience of the alternative, and the social norm. In the current version of ASIMUT[8], the convenience is defined as a combination of three factors: the number of interchanges, and the walking and cycling distances for that specific travel option. Also, social norms are limited to how much a traveler cares about the environmental consequences of her travel. The amount of CO_2 emissions emitted is used as an indicator for how much a specific travel damages the environment.

Furthermore, we believe that the decision-making process of the travelers, when choosing between the available travel options is to some extent individual and not the same for all travelers. Therefore, we assume that the best travel option can be different for different travelers according their characteristics and contextual factors, e.g., weather conditions. The individual characteristics in ASIMUT are age, income, work flexibility, and eco-friendliness. As an example, the perceived value (significance) of the cost factor is different for each traveler and depends on the amount of income of the traveler. We also use other information about travelers such as work and home address, working hours, access to car, and access to bicycle at home and at work, when generating and filtering the relevant travel options.

Using a utility function, we calculate a score for each of the travel options of the individuals. It should be emphasized here that the calculated score actually represents the disutility of a travel option; therefore, ASIMUT will always choose the travel option with the lowest score among the set of available options for each traveler agent (indiviudual).

5. Case study: Using web services for data collection in ASIMUT

Our proposed approach has been used as part of the ASIMUT model for data collection, preparation, and outsourcing of computations. In particular, we used on-line travel planners to generate travel options from the origin to the destination of each of the modeled travelers. In addition, we used a web forecasting service in order to collect the weather data used in the traveler decision making model. Instead of modeling the transport system explicitly, we used on-line web services in order to generate travel options in ASIMUT.

The set of travel options are generated by sending several requests to the APIs of the local travel planner, i.e. Skånetrafiken[1] and Google Maps Directions web service[2].

[a] https://www.skanetrafiken.se/
[b] https://developers.google.com/maps/documentation/directions/

After getting all the travel options of the travelers, we extract some information about each travel option, which is important in the decision-making model of the travelers. To summarize, the following information related to each travel option are extracted from the on-line services:

- Cost; refers to the cost for the travel option. In case of public transport, the cost is the ticket price for the route, while for driving, the cost refers to the fuel cost plus the parking costs. The cost for cycling and walking is assumed to be zero.
- Travel time; refers to the door to door travel time from the origin to the destination.
- CO_2 emission; the amount of CO_2 emissions emitted from each travel option.
- Number of interchanges; the number of times that the traveler needs to change the mode of transport.
- Walking distance; the total walking distance of the alternative.
- Cycling distance; the total cycling distance of the alternative.

As mentioned above, we used a combination of a local on-line travel planner, i.e. Skånetrafiken, and Google Maps in order to build travel options and extract the parameters (e.g. cost and CO_2) for each of the options. It is obvious that these on-line services can be replaced by any other on-line service that is relevant for the geographic region of a particular case study. Furthermore, the proposed approach for outsourcing data collection and modeling to web services can be used in any simulation model that needs to collect data about network, public transport schedules, etc. In general, the approach can be used to collect any other data that is needed.

At the first stage, ASIMUT generates two travel requests for each traveler according to their origin and destination coordinates and to their working schedule, i.e., one travel request for going from home to work and another request for going from work back to home. Thereafter, for each travel request, we generate the most promising travel options using different modes of transport. The sequence of collecting data and generating the travel options from web services in the ASIMUT model is shown in Fig. 2. Walking, cycling, and driving travel options refer to the options that use only one of walking, cycling, and driving as the only mode of transport all the way from the origin A to the destination B. ASIMUT sends a request to the Google Directions API in order to get bike travel options for the whole distance between A and B. The Google Directions API returns the bike routes and ASIMUT stores the bike routes data. In the same way (as for biking routes), the Google Directions API generates walking and driving routes.

In Fig. 2, the public transport options refer to the travel options that use public transport together with some short walking to and from public transport stops. The travel time and distance of these short walks are taken into account in the simulation. The public transportation options are requested from the Skånetrafiken API and the data is stored by ASIMUT. In some on-line travel planners, such as Skånetrafiken API, which we used in our case study, it is not possible to combine biking and public transport. Since it is very likely that travelers bike or walk to the nearest bus/train station, we generate those travel options that are not suggested by the Skånetrafiken API inside ASIMUT. In this way, we try to cover all possible travel options including the ones that combine bike and public transport, i.e., those that are not generated by on-line services used in the study. For this purpose, we replace long walking distances from origin (A) to a station (A´), and from a station (B´) to destination (B) by cycling. Long walking is defined as the walking distances (d) between 200 meters and 6000 meters. In order to generate these extra options, we send new requests to the Google Directions API to get the biking options, i.e. biking options from (A) to (A´), and from (B´) to (B). It should be noted that these options will be generated only if the traveler has access to bike at the origin and/or at the destination. Finally the weather data is requested and collected to be used later for route selection in the traveler decision model.

We developed a simple scenario in ASIMUT to investigate the effect of changes to the public transport cost on the travelers' choice of mode of transport, the total amount of CO_2 emission, the total travel time, and the total cost. The scenarios and details of the model are described in a previous paper[8]. The process of the simulation runs and the results of the study proved the possibility of using web services for data collection in a simulation model.

In the following sections, we describe how we used each of the external web services to prepare the input data for ASIMUT, i.e. Skånetrafiken travel planner, Google Maps Directions API, and a weather forecasting service called Weather Underground[c].

[c] https://www.wunderground.com/

5.1. Skånetrafiken travel planner

Skånetrafiken is an administration organization responsible for public transport in the region of Skåne in southern Sweden. The organization provides a travel planner called Skånetrafiken Reseplaneraren (In English: Scania county's Travel planner) in which travelers can get the available public transport options for their travel needs. The service is available through a website and as a mobile phone application for direct access by the travelers. The travel planner is also available via an open API for developers of transport-related information systems. The communication in this case is machine to machine via exchanging XML files.

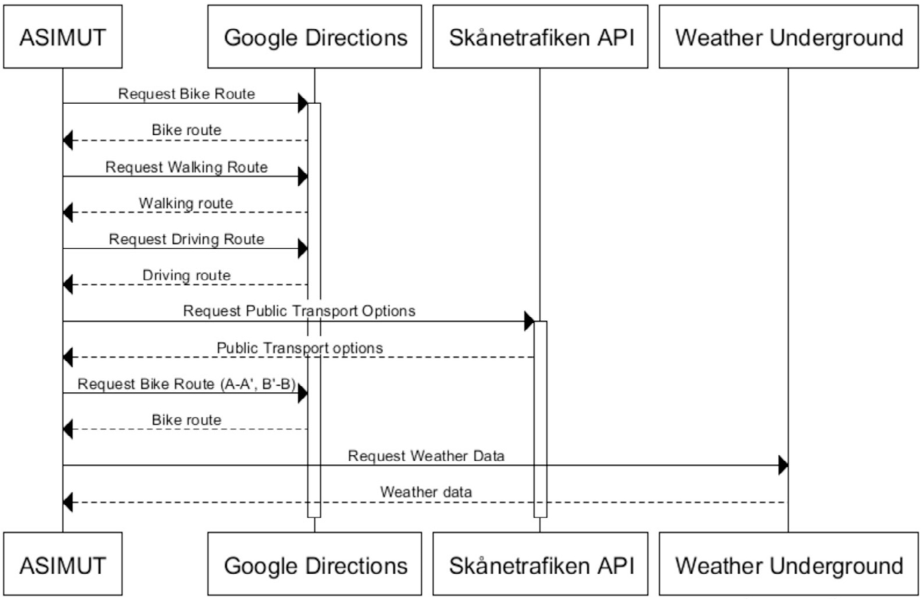

Fig. 2. Sequence of the ASIMUT model.

The API used in this service is SOAP based and returns an XML file as response. SOAP (Simple Object Access Protocol) is as an XML-based protocol for exchanging information when accessing web services, in this case exchanging data related to public transport options. In particular, a SOAP message is an XML file that consists of the encoding rules and the message itself[4]. The Skånetrafiken API provides a number of methods for accessing different information. Some of the functionalities provided by this API methods are to search for: available travel options, stops/stations, stops around a given point, departure times from a stop/station, and current modes of transport. We provide these information to the service: geographical coordinates of the origin and the destination, and departure or arrival time of each of the travelers. The information that we extract from the output of the web service and that we use as input to the ASIMUT model are: travel time, cost, CO_2 emission, number of interchanges, and walking distance for each of the suggested travel options.

5.2. Google Maps Directions API

Google maps provides a RESTful API that returns travel options for different transport modes between two points. We have used the API to generate walking, cycling and driving travel options. The geographical coordinates of each travelers' origin and destination, and the preferred departure time are sent as input to the service. For each of the travel options, the output is the travel time and the distance for each of the travel options.

5.3. Weather data

In order to access to the predicted weather data, we used a web service provided by the Weather Underground. The information about the temperature and weather condition (rainy, snowy, sunny) which is collected from this service, is used in the ASIMUT model as a determining factor in the travel choice prediction model.

6. Discussion & Conclusions

Our empirical study showed that the use of on-line travel planners for generating travel options enables us to capture the most recent information about route alternatives and their relevant characteristics such as cost and travel time. Moreover, it provides the model with real-time information that adapts automatically with updates. For instance, if the bus schedules change, this change will be automatically updated in the simulation model.

Due to the increasing popularity of the on-line travel planners, most travelers use on-line travel planners in order to retrieve almost all possible travel options at the time of departure. Therefore, we believe integrating web services provided by on-line travel planners with the transportation simulation models makes the model very close to the reality and reflects a more realistic picture of the travelers' behavior.

Furthermore, on-line services provide a unique opportunity to outsource the data collection, modeling, and computational work to third-parties[11]. In this case, the calculation of routes and all the relevant information about the routes is done by the travel planners' web services.

Apart from the above-mentioned advantages, our proposed approach has also some limitations. First of all, since the existing web services are designed to provide service to the users in real-time, they have limitations in providing historical and future data. In most cases, on-line travel planners do not provide travel information for travels that occur in the far future, e.g. more than 3 months ahead, even in case the timetables exist for future services. However, since the idea of the approach is to predict the consequences of a change in the transportation system, depending on the studied scenario, we argue that it is possible to use the current travel options and just change the factor that is being studied.

Second, in our approach the simulation model does not have any control over the output data provided by web services because the data is generated dynamically by the web services in real-time. This means, it is difficult to conduct controlled simulations. For example, in case we need to compare two different scenarios, the results might be affected just because we run the simulation at two different times. The same problem occurs when there is a need to repeat an experiment at a later point of time. The results we get might change from date to date. This limitation can be addressed by storing the travel data in a database locally to be used in future simulation runs. In this way, it is possible to do a controlled experiment using the stored data.

Third, the scalability of our approach might be limited by the capacity of the services provided by third parties, such as the Google API or the local travel planners. It is often the case that the servers that provide the web services have limitations in accepting requests and returning output without delays. The relevant public transport authorities typically use simulation models in order to support their decision-making, therefore they most likely would benefit from such a simulation model based on our approach and from the results it generates. Hence, it is most likely the case that they are willing to provide a special server for such a simulation model.

Finally, all the possible travel options that travel planners want to investigate in a simulation scenario are not necessarily covered by on-line travel planners (e.g. Skånetrafiken). To overcome this limitation, it is possible to let the model generate additional travel options based on the requirements of the simulation scenario, which is exactly what we did in ASIMUT (i.e. by adding travel options that combine public transport and cycling).

In general, we believe this new approach for data collection, preparation, and modeling can be an alternative approach to the existing modeling approaches. This new method can facilitate the process of modeling by outsourcing parts of the model to the third-parties and can increase the quality of the simulation by obtaining the most recent information.

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