Modeling Private and Business Travelers in an Agent-Based Travel Demand Model

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ABSTRACT

Worldwide travel and tourism are becoming increasingly important, and travelers have hence an increasing influence on traffic volume in cities. Therefore, it is important to incorporate them in future transport planning activities and to consider them in travel demand modeling. Until now, there has been no suitable model that differentiates between travelers and inhabitants and considers the different travel behavior of these two groups. This paper presents a framework that includes different types of travelers (business/private, overnight/same day) in a microscopic travel demand model. The application of the model to the planning area of Hamburg provides evidence that tourists are responsible for about 7% of Hamburg's traffic volume. A more detailed analysis, however, reveals differences (e.g., in the number of trips, mode choice and trip length) for all different traveler types and compared to inhabitants. Overall, the results obtained enhance knowledge and are hence beneficial for planning authorities.

Keywords: Travel demand model, Tourism, Touristic Travel

INTRODUCTION

Up to the global pandemic outbreak in March 2020, tourism was a prospering sector. The number of trips per person and the number of overnight stays increased worldwide several years in a row; without the pandemic, a continuation would have been expected [1]. City tourism also benefits from this growth of the tourism sector: On the one hand, cities offer various cultural sights and events for leisure travelers. On the other hand, business travelers are attracted by congresses, seminars, or other business appointments, which often take place in well-connected areas to facilitate the journey for traveling guests.

All these people contribute to a city's travel volume when moving from one destination to another. Hence, tourists should be considered when modeling travel demand in cities and their surroundings. However, touristic travel behavior can differ strongly from everyday-life behavior due to different circumstances. Travel modes used for arrival, for example, determine mode choice behavior during the stay significantly, as, e.g., the personal car cannot be used when arriving by plane or train.

The present paper suggests a model extension that incorporates touristic travelers in a microscopic travel demand model. First, tourism as well as different types of travelers are defined, and appropriate statistics demonstrate the relevance of tourism for travel demand. Second, existing literature and studies that indicate the differences between touristic and daily mobility patterns are reviewed and existing approaches to model tourists are presented. Subsequently, the agent-based travel demand model framework "mobiTopp" is introduced, and its extension "touriTopp", which was explicitly developed to represent tourism adequately presented. Finally, results from the simulation are shown, the suggested way of modeling is discussed, and conclusions are drawn.

LITERATURE

Tourism

The United Nations World Tourism Organization (UNWTO) defines tourism as a "[…] social, cultural and economic phenomenon which entails the movement of people to countries or places outside their usual environment for personal or business or professional purposes." [2] As the "usual environment" is a very individual parameter and difficult to measure, some definitions of tourism also incorporate a minimum distance traveled [3]. Furthermore, tourism can be distinguished based on the trip purpose – mostly business or leisure – and the duration of stay. The UNWTO recommends to name "visitors" all people performing tourism (indepently from trip-purpose), "tourists" people that stay overnight, and "same-day visitors" or "excursionists" that do not stay overnight [4].

Within the last decades, traveling has become more popular. Touristic activities have increased (see, e.g. [5]) due to globalization, rising incomes, and changing working patterns that allow for additional short breaks. Moreover, low-budget airlines even make far-off destinations accessible. Cities are convenient destinations for short trips because of their excellent accessibility (e.g., through train stations, airports, highways) and a wide range of on-site activities like shopping, sightseeing, or museum visits. [6]

The United States have achieved a record high with almost 2.4 billion person-trips (+1.6 % compared to 2018), among them 80 million international arrivals [7]. Germany accounted for 191 million person-trips in 2019 (+3.2% compared to 2018) of whom 20 % were non-domestic. Every traveler stayed on average 2.6 nights [8]. According to UNWTO, both countries were among the top ten destinations when counting international arrivals in 2019. The most popular cities in the

U.S. were New York and Los Angeles (about 30 million arrivals [9] [10]). In Germany, the cities Berlin, Munich and Hamburg were most visited (13.5-7.2 million arrivals [8]).

While observing an increase in leisure trips from both more travelers and more trips per person, a different evolution for business trips is found; fewer people tend to go on a journey more often. The United States counted 464 million domestic business travel trips [7]. In Germany, 78.5 million business trips were made by 10.3 million people (on average 7.6 trips per business traveler). Four out of five trips were domestic, every fifth trip had a destination abroad [11]. Moreover, according to the International Congress and Convention Association (ICCA), the United States and Germany were the two leading countries for hosting most international congresses in 2019 with at least 50 attendees (US: 934, GER: 714) [12].

In addition to overnight trips, day trips should not be forgotten as they also account for a substantial share of tourism. Harrer and Scheer [13] determined that almost 3 billion day-trips were made by Germans aged 14+ from 05/2012-04/2013. One out of six happened for business purposes. They concluded all demographic groups perform day trips, although with very different frequencies. When comparing time series of day trips, it is conspicuous that day trips are subject to greater fluctuations, for example due to weather conditions or the number of public holidays.

The preceding paragraphs provided evidence that travelers' contribution to mobility cannot be neglected. A comparison of the few existing studies reveals that travelers' behavior differs strongly at different locations. Weather, geographical (and topological) conditions as well as the destination's infrastructure and hence the accessibility through different transportation modes have a substantial impact on both arrivals and mobility on-site, as exemplified by studies from Kassel (Germany) and Salzburg (Austria). These studies can be used to demonstrate differences between residential and touristic travel behavior.

Bieland et al. [14] investigated touristic travel behavior by surveying over 700 tourists in Kassel, a city with +200,000 inhabitants in central Germany, known for the "Bergpark Wilhelmshöhe", a UNESCO World Heritage Site and for curating the exhibition of contemporary art "documenta". They conclude that about 14 % of Kassel's daily traffic volume is caused by tourists. Nevertheless, it differs strongly from everyday mobility in Kassel as can be seen in Figure 1 [15]. The travelers' modal split has a higher share of car and public transport trips, whereas the shares of bicycle and walking trips are much lower. According to Bieland et al. [14], mode choice on-site is predetermined by the mode used for arrival. Three out of four people, who arrived with public transit, also used public transit during their stay in the city. Similar tendencies can be observed for car users. Moreover, travel group size influences mode choice, for example, families use a car more often than young couples.

A very different touristic modal split can be seen in Salzburg (Austria), a city located in the northern Alps with +150,000 inhabitants. Well known for its historic city center, where multiple points of interest are located, most trips are made walking. The car, in contrast, has only a minor part, see Figure 1 [16].

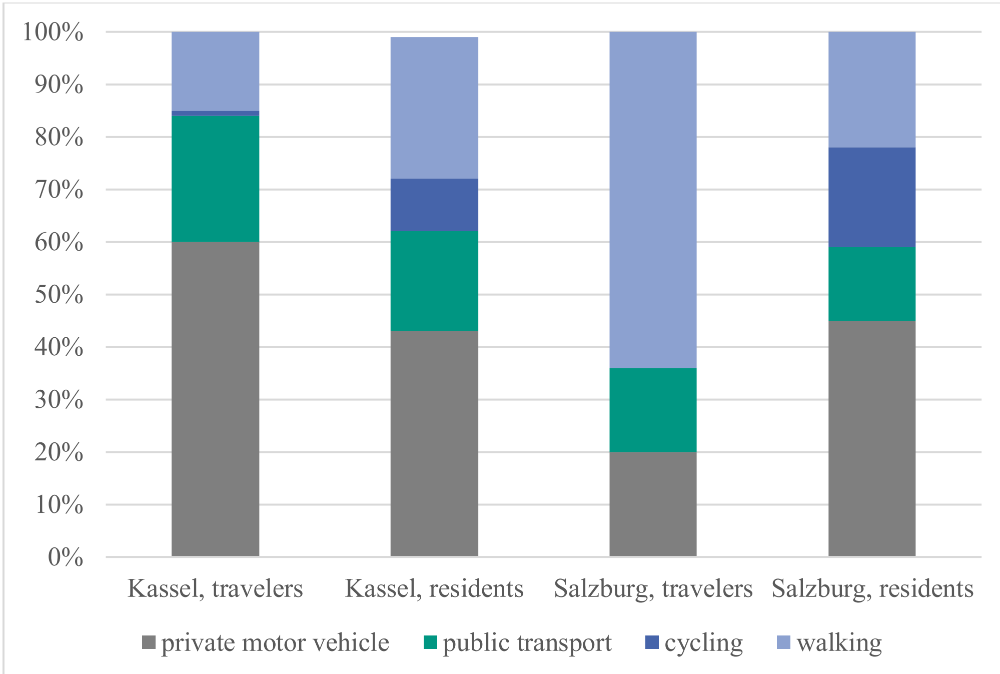

Figure 1: Comparison of the Modal Split from travelers and residents in Kassel [14, 15] and Salzburg [16]

Trip purposes also impact travel behavior, e.g., leisure travelers do more activities per day than business travelers [17]. Among leisure travelers, those who spend their time on sightseeing make most trips, and wellness tourists the fewest. Furthermore, when visiting cities for the first time, most tourists stay in central areas. The range of movement increases with the number of visits. Hence, people walk a lot during their first visit and take public transport more often when visiting repeatedly.

Modeling of tourism

When speaking of modeling tourism, different worlds of models need to be distinguished. On the one hand, there are models that originate in the field of tourism studies. On the other hand, there are approaches of integrating touristic travel in common travel demand models.

In tourism studies, models mostly take a higher order perspective. The questions that are tried to be answered include: Which destinations are chosen among all targets tourists may go to? How does tourism change when income or prices change? Especially a lot of econometric models have been developed that describe the tourism demand depending on different surrounding factors. In an overview of 124 empirical studies, Lim [18] finds that the dependent variable in such models is most often the number of tourist arrivals and/or departures, followed by the tourism expenditures and/or receipts. Another aspect that sometimes is tried to be explained is the duration of stay. As an example, the travel from Hong Kong and Singapore to Australia has been examined for an extensive time series [19].

Interestingly, several models exist where also agent-based approaches are applied: Zhang et al. model the influence of electronic word-of-mouth on tourists' choices [20]. Furthermore, studies include modeling the destination choice of tourists [21], and general influences on travel decision-making [22].

Overall, the aim is to explain and forecast the total number of tourists and to identify influencing factors. This is undertaken to develop the location as a touristic destination and to set suitable marketing and management strategies. However, in contrast to tourism studies, in travel demand models it is necessary to model tourism with the perspective of the target. The absolute number of tourists can be seen as an input value. The focus is on the activities at the destination, not the selection of the destination.

Models that try to describe the behavior on site, including activity schedules and destinations, can hardly be found. Among the exceptions, Doscher et al. conducted 140 interviews with tourists in New Zealand and based on these data started to formulate agent-based models describing the behavior [21]. Furthermore, there are several agent-based models of very specific parts of touristic behavior on site [22, 23, 24]. These are hardly compatible with the needs of regular travel demand models.

Travel demand models are generally based on the inhabitants of the area of study. Tourists represent exogenous travel demand, similar to through traffic, which depending on the model may or may not be included. In macroscopic (aggregated) models it is hardly documented how the trips by people living outside of the area of study are included. For macroscopic activity-based models, two documented exceptions can be found: There is a model of Lake Tahoe, that includes travel demand by incoming visitors [25]. Another exception is an attempt to include touristic travel demand in a model of the province of Salzburg (Austria) [16].

In agent-based travel demand models there is an even higher focus on inhabitants and due to the agent-based structure higher effort is required to include external persons. When analyzing current documented travel demand models, in some this external demand is not included at all [26], or it is added with "simple means" [27] or according to "best knowledge" without further clarification [28]. In consequence, Hörl and Balać [26] state that to their knowledge in most agent-based models this is not included but admit that this is a problem. An interesting research effort has been undertaken by Llorca et al. [29]. They apply methods for generating regular synthetic populations (iterative proportional updating) to tourists, using adapted control attributes and sample datasets. Thereby, they create a synthetic population of incoming visitors based on mobility survey results and visitor numbers. They, however, restrict on domestic visitors which stay at least one night, do not specify how activity schedules are created, and leave out simulation results.

Overall, integrating private and business travelers is not a standard method in travel demand models yet, despite its high relevance, especially for cities and regions that have major touristic attractivity. Therefore, a method for integrating tourists and business travelers into the travel demand model mobiTopp is proposed.

METHODS

Microscopic travel demand models allow to cope with the heterogeneity of a population and, hence, the individual framework conditions and resulting decisions of each individual. Thus, this approach is very suitable to incorporate travelers that behave differently than residents in their everyday life. By following the concept of mobiTopp, an existing agent-based travel demand model, that simulates residential travel behavior, it is possible to simulate inhabitants and travelers together. After the joint simulation, it is possible to distinguish both groups, to compare the results, and to describe the traffic situation more precisely. In the following section "mobiTopp" is described first, its extension "touriTopp" for travelers second.

mobiTopp

mobiTopp is an agent-based travel demand modelling framework that models every person, household and car of the study area [30, 31]. Persons are represented by agents following the definition of Bonabeau [32]. Agents make their decision individually and situation-dependent, taking into account the current state of the travel demand model. Every agent has an assigned activity program for a whole week following the concept of simulating activity chains [33]. Activity programs can either be gathered from representative empirical data or generated synthetically [34]. While carrying out their activity programs, agents decide where an activity takes place and which mode to use to reach their destination.

mobiTopp consists of two stages: initialization (long-term-module) and simulation (short-term-module). The long-term-module comprises the generation of a synthetic population using representative demographic data and the assignment of different mobility-related attributes of an agent (see Figure 2). Those attributes are the activity program, the selection of destinations for fixed activities (home, work, education), the ownership of a car or commuter ticket, as well as the membership at various mobility providers. The short-term-module consists of destination and mode choice. Destination choice is carried out for all trips to differing locations, while mode choice is executed on all trips. The modular nature of mobiTopp allows the use of different kinds of models during the assignment of attributes in the long-term-module as well as in the selection of destinations and modes in the short-term-module. In the past, utility-based models [35] and rule-based models [36] have been applied successfully.

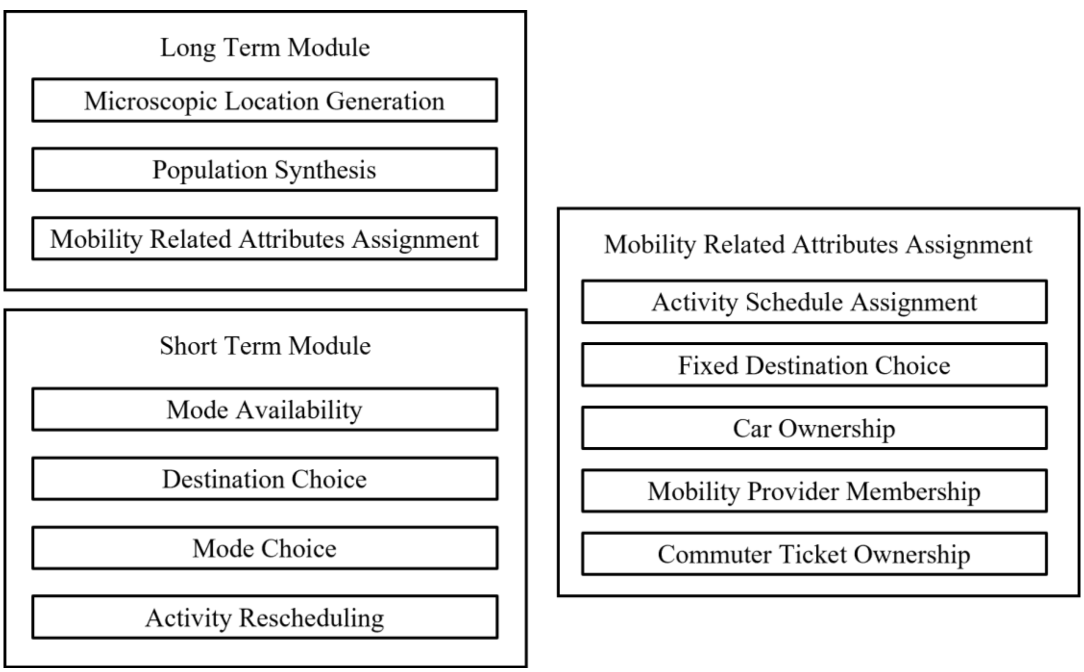

Figure 2: Structure of mobiTopp

touriTopp

As no existing model was found to adequately simulate travelers' behavior, a new one was developed. The modeling uses the data structures by the model mobiTopp to allow simple integration. General definitions of tourism are based on a journey outside the usual environment, or a minimum distance traveled. Both approaches were not ideally suited for the model. Therefore, in touriTopp travelers are defined as all those who enter the simulated planning area from outside and return to their place of origin, independent from their trip duration or purpose.

Requirements for modeling travelers

First, the specific characteristics of travelers were defined:

- Travelers arrive and depart

Travelers arrive in the simulated planning area from outside and return there at the end of their journey. Therefore, they need an entry and/or exit point in the model.

- Travelers are only temporarily active in the planning area

While residents are intended to have activity schedules for the period of one week, travelers require the possibility to stay only temporarily in the planning area. Since there is no provision for agents to be created, or deleted, during the simulation, they must exist for the entire duration of the simulation but may not actively move around the simulation space for longer than their allotted duration of stay. Since there is no provision for agents to be created, or deleted, during the simulation, they must exist for the entire duration of the simulation but may not actively move around the simulation space for longer than their allotted duration of stay.

- Travelers do not all arrive and depart at the same time.

Travelers have different rhythms during a week. They do not all arrive and depart on the same days or at the same time.

- Travelers can make a day trip or stay overnight

The assignment of different durations of stay to travelers is a prerequisite to differentiate between different types of travelers. Further, overnight travelers need an overnight location, whereas same-day travelers do not.

- Travelers may have a limited availability of transportation modes on site.

Travelers' availability of transportation modes must be limited. For example, during a trip, travelers may only use their own car if they have used it to reach the planning area. If a traveler arrives by train, a car or bicycle located at home cannot be used.

- Travelers do not only travel alone, but also in groups

Group journeys are not only journeys in the family circle, but for example also business trips with work colleagues. Since in mobiTopp no accompanied trips can be represented yet, another solution must be found, to model group journeys.

- Different traveler types need different attributes

There must be a way to select the submodules based on the traveler type. For example, a workplace must be assigned to business travelers but not to private travelers. For this purpose, decision rules have been implemented that enable or disable the submodules depending on the characteristics of the traveler (e.g., business trip yes/no; day trip yes/no).

Differences compared to existing models

Models from the field of tourism contain information about the number of tourists going to a destination. They do not represent the activities travelers perform on site during their stay (see Figure 3). In contrast, in touriTopp the journey from the place of residence is not represented, but only the part that is relevant for mobility in the planning area. Therefore, the simulation starts when travelers arrive at a traffic hub in the planning area. In addition, all routes that travelers make on site are represented here.

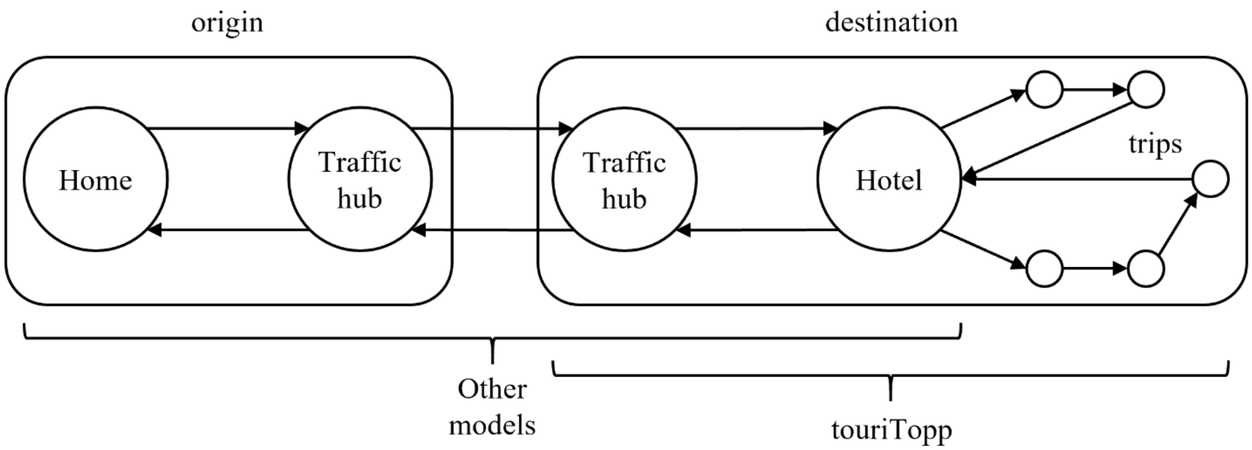

Figure 3: Difference between touriTopp and other models

Model structure of touriTopp

The model differentiates between four types of travelers according to trip duration and reason for travel:

- Private same-day travelers
- Same-day business travelers
- Private overnight travelers
- Overnight business travelers

This terminology differs from the UNWTO recommendation. Nevertheless, tourists and visitors can be easier misunderstood when not knowing the previously mentioned definition, whereas the nomenclature chosen is very accurate.

The basic structure of touriTopp corresponds to the structure of mobiTopp: The long-term module consists of all submodules that simulate long-term-characteristics which are fixed during simulation. The short-term module contains the execution of the simulation. For touriTopp only the population synthesis and the mobility related attributes (see Figure 4) in the long-term module were adapted for travelers. Therefore, it is possible to simulate travelers and inhabitants with the same short-term module, which allows for an integrated simulation of both.

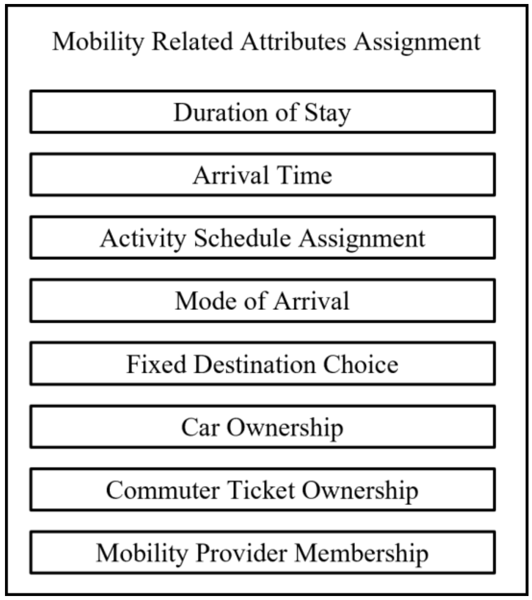

Figure 4: Structure of touriTopp

Population Synthesis
During the population synthesis, a synthetic population of travel agents is generated by using representative demographic data. The travel agents are drawn from data sets of real people. During this process, characteristics of the real person, such as age, gender or commuter ticket ownership, are copied to the travel agent. It is assumed that people who travel together make all the trips on their journey together. Therefore, these travelers are modeled as a travel group that a single travel agent represents during the simulation that takes along the so-called "non-simulated companions" on his trips.

Duration of stay
A new model was developed for the different durations of stay that assigns different durations of stay to overnight travelers. This is unnecessary for same-day travelers, as they only stay in the planning area for one day.

Arrival Time
The arrival time is the time at which the stored activity schedule of a travel agent is started. It is composed of an arrival day and an arrival hour. The arrival day is set by default via distribution. The arrival hour corresponds to the actual start time of the selected activity schedule. For overnight travelers, it is also possible to arrive before the simulation has started or to depart after the end of the simulation (see Figure 5). The earliest arrival time was defined as one week before the actual simulation starts. Therefore, the arrival days are between -7 (Monday before simulation start) and 6 (Sunday of simulation). If a travel agent arrives and departs before Monday of the actual simulation (corresponding to day 0), it is not considered anymore (see case 1 in Figure 5).

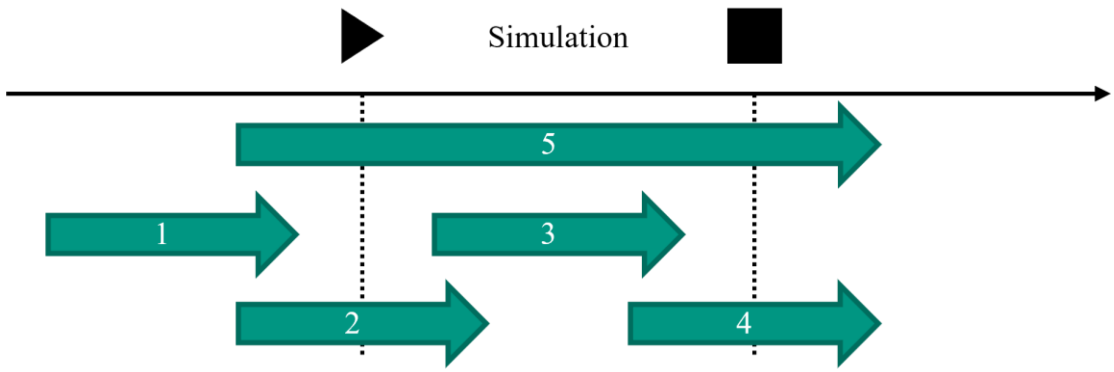

Figure 5: Different arrival and departure types: 1. Both arrival and departure before simulation start, 2. Arrival before simulation start, departure during simulation, 3. Both arrival and departure during simulation, 4. Arrival during simulation period, departure after simulation end, 5. Arrival before simulation start, departure after simulation end

Activity Schedule Assignment

Each activity in a schedule is defined by four characteristics:

- Start time (in minutes from simulation start time).
- Activity duration (in minutes)
- Route duration (in minutes)
- Activity purpose

The activity schedules given are sorted by duration and start time (during the week or at the weekend) to allow for an appropriate assignment to every agent. Only travel agents relevant to the simulation period can select schedules. The schedules of travel agents are determined according to their actual duration of stay in the simulation and their day of arrival. If a travel agent has a travel time of seven days, but only four of these are within the simulation period, the agent also selects only an activity schedule for these four days.

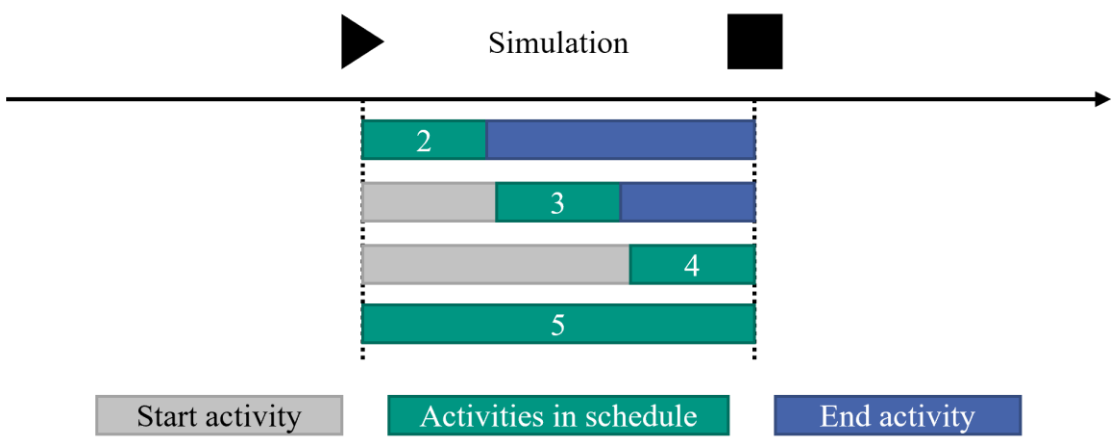

Figure 6: Start and end activites for different arrival and departure types: 2. Arrival before simulation start, departure during simulation, 3. Both arrival and departure during simulation, 4. Arrival during simulation period, departure after simulation end, 5. Arrival before simulation start, departure after simulation end

Since there is no provision for agents to be created, or deleted, during the simulation, they must exist for the entire simulation duration. Each agent needs a complete activity schedule over the entire length of the simulation period. However, they are assigned for activities only for the duration of their stay. Therefore, start and end activities are added to the selected activity schedule depending on the trip type (Figure 6). These bridge the time during the simulation period in which a travel agent has not yet arrived or has already departed. They spend the time in their arrival zone. Moreover, a new activity type "sightseeing" was introduced to better distinguish tourist activities from leisure activities and to choose appropriate destinations for tourists.

Mode of arrival

For the mode of arrival, different modes of transport can be chosen than for everyday mobility – for example, the airplane. Travelers can only arrive by car if they have a driver's license and own a car.

Fixed Destination Choice

Travel agents can be assigned to a maximum of three fixed destinations depending on the type of travel: The workplace, the place of accommodation, and the arrival zone. To guarantee that travel agents do not arrive at or depart from an arbitrary point in the model but at an appropriate transportation hub (corresponding to the mode of arrival, e.g., a train station for public transport), arrival zones were defined as entry and exit points. If there is more than one arrival zone for a mode of transport (e.g., a central train station and a small train station), these are weighted according to their importance.

The arrival zone is the last fixed destination selected for all travel agents and depends on the first activity on site. If this is a work activity or a stay at the accommodation, the zone is set depending on the workplace or the accommodation. In all other cases, the arrival zone is set close to the city center.

For the workplace and the accomodation, the fixed destination selection is modified so that only overnight travel agents are assigned a place of accommodation and only business travel agents are assigned a workplace. Private overnight travelers can stay in commercial accommodations (e.g., hotels, vacation rentals) as well as in private accommodations (e.g., family, friends).

The order for the assignment of fixed destinations varies for the different travel agent types. Private overnight travelers obtain their accommodation for overnight stay first, whereas business travel agents receive their workplace first.

Car Ownership

Only travel agents who have arrived by car or by coach as part of an organized trip have a car on site. Since a travel group traveling by coach as part of an organized trip is also represented by only one travel agent, the coach is simplified by the regular travel mode "car" on site.

Commuter Ticket Ownership and Mobility Provider Membership

All travel agents with a commuter ticket at home also have one available in the model (see Population Synthesis). Travel agents who do not have a commuter ticket at home and have arrived by car or coach as part of an organized trip will not be allocated a commuter ticket, as this is considered a negative affinity for public transport. For all other agents, the commuter ticket ownership is assigned randomly using a target distribution. The membership at mobility providers is given using target distributions.

APPLICATION

This framework is tested with the practical example of Hamburg. Hamburg is one of the largest cities in Germany, with 1.8 million inhabitants in 2019 [37]. In the same year, Hamburg was visited by 7.6 million overnight travelers and 106 million same-day travelers [38, 39, 40]. Since day trips also included trips within the planning area, these must be removed for the application, resulting in 48.9 million same-day travelers [38, 40, 41, 42, 43]. Since approximately 25% of each traveler type visits Hamburg in spring [38, 39, 40], this season is selected for simulation.

Table 1: Used data sets for Hamburg

Name	Origin of data	Year	Submodules	Travel type
Mobility in Germany (MiD) [44, 15]	National household travel survey	2017	Population synthesis, Arrival time, Activity Schedules, Mode of arrival	All
German Mobility Panel (MOP) [45, 46]	National household travel survey	2019	Activity Schedules	Overnight travelers
Mobility Panel for long-distance traffic (INFERMO) [47]	National household travel survey	2005	Duration of stay, Arrival time	Overnight travelers
Destination Monitor [42]	Survey of German-speaking people	2015	Mode of arrival	Overnight travelers
Quality Monitor [40]	In situ survey of visitors at destinations in Germany	2011-2019	Population synthesis, Arrival time, Activity Schedules, Mode of arrival, Fixed Destinations	All
Statistical series – Tourist accommodation in Hamburg [39]	Official statistics	2004 - 2019	Population synthesis	Overnight travelers
N.I.T Potential Analysis [48]	Not disclosed	2009	Activity Schedules	Overnight travelers
RA Business [41]	Survey of German-speaking people	2020	Mode of arrival, Fixed Destinations	Overnight travelers
Permanent traffic counting systems – highway exits Hamburg [49]	Official statistics	2018	Fixed Destinations	All
Passenger numbers – train stations Hamburg [50, 51, 52]	Official statistics	2019	Fixed Destinations	All

Unfortunately, no crossed data sets were available for the practical example of Hamburg. Ideally, there would have been a dataset containing travelers' data to Hamburg with all their characteristics, such as duration of stay, day of arrival, and activities. Instead, there were only independent distributions that were used as the data basis for the submodules. For the population synthesis, a dataset with data of real persons from a travel survey was used to draw travelers from it based on distributions [39, 40, 44]. In the case of the same-day travelers, these individuals were not exclusively travelers, as would have been ideal. Independent distributions from surveys of travelers were used [40, 47]. For overnight travelers, however, travelers generally were included and not specifically city tourism or travel to Hamburg. For the activity schedules, two large mobility surveys in Germany were used, which were evaluated specifically for travelers [44, 45]. However, it could not be guaranteed that the final datasets contained only travelers. It also was not possible to evaluate whether travelers went to cities or specifically to Hamburg. The modes of arrival were derived from travel surveys evaluated specifically for Hamburg [40, 41, 42, 44]. The attractivity values of each zone for fixed destination choices are based on the number of inhabitants [53] and the number of places to stay [54]. Unfortunately, there was no data available for travelers owning commuter tickets for public transportation. A distribution was assumed, which was validated during the calibration of the model. Table 1 lists all data sets used, a brief description of the survey, the submodules, and the traveler types for which the data was used.

Before running the simulation, the model output was compared to the existing input data for validation. The result obtained was satisfying.

RESULTS

The following paragraph presents the results from the mobiTopp Hamburg model. In addition to 1.87 million residents from Hamburg, 694,026 travel agents were modeled, some representing a whole travel group. For the evaluation, the travel agents were converted to the total number of travelers.

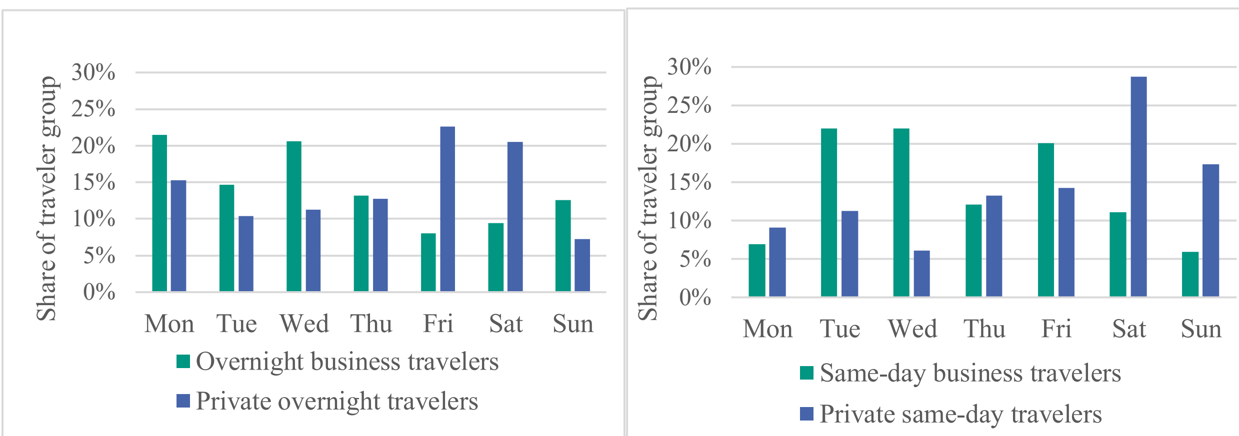

Figure 7: Comparison of arrival days of different traveler types

As mentioned beforehand, the arrival day is drawn based on a given distribution. This varies for the different traveler types, as illustrated in Figure 7. Private travelers arrive more often at the weekend, while business trips occur more likely during the week. Accordingly, mobiTopp's simulation time of one week is beneficial to model travel behavior correctly. The arrival hour is determined by the start time of the selected activity schedule and varies, hence, also for the different touristic types.

Figure 8 depicts the spatial distributions of accommodation (e.g., hotels, apartments,…) of private overnight travelers. They are distributed over the entire city area. In contrast, overnight business travelers first are assigned to their workplaces, which are often close to the city center in Hamburg. They subsequently choose their accommodation depending on their workplace. Hence, they tend to stay in the city center and other zones with many workplaces (see Figure 9).

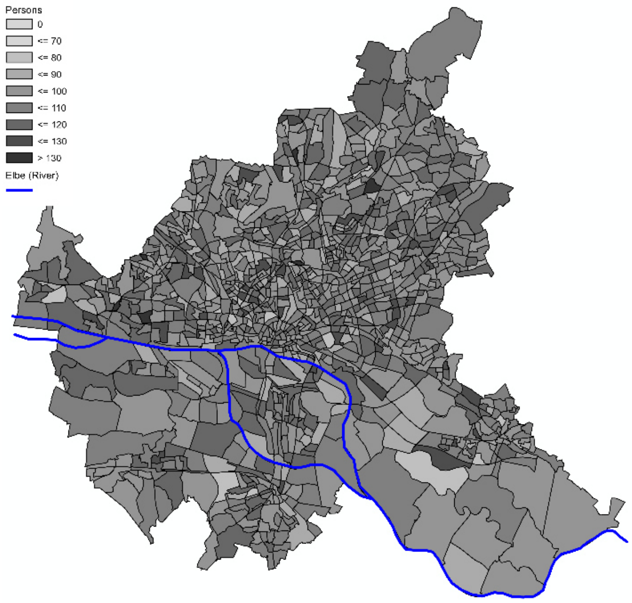

Figure 8: Distribution of places of accomodation of private overnight travelers in Hamburg

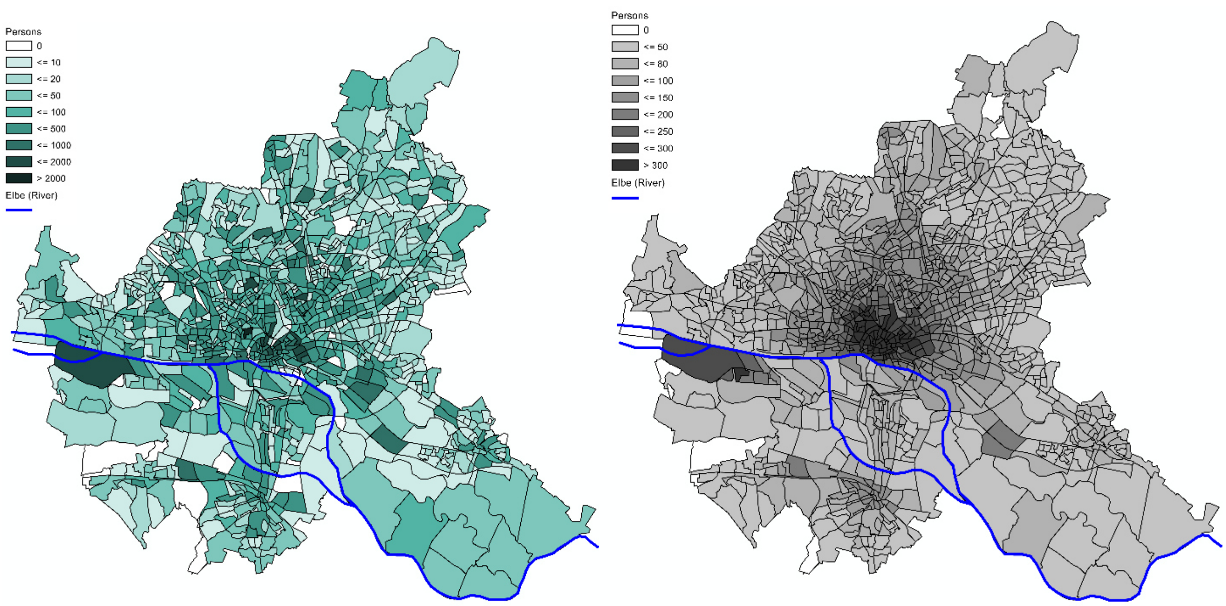

Figure 9: Distribution of workplaces (left side) and places of accommodation (right side) of overnight business travelers in Hamburg

In total, tourists account for 7% of all trips within Hamburg. Comparing the crucial mobility KPIs reveals that residents undertake more trips than travelers (see Figure 10). However, the comparison of all trips during one week's whole simulation period is slightly biased, as only traveler trips happening in the planning area are counted. Correspondingly, all trips made on the arrival or departure day at home are not considered. However, overnight tourists often arrive in the evening or depart already in the morning, when staying for several days, and make, thus, only one trip on these days. Consequently, their average -when considering all days- is significantly lower compared to the average when only counting the days entirely spent in Hamburg (overnight business travelers: 3.7 trips per day, private overnight travelers 3.5 trips per day). Most same-day travelers undertake only one activity on-site independently of their travel purpose, which results in mostly two trips: the trip from the entrance point of the city to their destination in Hamburg and the departure trip.Consequently, they cover shorter distances than overnight travelers. Further, private travelers cover larger distances than business travelers with shorter travel times on average. This could be due to business travelers' higher share of pedestrian trips (see Figure 11).

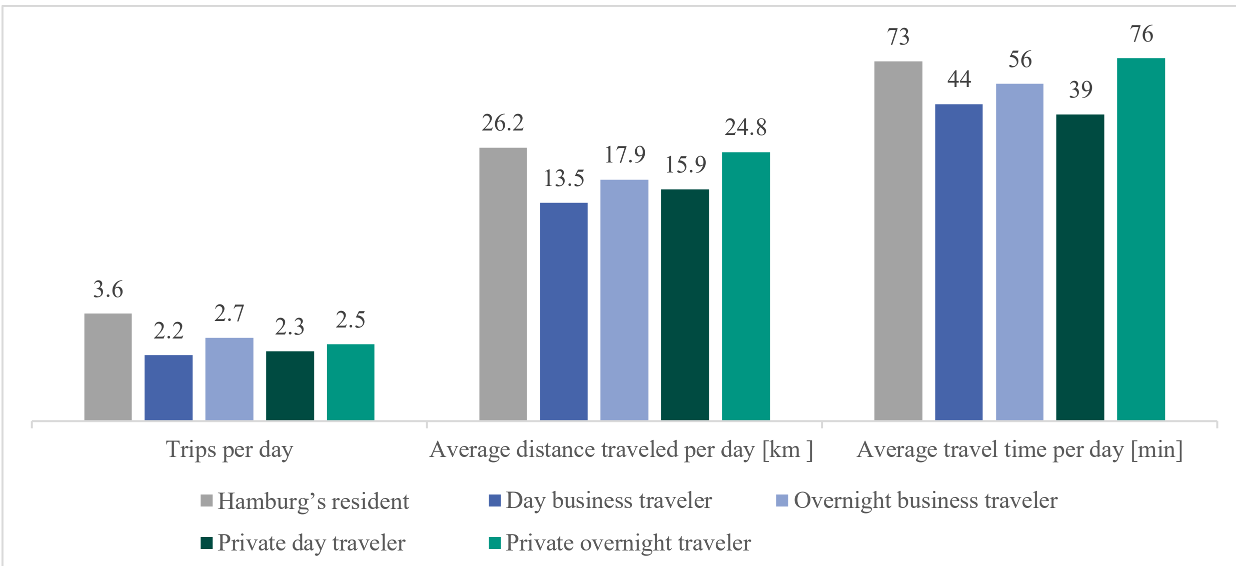

Figure 10: KPIs for different travel types and residents in Hamburg

As illustrated in Figure 11, different modal splits for different traveler types can be observed over the course of a week, all of them deviate from Hamburg's residential modal split. It is striking, that all tourist groups have a higher share of car trips, residents, by contrast, have a significantly higher share of cycling trips. This is due to restricted availability, as it is assumed that travelers that arrive by car, plane or public transport would not take their bike from home. Just as residential agents, some travelers have memberships for different mobility services. However, the share of new mobility services is so small (<1% for all types of agents), that it was neglected in this figure.

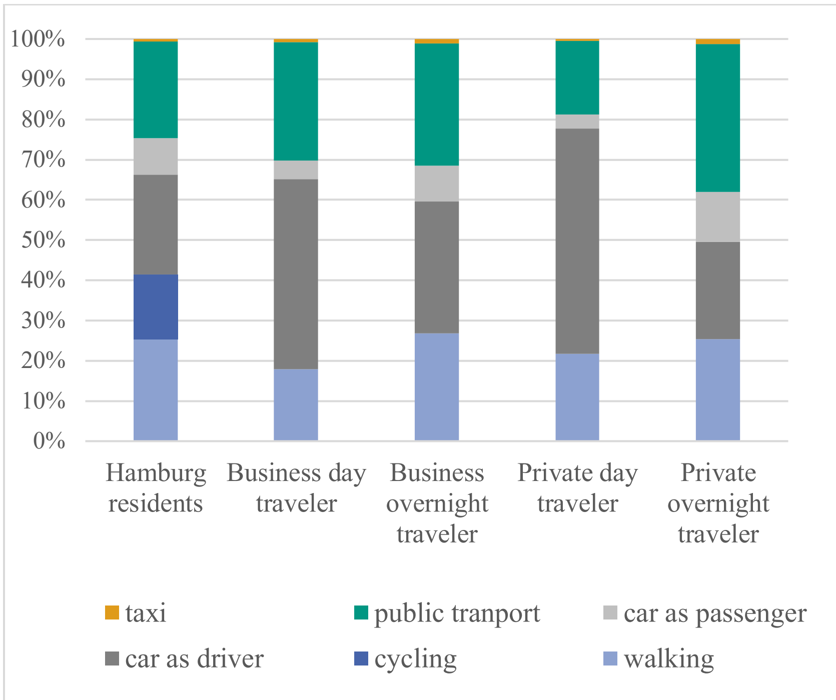

Figure 11: Modal split on site for different travel types and residents in Hamburg

The substantial differences in the agents' activities are not surprising but important to mention as they influence not only destination but also mode choice. To be able to compare the activities of same-day travelers, who do not have overnight stays in Hamburg, with the other agents, only "day activities in Hamburg" are considered in Figure 12. Residents have a more versatile activity schedule than travelers, which can be explained, on the one hand, by considering a whole week and not only certain days. On the other hand, being at home one has more duties to perform and hence a larger activity portfolio. In contrast, private tourists mainly perform leisure activities whereas work-related activities characterize business travelers' trips. When staying overnight, the share of leisure activities increases. This corresponds well to the so-called "bleisure phenomenon" of combining work-related trips with private or leisure activities.

40 % of all trips from agents that stay in Hamburg overnight, regardless of whether these are tourists or residents, account for driving home, to the hotel, or any other accommodation.

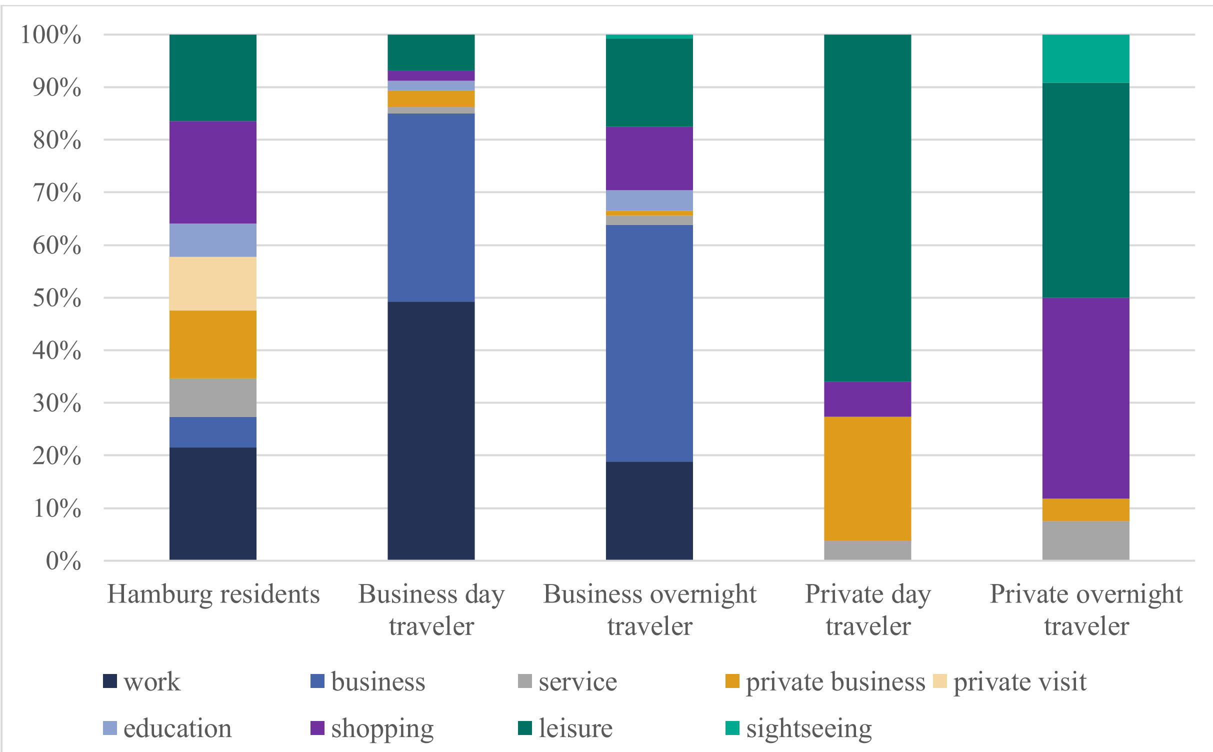

Figure 12: Distributions of activities on site for different travel types and residents in Hamburg

DISCUSSION

In contrast to other, simpler models, touriTopp allows a much more detailed simulation of travelers' mobility behavior. It grants the possibility to include empirically-based activity plans. Furthermore, travelers are distributed over the course of the week and obtain various characteristics. The model allows for differentiation between trips with business and private purposes and different durations.

Although in the practical example of Hamburg the data availability was in parts scarce, clear differences between travelers and residents could be shown. Due to the data availability, the modeling was challenging, and the model had to be simplified. However, the modular structure allows exchanging submodules easily when better data is available. Some possible improvements are listed below:

The traveler model presented is based on rule-based decision models. For the resident model, in contrast, parameters are estimated as a function of demographic data, place of residence, and others. This procedure could also be implemented for travelers, provided that appropriate (crossed) data is available and preferences for travelers can be estimated.

The origin of travelers is not considered in the current model. It would be interesting to know not only whether travelers are domestic or international but also how long they traveled to reach their travel destination. It is suspected that the length of the arrival distance also impacts the choice of arrival mode. In addition, a person's origin could also affect local activities or the duration of stay. Provided this data is available, the choice of arrival mode and activity schedules can be extended.

Reasons for travel currently are only considered to distinguish between business and private travelers. However, it is assumed that people who visit relatives and people who untertake cultural trips choose different activities. If corresponding data is available, the choice of activity schedules can be adjusted.

To be able to represent common trips, travelers are currently not simulated as individual agents. Instead, a travel agent represents an entire travel group. However, to allow travelers to make separate trips, it would be necessary to simulate them as separate agents. In the framework mobiTopp it is currently not yet possible to model common trips. Therefore, travelers, if modeled individually, could currently only move separately and never together. Once this restriction is removed, travelers can also be modeled individually, provided that better data on their mobility alone and in groups is available.

CONCLUSION

Travelers are responsible for a substantial share of a city's traffic volume; they account for about 7 % in Hamburg. Hence, they should be incorporated in future transport planning activities of city's authorities. So far, no suitable model was available that acknowledged the different nature of travel behavior on-site from tourists compared to residents. This paper presents a framework that includes different types of travelers (business/private, overnight/same-day) in a microscopic travel demand model. The application of the model in the planning area of Hamburg provides first evidence that results obtained broaden knowledge and are hence beneficial for planning authorities.

Nevertheless, during the model set-up, major gaps in data availability for touristic travel behavior were identified. Future research should focus on collecting adequate data. Thanks to the framework's modular structure, the models for the assignment of mobility-related attributes as well as choice models can be replaced whenever a more suitable data source is available.

AUTHOR CONTRIBUTIONS

The authors confirm contribution to the paper as follows: study conception and design: J. Ulrich, G. Wilkes, L. Briem; data collection: J. Ulrich, N. Kostorz; analysis and interpretation of results: J. Ulrich, G. Wilkes, N. Kostorz, L. Briem; draft manuscript preparation: J. Ulrich, G. Wilkes, N. Kostorz, L. Briem, M. Kagerbauer, P. Vortisch. All authors reviewed the results and approved the final version of the manuscript.

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