Determining the Attractiveness of Transport Zones Exemplified with Selected Cities

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Abstract. Transport models are mathematical tools necessary for many transport analyses. They are applicable among others in economic analyses, and especially in the development of feasibility studies. One of the key elements of such models is their credibility, which results from good technical assumptions. Important information is undoubtedly information about the spatial development of the area under investigation. Much data on the attractiveness of particular areas, so-called transport zones, needs to be collected when constructing a transport model for urban areas. The paper presents the ways of obtaining and aggregating data to determine measures of transport zones attractiveness for daily trips in the example of Bydgoszcz and Toruń.

1. Introduction
Trips taken by residents of a city and by persons who come to it result from different reasons. The set of such motivations is very large and includes, among other, trips related to a place of work, education (primary schools, junior secondary schools, high schools, post-secondary schools, colleges and universities), business, shopping, visits, appointments at healthcare centres, arranging matters at different institutions, using various services etc. In transport analyses, when defining a set of travel motivations, it is necessary to take account of the possibility of describing such motivations with the so-called transport attractiveness of specific urban areas (transport zones). It is important how attractive a transport zone is for the destination of a trip within specific travel motivations. Therefore, while developing a transport model, it is necessary to divide an analysed area into specific transport zones and to evaluate their transport attractiveness. Making such a division is not an easy task, because a certain compromise has to be made. Such a compromise results from the necessity to take account of contradictions between the objective of simplifying the process of collecting, processing, and analysing data, which is obtained with a lower number of zones, and the objective of obtaining a spatial map of specific fragments of the analysed area that will be as faithful as possible, which in turn is achieved with a higher number of zones. Moreover, in both cases it is necessary to obtain the adequate number of variable samples that describe transport zones that fulfill the criteria of mathematical statistics. Therefore, while developing a transport model, to minimise labour consumption and costs, it is important to collect and use skilfully different types of information that comes from local databases, and next to follow procedures that make it possible to attribute quickly and effectively the adopted attractiveness measures of spatial development facilities in separated areas and to aggregate them to the level of transport zones.
This article presents an example of using databases to determine selected attractiveness measures of transport zones [1] while developing transport models of two Polish cities of medium size, Bydgoszcz and Toruń, by the Department of Road Engineering and Transport, University of Technology and Life Sciences in Bydgoszcz.

2. Another section of your paper
When constructing transport models for Bydgoszcz and Toruń, it was assumed that the attractiveness of individual transport zones in analysed areas was to be determined with address points. They are understood as facilities or buildings of specific coordinates and addresses, where people live, work, study, do shopping, or relax. This concerns both local residents and visitors to the city. Therefore, it was necessary to develop a database of the above-mentioned facilities to be an integral part of a transport model. Considering the fact that both models were developed in the VISUM software [2] environment, the databases of address points were created in the same environment. It is noteworthy that the VISUM software is a specialist tool produced by the PTV Group, Germany, and is used all over the world in model analyses of traffic and public transport. It uses directly the Microsoft SQL Server database, which is a relativistic database with built-in tools for spatial analyses.

The database of every transport model collects information about facilities located in the whole area covered by the model. Such facilities are generally residential buildings, businesses, and public utility buildings, which are sources and destinations of residents from the area. Every such facility has to be described with a unique identifier and surveying coordinates (optionally geographic coordinates converted dynamically for the given surveying system). An additional parameter is the description of an address, which includes the name of street and house number. A facility defined in this way is attributed with additional fields, where data concerning its transport attractiveness is entered. Such data may come from different sources, e.g. GIS portals, acoustic maps, different types of databases kept by local authorities (e.g. population records, business records, etc.). Such databases are more and more easily available, while being gradually more accurate and complete at the same time.

In the transport model built in the VISUM environment, the database of the above-mentioned facilities is based on points of interest (POI). Individual facilities may be recorded as points or shapes that represent their actual form (e.g. a building outline, boundaries of a park). Facilities may be allocated with specific fields of a database that describe their characteristics, for example the number of residents aged 10-12 who live in a building or a number of jobs in services in a public utility building, etc. Such an approach in the description of attractiveness of transport zones has numerous advantages, because it enables the use of numerous GIS resources and SIP portals (Spatial Information Systems) in transport analyses. However, the biggest advantage of that solution is the high flexibility in defining both the number and boundaries of transport zones and their changes. A change of zone numbers, e.g. their compacting, does not require the repeated determination of their transport attractiveness. Owing to the application of spatial analyses with the GIS function (which enables the aggregation of attributes that describe transport attractiveness of individual POIs located within the limits of individual transport zones), it is possible to aggregate such data quickly, and thus to attribute them to the description of characteristics within generation and absorption of trips by individual transport zones. By applying such mechanisms, it is also possible to process spatial development data effectively and flexibly. On the other hand, a transport model may take account of any number of transport zones without the redundant and unnecessary work in determining the transport attractiveness of each and every of them. Hence, the much more accurate map is obtained of the actual attractiveness of individual transport zones in an analysed city. Moreover, it becomes possible to determine changes in spatial development in model analyses very accurately in prognostic periods. The construction of a new facility (a school, a shopping centre, a residential building, etc.) boils down to the introduction of a new POI into the database of a transport model together with its coordinates and address (at present, the application of relevant procedures makes it possible to determine the coordinates of a facility with a name of city, street, and
building number) and to define attributes that describe its transport attractiveness. It is not important in which transport zone a POI is located, because data of transport attractiveness of the transport zone will be updated automatically by the relevant GIS function.

2.1. Demographic data

The transport needs of residents are the main source of trips, including by individual and public means of transport [3]. Therefore, data on the number of residents and their characteristics (e.g. age, social status, means of transport possessed, and the number of trips made) is one of the basic pieces of information necessary to develop a transport model. A very good source of such data is the population register database. With respect to developing the models of the analysed cities, it was easy to collect such data, because the population register databases are maintained by the specialized Administration Departments of city offices in Bydgoszcz and Toruń.

The most important data available from the population register includes: a domicile, a name of street and house number, a gender, and a date of birth. The address data of a domicile has enabled to allocate residents to specific POIs in the VISUM database, and for this analysis such data has been aggregated into the following age groups: 0-9, 10-15, 16-18, 19-24, 25-60, 61 and more, 18-66, and 67 and more.

Hence, based on the database procedure, it has become possible to aggregate residents into the level of individual transport zones. Figure 1 presents the examples of definitions of the discussed POIs that describe address points.

The knowledge of the number of residents in each transport zone is used for several purposes, including:

• to determine the generation of individual trips with individual means of transport (usually on foot, by bike, by car as a driver or as a passenger) and by public transport (usually buses, trams, trains, and underground),
• to determine the attractiveness of zones in the motivation of private trips (applies in particular to home visits and revisits), and
• to determine travel generation in cargo transport (truck and van).

Every resident is a source of trips, where both their number and the mode of transport depend on numerous characteristics of residents, including so-called transport behaviour. Considering different transport preferences, which depend, among other, on the social status of residents (employed, unemployed, students) as well as access to the means of transport, residents have been divided into groups of homogenous transport behaviours. Such differences are particularly visible in the analysis of transport behaviour of persons who own or do not own a car (owning a passenger car means that a person has a vehicle at his or her disposal completely). The former group travels more often, usually using their own vehicle, and is characterised by lower travel resistance (much longer trips) and, importantly, much greater mobility (the number of trips). The latter group travels less often, trips take them longer, and they use means of public transport or walk. The differences in transport behaviours concern both the employed, the unemployed, and the students. They also depend on a place of residence: in or outside city limits. Therefore, to create a model of transport behaviour characteristics, it is necessary to divide the population into relevant categories, i.e. groups of homogenous transport behaviours [4, 5]. According to the studies carried out by the Department of Road Engineering and Transport, the University of Technology and Life Sciences in Bydgoszcz, in different regions of Poland (cities of different sizes and areas out of city limits, both rural and suburban), the following groups have been distinguished that are characterised by homogenous transport behaviours:
Figure 1. A fragment of a transport model map of the city of Toruń – population figures in each building

A. Residents of a zone:
   - pupils of primary schools (aged above 9) and junior secondary schools (gymnasium),
   - students of secondary and vocational schools,
   - students of post-secondary full-time schools, colleges, and universities,
   - the employed who own a car,
   - the employed who do not own a car,
   - the unemployed who own a car,
   - the unemployed who do not own a car,

B. Persons who rent rooms, live in students’ hostels and boarding schools (the same division as in A),

C. Persons who are not taken into account or do not travel (e.g. children aged 9 or less, patients of hospitals, etc.),

D. Persons who come from outside the city (division as in A).

Thus, 29 groups of people with homogenous transport behaviours have been distinguished in total.

Another objective of collecting data about the population figures is to determine the transport attractiveness of specific zones in terms of visits. The figure is determined according to the analysis of questionnaires among the residents. As regards Bydgoszcz, the ratio of visits per one resident during a typical working day is at 0.42, and in Toruń at 0.46. Also as regards the data about the cargo traffic volume, which means the traffic of trucks and vans, the data of population figures is an element of the traffic function; therefore, such population numbers are necessary. According to the analyses, the population numbers affect the volume of cargo traffic. Understandably, the more citizens, the higher the demand for deliveries of goods (e.g. products from online stores and large sized shopping) and for waste disposal.
2.2. Data on area development
To determine the attractiveness of individual transport zones in an analysed area, it is necessary to obtain much data about the area development in a city. Such data has to characterise the individual elements of town and country planning in terms of their attractiveness for generating and absorbing trips with specific motivations and concern the numbers of:

- jobs,
- pupils at primary schools and junior secondary schools,
- students at secondary schools,
- students at universities, colleges, and post-secondary schools,
- persons who live in students’ hostels, boarding-schools, etc.,
- customers who visit shopping malls, markets, points of service, shops, etc.,
- customers of hypermarkets, supermarkets, etc.,
- patients who use healthcare centres, surgeries, dental practices, etc.,
- people who use public utility facilities, culture centres (galleries, theatres, museums, cinemas, etc.),
- people who visit friends,
- people who go to recreation and wellness centres, facilities, sports centres, parks, etc.

The above-mentioned characteristics determine the attractiveness of specific transport zones in a city. It is particularly important to determine the following data for facilities that generate and absorb traffic:

- their exact location in the area of a city — the name of street and building number or geographic or surveying coordinates,
- the determination of the business activity,
- the determination of visitors at specific times of a day on an average working day.

The location of a point in the area of the city and the characteristics of its activity have been determined based on address data and information from a relevant Statistical Office. Each Statistical Office was requested for providing access to a database of active entities with information about their operations.

**Determination of the number of jobs**

It was very problematic, labour- and cost-consuming to determine the number of jobs for each point located in an analysed zone. Considering the fact that the information about the headcount is ‘sensitive’, the Statistical Office grouped such information into 4 categories:

- A: 0-9 persons,
- B: 10-49 persons,
- C: 50-249 persons,
- D: 250 persons and more.

As a consequence, only general information was obtained about the number of entities and the number of employees attributed to each of them. This division is certainly very inaccurate, but in the Polish conditions it has proven to be the only possible way to obtain data from the central database. The list of individual entities by groups for Bydgoszcz and Toruń have been presented in Table 1.

However, the employment attractiveness in terms of travel motivation adopted in the transport model necessitated the determination of a much more exact parameter that would describe the number of jobs. Therefore, a decision was taken to use additional data sources, namely:

- Directories made available by selected entities online (in particular local government administration, e.g. Marshal Office, City Office),
- Departments of City Office (applies only to entities that are subject to local administrators):
o Education (e.g. teachers and service providers at primary, junior secondary, and secondary school),
o Culture (theatres, museums, galleries, art centres, modernity centres, etc.), Health and Social Policy (emergency and education centres, pensioners’ homes, hospices, social care centres, social care institutions, hospitals, healthcare centres, specialist clinics, etc.),
o Sport and Tourism (administration and services of stadiums and sports grounds, sport halls, swimming pools, etc.),
\begin{itemize}
  \item direct correspondence with selected larger entities, including by e-mail and direct interviews (e.g. phone calls),
  \item own research.
\end{itemize}

Table 1. A slightly more complex table with a narrow caption.

| Group | Bydgoszcz | Toruń |
|-------|-----------|-------|
| A     | 40 430    | 22 901|
| B     | 1 624     | 781   |
| C     | 353       | 213   |
| D     | 74        | 45    |
| Total | 42 481    | 23 940|

The direct communication with selected largest entities enabled to gain more data from large businesses (groups D and C). Smaller entities were reluctant to give answers, by referring to the interest of their companies. In order to extend the data to all businesses, the missing data about the headcount in entities of Groups C and D was adopted by analogy with other entities from such groups. As regards the number of jobs in entities of groups A and B, the arithmetic average was adopted from the data collected by authors for such groups and based on own field studies.

Determining the number of pupils and students

The data concerning the number of pupils and students is usually public. Educational institutions often present figures of their pupils on their websites for advertising purposes. Moreover, local Education Departments in each city have such data and it is public. Likewise, information on the number of students comes from universities (full-time students) and their administrations (vice-chancellor and dean offices).

However, it has been problematic to gather data about the number of students at post-secondary schools. Such data is not available in the city departments of education. A good source of data can be either a direct interview or a contact by phone. According to the experience of the authors, mailing or e-mailing such entities is not effective, and information collected in this way is fragmentary.

Determining the number of persons who visit individual Points of Interest

To determine the number of visitors to POIs is another very important element in building transport models. The experience collected by the authors shows that this is a very good measure of attractiveness of individual area development zones. A very large number of entities that operate in urbanised areas (Table 1) prevents in practice the measurement of people who visit each such POI. Therefore, the study was conducted for a randomly selected sample of representative business entities divided into sections, departments, groups, and classes, and discretionally referred to by authors as categories.
The way of classifying entities into individual categories can be shown in the example of bars and restaurants. The applied procedure involved:

a) selecting from the set of all business entities the category of restaurants and other catering facilities, which includes restaurants, cafes, fast food bars, ‘milk’ bars, ice-cream shops, pizza bars, and take-away bars,

b) selecting from the set of all business entities a category of those that render the services in the preparation and service of drinks for consumption at the site, including bars, taverns, cocktail-bars, pubs, beer cellars, coffee shops, fruit juice bars, and

c) the allocation of individual entities selected in a) and b) to the groups in terms of headcount (groups A, B, C, and D).

Out of the entities selected in this way, the representative entities were chosen, for which field measurements were carried out in order to calculate the number of people who entered them in one-hour periods. For example, in Toruń the number of catering facilities in group A was 498, and in group B 23, i.e. 521 in total (there are no catering businesses in this city that would be classified in groups C or D).

The researchers who measured the number of people entering and exiting the facilities in each category determined additionally a so-called ‘general’ attractiveness of a zone where an entity was located. It was necessary to determine that factor, as the earlier studies of the authors showed that the number of visitors to a facility depends not only on the type of an activity and number of seats but also on the location in a city. The number of guests to e.g. a café with 5 employees and located in the city centre will be different from the number of guests to a similar café that also employs 5 persons but is located in a residential estate.

Table 2. List of largest shopping malls in Toruń

| No. | Name                  | Address                  | Number of jobs allocated to the centre | Number of visitors per day (exclusive of personnel) |
|-----|-----------------------|--------------------------|----------------------------------------|------------------------------------------------------|
| 1.  | C.H. Plaza            | Władysława Broniewskiego 90 | 560                                    | 4550                                                 |
| 2.  | C.H. Atrium           | Żółkiewskiego 15          | 850                                    | 6800                                                 |
| 3.  | C.H. Bielawy          | Olsztyńska 8              | 350                                    | 4760                                                 |
| 4.  | Castorama             | Szoza Bydgoska            | 50                                     | 1970                                                 |
| 5.  | C.H. Kometa           | Grudziądzka 162           | 120                                    | 4880                                                 |
| 6.  | C.H. Twierdza         | Dąbrowskiego 6            | 20                                     | 930                                                  |

The measurements covered the selected shopping-service points (both large, medium, and small shops), cultural centres (galleries, museums, and cinemas), healthcare centres (clinics, surgeries, and dental practices), factories, schools and universities, religious institutions and centres, sports and recreation centres, etc. The results of measurements and analyses were transposed to other entities, taking into account the type of activity, the number of jobs, and the general ‘attractiveness’ of a facility. For example, table 2 presents the list of the largest shopping malls in Toruń, and Figure 2 shows the daily entrances/exits distribution (including employees) according to field measurements on an average working day.

It is noteworthy that the listed attractiveness of individual facilities is a part of data that describes the area development in specific zones. Much supplementary data to this description comes from the results of questionnaires conducted among residents of such zones with direct interviews conducted at homes. This applies in particular to data such as the number of trips for private or business destination.
3. Summary
To develop a transport model of a city, it is necessary to gather much data concerning attractiveness of its specific areas, represented by the so-called transport zones. Collecting such data is very labour- and time-consuming, and hence also costly. It has to be emphasized that the quality and reliability of such data will determine the accuracy of mapping the actual trips of residents in an analysed area. Therefore, it is very important to collect and use all types of local databases skilfully, and next to apply relevant procedures and spatial functions that enable the fast and automatic attribution of adopted attractiveness measures to a specific analyses period (e.g. a day, morning rush hours, etc.) to facilities and to aggregate the same to the level of a transport zone. The primary advantage of such solutions in transport analysis is the option to develop any number of transport zones without the necessity to carry out additional and painstaking work involved in the determination of attractiveness for each zone.

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