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Transport Demand Model Management System

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Abstract. A huge amount of data is required to the contemporary city management, control over its operation and sustainable development. Transport systems are one of the basic components of society each day life. Effective management of the present operation of transportation systems as well as their effective development according to transport demand management requires the use of a number of IT tools. One of them is undoubtedly the transport demand model. The main purpose of such mathematical model is to reconstruct the phenomenon of the transportation systems operation being a service to meet the current transport demands of residents of the study area, including private and commercial trips. Large amount of data is needed to build such a powerful tool. Both land use and transport infrastructure data must be included, and additionally their users - residents and visitors. The sources of this data are located in various council of city/town or county administrators, including, among others, urban planning councils, road administrators and public transport supervisors. Undoubtedly, the reliability of data collected in these models is one of the biggest problem. With intensive technical and social progress, many residential, industrial, etc. investments, data is very quickly outdated. Consequently, it leads to erroneous results of transport analyses, which may lead to an increase in broadly understood transport costs. Therefore, there is a need for such organization and availability of this data to enable fast and efficient updating of transport demand models. Bearing in mind the above, the article presents a framework for a comprehensive transport demand model management system. The article is summarized by conclusions regarding further work on the transport demand model management system.

1. Problem definition

Transportation systems, as the fundamental element of each city/town or village, are one of the basic components of society each day life. They enable to meet of the main social demand of residents living in the analyzed area – private and business trips made by them every day. Effective management of the present operation of transportation systems as well as their effective development according to transport demand management is one of the mile step into sustainable and effective development of each city, town or region. Actually, keeping in mind lots of data involved in such management, the use of a number of IT tools seems to be required. One of them is undoubtedly the transport demand model.

Transport demand models are used mainly by the well developed countries, where the optimization of transport processes is one of the key task of the city authorities. The mathematical description of phenomena related to the current operation of transportation systems and satisfying the current transport demand of residents, including private and commercial trips, is the main purpose of these models At the same time, the predictive transport demand models allow to define forecasted transport demands in next 20-25 years and the effects of investment activities aimed at satisfying these demands.

The ideas of building demand transport models, their various constructions and mathematical formulations have been described many times in the literature [1, 2, 3]. From the very beginning their

construction and mathematical formulations were very simple, based on many simplified assumptions which were primarily the result of lack of computing power and access to detailed and reliable data concerning transportation systems and land use. Along with the increase in computation power of numeric devices, the development of knowledge, computing techniques and easier access to data from increasingly common databases, often also GIS databases, the accuracy of mapping of real transportation systems in these models has significantly improved. At present, these models are more and more often not limited to the basic transportation system (mainly private and public transport network - the major arterial system) [1, 2], and cover almost the entire transport service including minor arterials, collector roads, local service roads, and also the whole transit service, sidewalks and bicycle paths, as an important component of transportation systems [4]. However, one of the basic problem of transport demand models, both those that describe the existing transportation services in a study area, as well as those for forecasted scenarios in which planned transport investments and forecasted changes in land use are included, is their ongoing update. The time required to develop the preliminary version of transport demand model describing the existing transportation services for medium and large study areas, including field inspections and data collection process, often exceeds one year. Acquisition of data on the supply layer - transport facilities of the study area, describing both their technical parameters e.g. length of arteria sections, their capacity, speed limits, public transport lines' routes along with detail timetables (headways, run time between individual stops, etc.), their technical state, as well as the demand layer - users of these transportation systems and their transportation behavior, requires a lot of work, money and time. It is quite typical several or even several dozen months are required to build such a model, during which new changes in these systems occur (changes in timetables, traffic organization, new transit lines and routes, and even transport systems like the public bike or park and ride system). This is because study areas, and especially those with a high degree of urbanization, are subject to constant changes and transformations. They are, in a sense, living organisms in which various phenomena occur, being a consequence of demographic, social and economic changes. Because of that, usually, ready-made transport demand model is out of date on the day it is transferred to the local authorities as an institution responsible for its operation. Updates of transport demand models for the present state and forecasted scenarios seem to be an equally large and even bigger problem. In these models, both transport and land-use investments are recorded, whose timing and scope usually change. It often happens that due to the lack of detailed data on transport investments, new investments included in forecast scenarios models, especially those that are planned in a distant time horizon, are described as exaggerated, with a large degree of generalization of their probable technical parameters (e.g. routes of new transit lines and their headways, types of new intersections and interchanges) which influent into the results of traffic analysis. Analogical problems relate to changes in land-use investments - a description of future sources and destination of residents' and visitors' trips. This particularly applies to the construction of large housing estates or shopping malls. It is common that decisions regarding these investments change, like the scope and size of these investments, assumptions regarding accessibility to transport infrastructure, etc. It also happens that the planned large investments do not come to true, and the areas assumed in transport demand models as future huge trip generators do not really exist. In addition, usually studies related to traffic forecasts as the input for cost and benefits analyses or studies on the impact of the given transportation investment on the environment and technical specification of these investments are carried out by various design and research teams, and the results of their work are not mutually coordinated.

As a consequence, the results of analyzes for two different projects are not consistent which creates a big problem when assessing the legitimacy of investment. What's more, many inconsistent versions of the same forecast scenarios of transport demand models are created, which leads to chaos. It is not clear which version of transport demand model is correct and which one should be used in the analysis of subsequent transportation investments.

Therefore, there is a need to implement procedures and tools enabling ongoing work on the timeliness and coherence of these transport demand models: models that reproduce the current state of transport systems, as well as those developed for the future periods.

The Transport Demand Model Management System (TDMMS) can be such a tool, which is foreseen as the IT tool supporting both the process of data collecting, synchronizing and processing for the needs of the current update of transport demand models, as the basic IT tool for transport demand management (TDM) [5, 6]. This paper presents the framework of the construction of the TDMMS.

2. Conceptual TDMMS framework

The basic role of the TDMMS is to manage the transport demand model of the study area, especially important urbanized one, first of all by allowing easy and quick access for both those responsible for the transport demand management and for individual offices dealing with transport to:

- data necessary in the process of updating and using transport demand models for day-to-day transport management or for any related activities;
- data supporting planning process, designing, construction and maintenance of road infrastructure;
- results of current transport demand analyzes, including feasibility studies for investments in road, public and rail transport (in accordance with the recommendations of the Blue Book, Jasper 2015 for each of the above transport systems [7]);
- results of monitoring of transport demand model consistency to results of traffic counts, including consistency to results produced by previously developed prognostic models;
- results of specialist analyze regarding the operation of transport (usually performed as a contract work for a specific agencies);
- all auxiliary materials in broadly understood education in the role of transport, its impact on the lives of both residents and the economy, the impact on the environment and climate, etc.

Publishing the results of transport research and analysis, both current and prognostic, as well as other parameters directly related to transport (e.g. data from the scope of pollution from transport and noise) is an additional role of the presented systems. The assumption of the system is also to enable active action to make transport models more detail and precise by all offices and companies not directly related to transport demand models (including members of numerous social associations) and to individuals, while educating them on the role and importance of transport issues. Such an assumption gives an opportunity to conduct current changes in the collection of data necessary in the management of transport demand models. The active use of the TDMMS database resources by users enables to collect a series of hard-to-access and expensive data on transportation behavior of transport systems' users.

It should be borne in mind that the user of any area, especially the urbanized one, realizing daily trips on streets and roads, as a pedestrian, passenger of a car or other means of transport, or as a driver is exposed to large losses of time and costs resulting from these trips. What is more, he/she is exposed to be a victim of an accident in a trip, as a consequence of common conflicts between various users of transport infrastructure, as well as damage to health as a result of common pollution from transport accompanying the trip. Therefore, not only administrators, not only transport-related companies, but every resident as a user of transport infrastructure, and every social association should have constant and quick access to data related to transport systems, available possibilities of take trips, as well as opportunities for efficient mobility. At the same time, it should be aware of the causes and needs of actions in the field of improvements in transport systems, new transport investments, taking active part in their planning and giving opinions through the exchange of own ideas and experiences. Opinions of transport systems users constitute a source of valuable information for social functioning and transport preferences for those who operate them.

The basic features of the presented TDMMS, which on the one hand enable the current management of the transport demand models, and on the other ensure their effective use are:

- real low implementation and operation costs;
- ease of access;
- user-friendliness;
- credibility and timeliness.

Bearing in mind the huge number of web portals, including social networking sites, their universality and availability from both personal computers and mobile devices (mobile phones and tablets), the application of advanced IT techniques based on websites idea, including map services, GIS techniques and social media experiences, is the basic condition for achieving the assumptions for the TDMMS. The application of database portals techniques allows to avoid the need to purchase specialized software by institutions and offices co-creating the TDMMS database, it is ease of development, easily customized interface, rich functionalities, and pluggable architecture [8]. Thus, the first of the assumed features is partially fulfilled - a low cost of implementation and operation. The fast, easy and free of charge access to basic information about transport systems, the possible trip mode, forecast time and cost of trip guarantees the fulfillment of its other features. The transparent structure of the TDMMS web portal, with the appropriate user friendly graphic layout and intuitive access to all necessary tools, using good and tested practice implemented in the most popular news, social and map websites, modeled on Google Maps or so on web services, enable simply operation without special training for its users. This in turn is an element encouraging to actively use it. The validity and credibility of information and data collected on the portal, verified by database administrators, should encourage both institutions related to the current maintenance of the TDMMS and other users to the current use of its data. And this, in turn, should contribute to a significant improvement of everyday trips carried out in the area covered by the TDMMS.

Proper identification of potential users of the TDMMS web portal, personalization of the content of the web portal to individual user groups, should ensure efficient use of its resources, and at the same time contribute to its further development. Therefore, to meet these demands, the separated groups of users should be indicated:

a) Inhabitants and visitors, taking everyday trips related to work, study, and remaining activities for which efficient and at the same time cheap trips between sources and destinations is one of the most important elements of everyday activity.

b) Tourists for whom an efficient trip in a strange place are an indispensable element of their travel.

c) Agencies directly responsible for land-use planning, including future changes in these planes, development of transport systems infrastructure, and facilities accompanying these systems.

d) Local authorities - including, in particular, presidents of cities, gubernators and mayors, as well as councilors in local governments, for whom ensuring safe and efficient daily trips of residents is one of the basic statutory task, and at the same time it is a tool in political rivalry and presentation of the effects of their work.

e) Road administrators and those responsible for traffic - in their daily activity in the field of administration, organization, control and optimization of traffic flow.

f) Public transport administrators - in planning transit services for residents, optimization of its operation, research on transport demands, updating of routes and timetables of transit lines, as well as ongoing monitoring of individual transit lines operators.

g) Agencies responsible for public safety, including the Police, Fire Department and Emergency Medical Services, for whom data on the current status of transport systems significantly corresponds into the effectiveness of current activities.

h) Social organizations, associations and housing councils - acting to improve the transport operation of the city and its housing estates, promoting their ideas and proposals for new transport solutions.

i) Media - informing residents about the current situation in transport, observing residents against potential difficulties and threats, as well as providing reports and discussions in the field of transport service and its improvement, educational programs and promoting changes in the way trip are and maybe be performed, the role of individual transport systems, etc.

j) Pupils and students, as well as older people – learning issues related to transport, its development, the role of transport systems, new technical solutions and challenges in transport, the need for changes in transport behavior, etc.

k) Planners and designers – employed by design and consulting companies, developing transport designs for which data from the scope of current and forecasted transport demands are the basis for dimensioning transport investments as well as economic analyzes justifying individual transport solutions.

l) Scientists and researchers - dealing with phenomena occurring in transport, including transport behavior and preferences of users of transport infrastructure, working on improving the quality of transport demand models, their accuracy and reliability.

The scope of necessary data for the proper operation of transport demand models on the one hand and knowledge of the users' expectations of the web portal make [9, 10] it possible to determine the necessary content of this web portal. Bearing in mind the dynamic development in the IT industry, whose achievements are successfully implemented in individual areas of transport systems (e.g. ITS - Intelligent Transportation Systems, dynamic passenger information systems, etc.), enforces the modular construction of the TDMMS. This modularity consists in the possibility of supplementing the TDMMS with new, at present unpredictable blocks of static and dynamic data as well as new analytical modules as a consequence of the development of the state of art, progress in a mass information technic and technology, as well as the development of new forms of transport (bike share, car share, or private light electric vehicles - skateboards, scooters, etc.).

At present it is expected that the following thematic and analytical blocks will be included in the TDMMS (see figure 1):

a) Current data on the operation of individual transport systems in the area covered by the TDMMS, including the following data on transport systems:
- road transport infrastructure and its properties, i.e. sections (length, traffic permits for groups of vehicles, capacity, speed in free flow traffic), intersections, interchanges, parking lots (number of parking spaces, parking fare, etc.);
- public transport infrastructure and its properties, i.e. transit lines and their routes, detailed timetables for each transit line along with times of run time between stops, properties of stop points and transfer stops are;
- bicycle infrastructure, i.e. path sections (length, capacity, vertical inclination), intersections, as well as cycle parking lots (number of parking spaces, parking costs, etc.);
- bike-share infrastructure, described as above, but additionally supplemented with data on bike-sharing docking stations, accessibility and fees rules;
- pedestrian infrastructure, i.e. sidewalks (length, pavement state, vertical inclination), zebra crossings etc.

and statistical data calculated by the transport demand model including for example results on:
- the total number of trips and their spatial distribution (trips table) by all transport systems;
- transit transport statistics, including average ride speed, trip time, average number of transfers per trip, total number of passengers, average occupation of transit vehicles; etc.;
- traffic volume and vehicle mix, along with plot presentation;
- vehicle-kilometers and passengers-time in road transport subdivided by road classes;
- traffic-related environmental impacts and quality of life of residents, including the air pollution from cars and trucks such as CO and NOx, as well as noise.
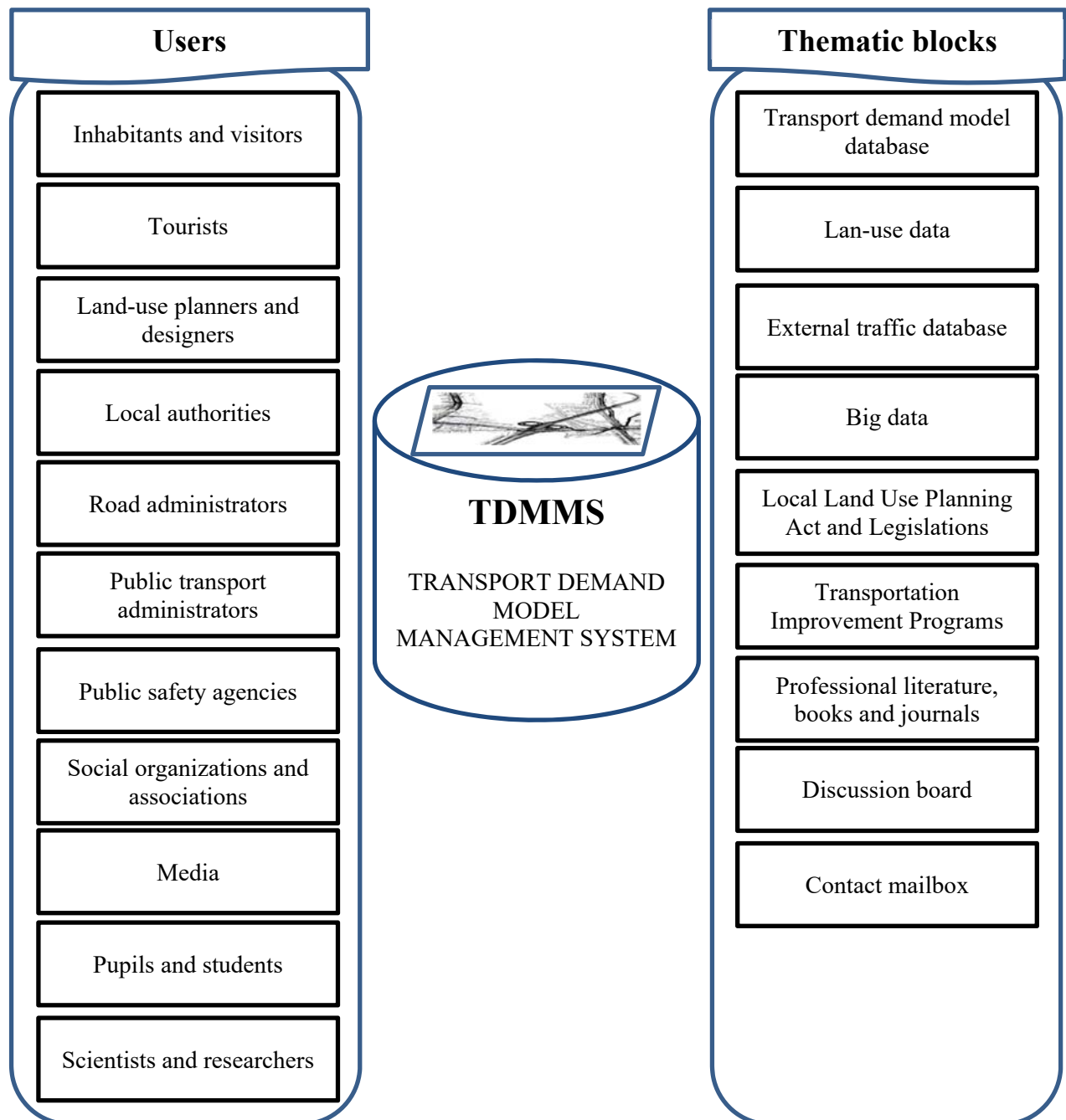
Figure 1. Thematic blocks of the TDMMS and its users.

b) Data on land use of the study area, including data for the current state and forecast years regarding:
- number and the age structure of residents living in areas/zones being trip's sources and destinations grouped by persons with the homogeneous transport behaviour;
- characteristics of the residents' transport behaviour living in the study area (in particular areas/districts), i.e. mobility, trip time preferences, average trip distance and duration, preferences in the trip mode choice, assessment of factors affecting transport preferences, etc.

- number of houses, households, office areas, production halls, commercial spaces, as well as their operation characteristics (e.g. amount of electricity and water consumption, volume of waste and contaminants removed, etc.);
- attractiveness of particular areas/zones described by work places, education, private activity, shops and services, shopping malls and others.

c) Data on external traffic, that is: absorbed by (entering), generated by (exiting) and through (passing) the study area subdivided into trip modes, also research results on traveller transportation behaviour (mobility, trip motivations, distance and time, mode choice etc.).

d) Mass data (so called the big data), derived for example from users of mobile devices, enabling analysis of the directions of displacement of users of these devices, but characterized by high uncertainty and incompleteness of information about them.

e) Data based on Local Land Use Planning Acts and other public documents, studies and legislations related to land use and transport.

f) Data based on transportation improvement program and planned transport investments together with a detailed description including:
- detailed schedule of investments implementation along with the history of their updates;
- designed parameters of new investments in road infrastructure, e.g. alignment of new road sections (lengths, traffic permits for groups of vehicles, capacity, free flow speed), types of intersections and permitted turns at intersections, interchanges, parking lots (number of parking spaces, parking fare system, etc.);
- designed solutions for public transport and its properties, including privileges and priorities for transit vehicles, routes of new or modified transit lines, planned detailed timetables to be served, forecasted run times between individual stops, data on vehicles in service (specification of buses, trams etc.), planned public transport stop areas, etc.;
- designed solutions for bicycle transport, including new bicycle routes and paths, and the development of the bike-share system;
- designed solutions in the field of innovative forms of transport (like electric bikes, skateboards, scooters, rollers);

g) Transportation improvement programs and effects of investment activities, including their benchmarks, justifications, their impact on travel costs and the environmental impacts of those investments.

h) List of journals, books, professional literature and references to other websites undertaking similar issues, as well as legal acts regulating activities in the field of transport systems (e.g. transport plans, laws and regulations) and other studies and papers.

i) Discussion board (forum) - in the form of an open discussion panel, to exchange of information, comments and chats of portal users on issues related to the operation of individual transport systems, new implemented and planned transport investments, plans for changes in land use, comments and recommendations to the content of the portal, etc..

j) Contact email box - the place of reporting any comments to transport demand models, including: noticed their incompatibilities with reality in the field of transport systems and land use, transport operation or erroneous or doubtful reports from model calculations.

The content of the TDMMD should include both current and historical data in the above-mentioned topics. Thus, as part of the system, it will be possible to analyze trends and changes in socio-economic characteristics, socio-demographic characteristics, transport system performance parameters, changes in transport behaviour of users of individual transport systems, changes in external traffic, etc.

The modular design of the TDMMS means at the same time, that the above range of this IT system content should be treated as the initial one - its initial version. The development of information technology, the growing computing power and data storages capabilities of hardware, speed and data transmission capabilities, access to newer and more accurate database resources, and the continuous development of numerical and metering techniques, including the wider use of ITS will force the

emergence of new forms of content and data analyzes presented in it in the future. It's predicted, that the TDMMS will be flexibly adapted to the real present and futures needs of its users.

The wide range of data expected to be collected in the TDMMS on the one hand is to enable the full up-to-date transport demand models, their coherence and homogeneity, and on the other hand contribute to lowering the costs of this data collection. Some of the above-mentioned data undoubtedly has the character of sensitive data, partially or fully protected by law. Therefore, in the TDMMS, access to its individual modules is controlled by the granted access rights guaranteeing the protection and credibility of the data contained therein. That is why, five groups of data are provided:

a) data necessary for work related to the ongoing maintenance of transport demand models, their adjustments, calibration and updating in accordance with current and planned investment activities;

b) open data, available to everyone, presented without restrictions within a internet portal;

c) results of research and calculations of a commercial nature, ordered by business units, design offices, social organizations, as well as companies and consulting agencies on a fee basis, being one of the sources of financing the TDMMS maintenance and development;

d) data collected and processed by local authorities, e.g. road administrator, urban planning agencies, transit administrator and supervisor, energy suppliers, water suppliers etc.

e) research data for the development of science and knowledge in the field of transport demand models and phenomena occurring in transport.

3. SWOT analysis of the TDMMS

Presented framework of the Transport Demand Model Management System are the foundations for its construction and implementation stages. The wide range of both the TDMMS's users and its intended scope of content on the one hand give an opportunity for its active service, and on the other hand it may be a significant barrier to its implementation. Therefore, in order to identify the potential possibilities of this system implementation, but also the barriers that may stand in the way of its start-up, a SWOT analysis of the assumptions to the TDMMS's construction has been prepared. The strengths and weaknesses as well as opportunities and threats indicated below are the perceived features of this system, to which particular attention should be paid at the stage of its implementation and service.

The strengths of the presented the TDMMS should include:

1. Integration of many important transport and land-use databases of the study area in one place, at the same time ensuring the possibility of data sharing and creating more reliable database in above mentioned issues.

2. New and planned transport investments database, their scope and impact on the level of transport service of the study area - ensured by the continuous data update by all responsible for individual thematic blocks.

3. Educational role, which means that thanks to the access to current transport data, actual state of transport systems, residents have the opportunity to learn about the role of transport issues, and also get the opportunity to participate in shaping the transport service.

4. Modular construction, enabling the development of new blocks with thematic areas in accordance with the development of knowledge and actual needs.

5. Easy access to service on any device connected to the Internet (mobile phone, tablet, laptop, computer) without the need to use dedicated software.

6. Openness to all transport infrastructure users - everyone can use the website, he/she can suggest his/her corrections in descriptive and mapping data, just as, for example, in the OpenStreets website [11].

7. It provides a place to share data and information between users of transport infrastructure, giving the opportunity to discuss, consult, provide directions and advices, and even to survey users of transport infrastructure.

The identified weaknesses comprise the following:

1. A relatively high level of financing required during the construction phase of the initial version of the system is required.
2. A large amount of work while aggregating data coming from different sources and verifying their reliability.
3. The reluctance of administrative offices to share the collected data, as the results of uncertainty in the reliability of the data their held.
4. Risk of sharing sensitive data, including personal one.
5. Large diversity of databases created by various agencies and companies, their low quality and reliability, as well as mutual incompatibility.
6. The necessary large space capacity for data storing and their backup copies.
7. Exposure to be infected by viruses and cyber-attacks.

The opportunities arising from implementation of such system are:
1. Increasing activity of transport infrastructure users, especially of various associations, in the field of solving transport problems.
2. Growing interest in different sort of social network web portals.
3. Increasing public awareness of the role of transport, transportation facilities and transport behavior in everyday life.
4. Increasing possibilities of numerical data storing and computing power of digital machines, including dedicated computing servers.
5. Growing number of detailed databases on land-use and transport systems, both open and paid ones.
6. Increasingly faster and cheaper data transfer within the Internet network, including primarily mobile internet networks.
7. Self-financing from advertisements presented on the service website and from business side interested in promoting their own transport solutions.
8. Development of new system's blocks supporting taking trips by all possible modes in the study area.

The threats to the development of the described system include:
1. Lack of adequate financing for ongoing maintenance and development.
2. Difficulties in acquiring new service users.
3. Competitiveness of other systems with similar problems, but not related to transport models.
4. Delays in updating the data contained in the system, affecting its timeliness.
5. Strong impact on the protection of personal and sensitive data limiting access to detailed data about residents and their transport behaviour.

4. Conclusions
On the basis of the presented study, the following final conclusions are formulated:
   a) information modelling about object at various stages of its existence, from the design stage, through construction, to its liquidation, modelled basing on BIM solutions, is increasingly applicable;
   b) the growing role of transport demand models enabling replication both the present life of the society in the study area, the optimization of the broadly understood transport and forecasting of future transport demands, forces the need to integrate and organize work related to these models through, among others, building information models about these solutions;
   c) the main goal of these activities is to obtain the highest level of accuracy and reliability of transport demand models, by feeding them with current data, as well as to consolidate the results of transport analyzes in the field of planning transport infrastructure and land-use development;

    d) the presented assumptions for the construction of a transport demand model management system are the basis for the development of a block diagram of its construction, and these for building logical structures of its relationship with agencies responsible for its life time and future development.

    e) identification of potential the TDMMS users allows to determine its content, and thus the sources of important data on the manner of implementation of daily trips of the inhabitants of the study area;

    f) the modular structure of the system enables not only adjusting its content to the present transport systems, but also to the needs of the developing information society, for which access to social networks and news services becomes the basis of existence.

There is a growing need to build IT systems that enable ongoing management of increasingly complex transport models. At the same time, it should be emphasized that the SWOT analysis presented in the work indicates potential weaknesses noticed by the author and threats to the presented solution, as well as a large range of challenges that will appear at the implementation stage of the proposed solution.

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