Design and development of a road traffic redirection system

M. BAZAN, T. JANICZEK, K. HALAWA, R. DUDEK, Ł. RUDAWSKI
WROCŁAW UNIVERSITY OF SCIENCE AND TECHNOLOGY, Faculty of Electronics, ul. Janiszewskiego 11/17, 50-372 Wrocław, Poland
EMAIL: marek.bazan@pwr.edu.pl

ABSTRACT
Nowadays, the crucial issue of guidance systems based on a GPS signal is that they are not able to redirect road users, taking into account the current state of traffic (and the predicted state within the time of the travel) in the city. In this paper we present a three layer architecture of a computer system capable of redirecting users of an urban road system via routes with a lighter traffic load in order to reach their declared destination in the city. A basic layer is a multiprocessor calculation server running Dijkstra path search tasks, the middle layer - the one which is visible to the road user - is a replicable proxy server that collects route requests from road users. The third layer is a mobile application. The prototype of such a system was developed by the ArsNumerica Group. The crucial feature of the system is feedback from road users that allows us to adjust the whole Intelligent Transportation System in the city to changes in traffic flow at various road links introduced by the redirection process applied to many users. The performance test strategy to prove the efficiency of the architecture was carried out for the city of Wrocław.

KEYWORDS: traffic redirection, Dijkstra algorithm, fastest path finding algorithms, dynamic rerouting, guidance systems

1. Introduction
In recent years the ArsNumerica Group has implemented and tested three designs of a redirection system that would serve a road user as a guidance system that enables to drive from one point in the city to another via the fastest route (in the shortest time). The fastest of course does not mean the shortest one – it means the route calculated taking into account traffic load in particular places of the city – places that are controlled by an Intelligent Transportation System. The implementation of the prototype of the system that is presented in this paper enabled the establishment of scalability parameters so that the system extended with many calculation nodes becomes a high availability, high responsiveness system.

Figure 1 shows a sketch of the design of the system. It consists of three layers. The one visible to road users is a mobile phone application that enables logging on to the system and to enter a destination point. Afterwards the origin and the destination is sent to the server proxy that checks whether such a query has not been requested by another user recently. The check is done within the local cache. If the same origination - destination has been within the prescribed time it is accessible for users from the cache on the proxy server and no communication with the calculation server – the deepest layer of the system - is necessary. The calculation server obtains a task to process from the proxy server – i.e., to calculate the fastest route between the origin and the destination only if a task is not in a local cache of the proxy server. The calculation server is also responsible for downloading a description of the current traffic situation from an Intelligent Transportation System of the city.

In Poland, systems of a similar functionality are already available. To our knowledge however, all systems available are based on GPS speed estimation [8, 9]. Moreover such centralized systems as [10] are based on GPS data collection from users who possess an Android phone.

The prototype of one calculation node system presented in this paper enables us to establish conditions for a multiple calculation node system (currently being developed by the ArsNumerica Group) to possess a property of high scalability using low cost machines (11)).
The ITS, all the tasks that are currently processed are canceled. The new weights corresponding to the traffic load in the network from the supposed to react? After downloading the package containing a substantially changed situation on the road. How is the system expected to act? A package with the current state from the city ITS and updates a map of the urban area. Secondly, it maintains the current route solutions for a given pair of nodes in the graph that represent the roads in the whole system. First of all it provides the quickest path between start and end nodes in an urban area. The weights on the edges are inversely proportional to the travel speed or the congestion on the corresponding road section. The classical method to calculate the shortest path between nodes in a graph are Dijkstra and A* algorithms [2]. These algorithms do not require any time consuming preprocessing of a graph and thus fit to the architecture of the tested system. In [1] we tested various versions of multithreaded Dijkstra algorithms to find out that the most effective shortest path algorithm from the Dijkstra family is the two thread bi-directional Dijkstra algorithm with Fibonacci heap used to calculate the closest node to the currently processed one. Each thread starts to search from the start and the end node until the balls around the start and the end node meet and to search for the closest node at each step two instances of a Fibonacci heap are employed – one per thread. Similar evaluations of road networks can be found e.g., in [5].

Such a version of the Dijkstra algorithm was implemented in our calculation server. The results of our tests are in accordance with the ordering of the algorithms for finding the shortest path with respect to their computational complexity [3]. The bi-directional Dijkstra algorithm is asymptotically the fastest amongst algorithms without any preprocessing.

Algorithms with preprocessing, such as arc flags family algorithms [4] turn out to be problematic since the calculation of arc-flags may last longer than the time between the current road traffic state downloads, therefore their usage in real time may be limited. On the other hand, if we used such an algorithm as the arc-flags algorithm, the separation of a calculation server from a proxy server would be questionable since the calculation server would do only preprocessing common for all client applications. The bi-directional Dijkstra algorithm is used commercially in such software as MapQuest, Yahoo! Maps or Microsoft MapPoint (c.f. [6]).

### 2. The architecture of the system

The architecture of the system consists of three layers: a calculation server, a proxy server and multiple client applications.

#### 2.1. The calculation server

The main aim of the calculation server that is the foundation of the whole system is twofold. First of all it provides the quickest route solutions for a given pair of nodes in the graph that represent a map of the urban area. Secondly, it maintains the current state of the weights of the graph based on connection with the intelligent transportation systems. Every 5 minutes it downloads a package with the current state from the city ITS and updates a graph by a procedure of swapping. Here the problem arises with a substantially changed situation on the road. How is the system supposed to react? After downloading the package containing new weights corresponding to the traffic load in the network from the ITS, all the tasks that are currently processed are canceled. The information on cancelation is also sent to the proxy server since some of the queries from the client are not sent from the proxy server to the calculation server but the response is retrieved from the local cache of the proxy server. This operation is performed by the thread that downloads ITS data and is done every 5 minutes.

In case of the ITS state update the cache of the proxy server is cleared. After updating the map graph by a thread on the server the tasks are recalculated. One may think of the UDP message broadcast to all waiting clients that recalculations due to traffic changes is taking place. The protocols used to connect to the ITS can be TCP. The protocol that is used to connect to the proxy server is also TCP. The format of the message that comes from the proxy server is shown in Figure 2, whereas the format of the response is shown in Figure 3. Each request in the calculation server is served in a separate service thread. The aim of a service thread of the calculation server is to effectively calculate the shortest path between start and end nodes in an urban area. The weights on the edges are inversely proportional to the travel speed or the congestion on the corresponding road section. The classical method to calculate the shortest path between nodes in a graph are Dijkstra and A* algorithms [2]. These algorithms do not require any time consuming preprocessing of a graph and thus fit to the architecture of the tested system. In [1] we tested various versions of multithreaded Dijkstra algorithms to find out that the most effective shortest path algorithm from the Dijkstra family is the two thread bi-directional Dijkstra algorithm with Fibonacci heap used to calculate the closest node to the currently processed one. Each thread starts to search from the start and the end node until the balls around the start and the end node meet and to search for the closest node at each step two instances of a Fibonacci heap are employed – one per thread. Similar evaluations of road networks can be found e.g., in [5].

Such a version of the Dijkstra algorithm was implemented in our calculation server. The results of our tests are in accordance with the ordering of the algorithms for finding the shortest path with respect to their computational complexity [3]. The bi-directional Dijkstra algorithm is asymptotically the fastest amongst algorithms without any preprocessing.

Algorithms with preprocessing, such as arc flags family algorithms [4] turn out to be problematic since the calculation of arc-flags may last longer than the time between the current road traffic state downloads, therefore their usage in real time may be limited. On the other hand, if we used such an algorithm as the arc-flags algorithm, the separation of a calculation server from a proxy server would be questionable since the calculation server would do only preprocessing common for all client applications. The bi-directional Dijkstra algorithm is used commercially in such software as MapQuest, Yahoo! Maps or Microsoft MapPoint (c.f. [6]).

#### 2.2. The proxy server

The proxy server is a pass through server that collects two types of messages from mobile devices connecting from the city. The first type is a logon message in which the origination and destination nodes are contained. The requests originate from the devices via UDP protocol in the format presented in Fig. 2.
A format of a message that is received by the calculation server from the proxy server. The first number is a unique identifier of the mobile device that the request has come from – perhaps e.g., the MAC number of the network card. The starting node number is an ID of the node in the map. A database of the GIS locations of nodes should reside on the calculation server and on mobile devices [own study].

The second type of message is a message containing a piece of information on the travel time between the two subsequent nodes that the vehicle containing the mobile device has just achieved. The format of this type of message is shown in Figure 3.

A format of a message that encodes a response of the calculation server and is sent to the proxy server. The first number is a unique identifier of the mobile device that the request is going to return to. The second is the number of nodes that the optimal route consists of. N_k is an ID number of the k-th node (the vertex in the graph) in the optimal route. Hence, t_k is the travel time required to pass the connection between nodes with IDs N_{k-1} and N_k. It is important that in the graph there is a direct connection between N_{k-1} and N_k for k=2,…,N [own study].

After receiving a request from a road user’s mobile device, the first thing the proxy server does is check whether the calculation for the same request has already been done by the calculation server since the last update of the traffic state from ITS or from the proxy server itself – that collects travel times from vehicles already driving via routes sent them from the system. If such a calculation has been performed already it is in the local cache of the proxy server.

The local cache is implemented on the SQL database. The database schema that implements a local cache required to maintain data in order to prevent a considerable number of requests to the calculation server is shown in Figure 5.

A format of the message sent from a mobile device to the proxy server to update a current travel time on the link starting from N_s and ending at N_e that the vehicle with the device has just driven [own study].

In such a situation the table CURRENT_TIMES table is updated. Please note that there is no problem with concurrency since only the recent travel times record received is stored for a particular pair of nodes.

The content of the cache is sent to the calculation server every prescribed period of time. It is clear that the travel times contained within the cache are very reliable and thus they can overwrite times from the ITS, those which are not measured using license plate recognition but estimated from the fundamental diagram using only vehicle counts on the intersections (see [12] for a method).

2.3. The road user application

The task of the client application is twofold. First of all it is for sending a request to the proxy server in a format shown in Fig. 2. The N_s is a current spatial position of the device. The request is sent to the proxy server asynchronously with UDP. Once a response is received from the proxy server – which in turn got the response from its local cache or got it from the calculation server – the route is visualized. To do this the application has to have a city map installed. The city map has to be stored in a form of the database table – similar to the table NODES_COORDINATES at the proxy server. It is necessary for the client application to be able to find the closest node from which the route can be tracked with a traffic load. It of course cannot calculate naively the closest
node to the current start position, since the closest node may not give the possibility of reaching a destination point. So the client application has to have the ability of performing the Dijkstra shortest path calculation – of course the weights of the graph would be the length of the edges. As a simple database manager one can use one of the in-memory solutions for mobile systems (e.g., [19]).

The second role of the client application is to provide the calculation server – via proxy server - with the update of the current travel time on the edge the vehicle with the device has just passed, while traveling on the route received from the proxy server. This information is sent to the proxy server also via UDP in a format presented in Figure 5 every time a map node is passed while driving.

To provide the multi-platform application the Xamarin package can be used (c.f. [13]). The Xamarin development environment enables us to write a code in c# and to build the executable and deploy it not only on the Windows Phone platform but also on Android and iOS platform.

3. Tests of the system with the Apache JMeter

The implementation of the server side of the solution was done in c++ language. Both the calculation server, as well as the proxy server are multithreaded, enabling to serve multiple users at the same time. The tool that we used to measure how the solution is able to handle a load of many concurrent users is the JMeter created by Apache (see [7]).

The Apache JMeter is a testing tool that allows us to analyze a throughput of internet services and databases via such protocols as TCP/IP or FTP. With this tool one can measure response times, the influence of the volume of the requests handled, the amount of data sent and received. It is written in Java and therefore is fully portable and is an appropriate tool to measure the effectiveness of the implementation of a client-solution deployed on any platform.

The usage of the Apache JMeter in our application for the system testing relies on the creation of the parallel threads which send requests to the tested servers. Then the performance report is created. To generate requests from JMeter threads one has to define their message content and specify a number of messages that are to be sent to the tested server in a prescribed period of time. In this work the JMeter tool is used to test the availability of the solution, scalability and to get the estimation of how to make a load balancing of the system.

3.1. Tests description

To determine the performance of the entire system, each component needed to be tested separately. Based on the result of the tests an overview can be created showing which component is the slowest. Thereby an assessment of the number of processed requests at once is possible as well as a further optimization of the whole system.

All tests presented in this section were carried out on a low cost machine, i.e., a computer with AMD E2-3000M APU processor, with 2-cores, 2GHZ with 4GB RAM SODIMM DDR3. Such a choice was intentionally done to have an insight into the future behavior of low cost machines as part of the calculation cluster implementing the final version of the system (c.f. [1], [2]). During testing each application worked on an individual computer communicating wirelessly via a LAN network, so delays associated with the load of global network were not taken into account. A JMeter tool was tracking response times of each application and their CPU usage, based on the results the charts positioned below were created (Figure 6, Figure 7 and Figure 8).

3.2. Tests of the server proxy only

For the implementation of the proxy server the following scenarios were tested. Responsiveness of the proxy server itself (without the calculation server) was tested on the sequence of tests with the JMeter for

• 100 requests per 1 minute,
• 200 requests per 1 minute,
• 300 requests per 1 minute,
• 400 requests per 1 minute,
• 500 requests per 1 minute.

Fig. 6. 300 requests to the proxy server per minute: a) number of seconds needed to serve a request from the client applications, b) a histogram of the service time for requests, c) a percentile plot for responses, d) a scan of a period of 1 minute – a response time on Y coordinate [own study].

The performance of the proxy server was mainly affected by the number of requests received from the client application and size of database content. The greater number of data contained in the database resulted in a longer retrieval time, which caused that the handling of further incoming requests took longer to complete. However, the use of a database on a proxy server, buffering designated routes, is still much more efficient than performing additional calculations on a computing server.
3.3. Tests of the calculation server only

To test the calculation server only a sequence of tests consisting of considerably fewer requests were carried out. This is due to the fact that considerably fewer requests will come to the calculation server because of the caching on the proxy server. Therefore test scenarios covered

- 25 requests per 1 minute,
- 50 requests per 1 minute,
- 100 requests per 1 minute.

Figure 7 shows results for the cases of 50 and 100 requests per 1 minute. One can see that such an overload is too much, because the response time increases during the whole time. The saturation point for the calculation server was about 25 requests per 1 minute.

3.4. Tests of the whole system

The third test of the server side of the implemented system was to measure responsiveness of the calculation server when the request came from the client application through the proxy server. After the calculation of the route is completed the response with appointed route is transmitted to the proxy server, which sends it back to the mobile application. We performed the search for a level of cached requests with respect to the total number of requests served by the proxy server, so that the system manages to handle all requests and is not overloaded. As parameters of the optimization we used

- the percentage of the number of messages \( a \) that the proxy server handled using its cache,
- the number of requests to the proxy server \( b \).

We carried out tests for boundary conditions i.e., sending requests to the computing server via proxy server and awaiting for a response in scenarios where

- 90% requests is served by the proxy server cache,
- 80% requests is served by the proxy server cache.

We found that the best performance is obtained for \( a = 88\% \) to be served by the proxy server cache and not more that \( b = 200 \) requests per minute. Figure 8 shows plots with measurements from the JMeter for this configuration.

3. Conclusion

In this paper we presented a prototype of traffic redirection system that allows us to redirect vehicles via the fastest routes through the city. The system consists of the calculation server responsible for the shortest path calculations based on the current state of the traffic, the proxy server responsible for sending requests to the calculation server, or retrieve previously calculated results from its local cache and from mobile applications installed in vehicles of the end users. The two threaded bi-directional Dijkstra is used for finding the fastest route. We presented the results of the tests for responsiveness of the prototype carried out using the Apache JMeter. The prototype intentionally was tested on a low-cost machine. The tests show that the optimal load of the system is about 200 requests per minute to the proxy server and about 12% of all messages arriving to the proxy server is sent further to the calculation server to calculate a new route. The majority of the responses for requests i.e., 88% is retrieved from the local cache. These results show that if the calculation server consists of 20 replicated inexpensive nodes then assuming around 90% of repeated requests (that may be served by the cache of the proxy server) about 4000 vehicles (about 7% of the number of vehicles at one time during morning rush hour in Wroclaw – about 56,000 – the value calculated using methods in [15] based on data published in [16]) can effectively use the system within the period of one
minute. It means that for a period of 10 minutes approximately 70% of all vehicles on roads in Wroclaw in the morning rush hour could be handled. Another conclusion from these results is that we can now propose a load balancing strategy based on FIFO queues so that not all requests at once, from those that need to go, are forwarded to the calculation server but are queued on the proxy server until there is no calculation node with fewer than 3 parallel tasks running at a time (see Figure 8). The load balancing strategy however is a subject for further study.

Acknowledgements

The work in this paper was partially financed from grant 0401/0230/16.

Bibliography

ROUTE4ALL: a novel approach to pedestrian navigation for people with special needs

P. BUREŠ, J. BALATA, E. MULICKOVA

a CZECH TECHNICAL UNIVERSITY IN PRAGUE, Faculty of Transportation Sciences, Konviktska 20, 110 00, Praha 1, Czech Republic
b CZECH TECHNICAL UNIVERSITY IN PRAGUE, Faculty of Electrical Engineering, Konviktska 20, 110 00, Praha 1, Czech Republic
c CENTRAL EUROPEAN DATA AGENCY
EMAIL: bures@fd.cvut.cz

ABSTRACT
Within ROUTE4ALL project we created an extended data model of geographical information database suitable for navigation of people with special needs as well as of general population. Moreover, we provide a methodology for its interpretation and a guide for its implementation into navigation devices. The results of the project could be used by navigation device developers for creating a fully-fledged navigation for people with special needs. First, we describe the requirements for the extended data model, which rise from the research we conducted with people with special needs and from the survey of existing solutions. Second, we introduce a catalogue of geographic elements, their attributes and relationships. Finally, we discuss its benefits over the traditional approaches.

KEYWORDS: geographic information database, landmark-based navigation, routing algorithms, disabilities

1. Introduction
Mobility and ability to travel independently is one of the key requirements for satisfactory level of quality of life. The limited possibility to travel freely can often lead to social exclusion and all of its negative impacts such as loss of work, friends, and hobbies and eventually to worsening psychical condition of a person.
This applies specifically to people with limited orientation and mobility abilities, e.g. visually impaired [1] and mobility impaired persons (e.g. wheelchair users). Their limitation affects the efficiency of the wayfinding process, which consists of ability to avoid obstacles and hazards in their vicinity and of finding a route to a remote destination [2]. There are already a number of navigation aids and systems focused on people with special needs. They range from “human” assisted systems and tools (i.e. tele-assisted navigation centers for visually impaired SONS, http://navigace.sons.cz) to individual navigation tools (e.g. BlindSquare, Navigon), with the tendency towards individual unassisted navigation. Unassisted navigation systems often require hardware allowing the localization of the user and the software for route planning and navigation instructions. The backbone of such systems is a geographical information database. However, even navigation systems for people with special needs usually uses geographical information databases primarily designed for car navigation. These databases uses street network for route planning and presentation of the navigation instruction, which are the weakest part of today’s navigational aids.
The project ROUTE4ALL – “The extended data model for the disable people and the methodology of its interpretation in the navigation” aims to eliminate this problem by means of enhancing geographical information database with sidewalk network. This is in line with conclusions of the meeting Galileo User Forum in
2013\(^1\), that basically states that common models used in pedestrian navigation still use street network, which is not acceptable and that if there are special pedestrian databases they are scattered all around the world and not unified, which poses a problem for wide scale implementation.

One of the main goals of the project is to bring together expectations of pedestrians and people with special needs and experience with creation of car navigation maps in order to create easy to maintain map data model with all the required features in sufficient level of detail.

2. Related Work

Currently, there are a number of projects and applications focused on navigation of pedestrians with special needs. The main aspects negatively affecting the wide-spread usage of these systems are: positioning accuracy, usability of user interface (both software and hardware) and navigation functionality – route planning and navigation instructions.

The positioning accuracy is affected by the precision of satellite positioning systems (up to 24.5 meter mean error in buildup areas \(^2\)). Therefore, it has not yet been possible to develop a navigation system precise enough to recognize the precise location of the user in the urban environment. The accuracy problems are caused by distortion of the navigation signal on the way from the satellite to the receiver. Most of these errors can be eliminated using a combination of several existing satellite navigation systems (e.g., GPS\(^3\), GLONASS, COMPASS and Galileo together with satellite correction systems, e.g., EGNOS\(^4\)). The combination of different satellite navigation systems and built-in sensors of a navigation device (e.g., accelerometers) can significantly improve the positioning accuracy. However, the final accuracy error is caused by multipath signal distortion present mainly in the urban environment. These errors cannot be mitigated easily and developers of navigation aids have to focus also on other possibilities than just satellite based navigation.

The software and hardware development has resulted in significant advances allowing comfortable use of navigation devices by people with special needs. Majority of modern smartphones is equipped with text-to-speech and speech-to-text technologies and they are already used as a primary navigation device. Even though modern navigation devices are often equipped with touch screens, which are highly impractical for people with special needs, there has been an extensive research focused on improvement of usability. Approaches such as dividing screen of the device into a several virtual keys with different functions assigned or tactile stickers overlaid over the virtual keys have been explored \(^5\).

The route planning algorithms and navigation instructions and their presentation need to be adapted for specific needs of users with special needs. For example aspects of length and speed of a route are may be less important than a requirement of the route with fewer barriers. Moreover, the route planning algorithms have to combine more criteria than standard car navigations, which are nevertheless still used for pedestrian navigation despite the lack sidewalk information (important landmarks, staircases, barriers, etc.). It is apparent that standard turn-by-turn car navigation instructions and route planning are insufficient for navigation of people with special needs, particularly visually and mobility impaired.

There is an intensive need for extended data model of sidewalks suitable for navigation instructions based on sidewalks and landmarks and optimized route planning. Moreover, experimental navigation systems with instructions enhanced with landmarks (corners of buildings, slopes of pavements, or even photos of buildings) proved to have higher acceptability by users and improved their comfort during the travel \(^6\).

Even though navigation systems still use the standard “street only” geographical information databases, research is focused on experiments with “sidewalk level” navigation. Results from this area bring new knowledge and concepts of geographical information databases as well as new drawbacks. However, only small test areas have been covered by these experimental geographic information databases so far. Further, different approaches of different research groups are leading to incompatible data models. In most cases experimental geographic information databases cover university campuses \(^6\), and therefore cannot be used as a suitable exemplar for the creation of geographical information databases covering large scale areas such as centers of capital cities.

The lack of focused research and development in the field of geographical information databases based on sidewalk networks tailored to the needs of navigation of people with disabilities hinders the mass use of navigation devices in the community.

2.1. Navigation systems for people with disabilities

The research of navigation problems related to people special needs also focuses on utilizing existing products and services. As an example, we mention several projects and applications that help people with special needs when navigating in the urban environment.

Projects:

- Project Sidewalk – a project focused on crowdsourcing of curb information for navigation of wheelchair users. http://sidewalk. umiacs.umd.edu/
- HaptiMap – a project focused on user requirements and design guidelines for map applications used in navigation http://www. haptimap.org
- Inclusion – a navigation system for mobility impaired users moving on the electric wheelchair with route planning based on the type of disability. http://www.gsa.europa.eu/innovative-lbs-socialpublic-dimension
- WAYS4me – a project aiming at barrier-free navigation on mobile devices. Emphasis on additional information for the blind, for entire route including public transport and trains. http://www.ways4all.at
- Rollstuhlrouting – a project for wheelchair users from Germany, which allows calculation of the route to the destination point, taking into consideration parameters selected by the user from

---

\(^1\) Use of GNSS services for persons with reduced mobility or orientation

\(^2\) http://www.space.com/19794-navstargl.html

\(^3\) http://www.egnos-portal.eu
the list. Uses OpenStreetMap for navigation http://www. rollstuhlrouting.de

- ACCESS – a project aiming at navigating blind people or older people, with lot of available documents. http://www.fp-access.de
- BIS project – a project aimed at creating a routing web applications tailored to the needs of wheelchair users for the city of Vienna. The data model is formed on the basis of findings from consultations with the “wheelchair” community (http://wege-finden.at)
- Atlas of accessibility of Prague by the Organization of Wheelchair – a printed map covering the accessibility of buildings within the city of Prague, parks and monuments. It includes accessibility information and classification for selected objects. The publication is a practical and useful guide also for people with strollers and other groups for which can be stairs or other barriers in public spaces unpleasant obstacle http://www.presbariery.cz/publikaci-inos/publikace-pov.html

Routing

- Loadstone GPS application – a mobile application. Blind person has the possibility to determine its location and to find out information about nearby objects, or to get routed to the specified destination. Maps used by the application are from freely available sources, particularly from OpenStreetMap http://www.loadstone-gps.com
- Navigation service center SONS CR – provides navigation over the phone (by an assistant). Use special tracking unit. In the center the user position is visualized on the aerial map http://navigace.sons.cz
- Easy Walk service – application for mobile phones that enables blind people to get a voice information about his position and eventually to get an assistance from call center – similar to the navigation center SONS http://easywalk.livillage.it/en/index.jsp
- BlindSquare – a mobile application listing points of interest in the vicinity of visually impaired user http://www.blindsquare.com

3. Extended Data Model

Requirements

The projects and applications mentioned in Related Work section are each focused on a specific community of people with special needs. However, the specific needs of visually impaired and people with mobility impairment with regard to the identification of barriers in urban environments largely overlap. For example stairs are a barrier for wheelchair user, however, a significant landmark for visually impaired person. Therefore, there is a potential for creating a common data model of navigation maps.

3.2. General requirements

Based on the related work, we have identified that there is a general lack of an appropriate geographic information database model usable by more groups of users with special needs. Regardless the individual navigation techniques of the groups of users, the extended data model has to build on several fixed rules and requirements:

- Compliance with existing standards and rules of a barrier free accessibility i.e. determining and deriving of attributes and their limit values.
- Maximum possible compliance with the GDF standard, used for navigation model description, i.e. if possible, use existing nomenclature.
- Maximum ease of administration and updating data given by the model, i.e. if possible the simpler and more forward solution is better than a complex one.
- Extensibility of used dictionaries and enumerations by new values when the need arises, and its implementation into data model.
- Incorporation of different user perspectives on map attributes (physical landmarks), e.g. lamp post, a restriction for a wheelchair passage due to narrowing of the sidewalk, is a good information landmark for visually impaired, the important attributes has to be not only remaining width of the sidewalk but also lateral and longitudinal post position relative to sidewalk.
- Possibility of a crowdsourcing (community supported update of the map data). Data model is created so that it is possible to store information about current phenomena (barrier, obstacle) or degraded surface conditions without the necessity to change an underlying geometry. For example by indicating the beginning and end of the phenomenon relative to the geometry.
- To respect the „multi-phase“ data collection, for example, orientation points for visually impaired can be collected at a later stage, if it turns out that it is a busy route for a blind people.
- Possibility to import (use) geometry or attribute information from other existing databases. Vectorization should be based on a technical map, which is a ground truth for other elements.
- Ensuring direct linkage / interconnectivity to navigational road databases (i.e. StreetNet), where some sections are for both vehicles and pedestrians and their representation already exists in a road database (e.g. Pedestrian zone). To ensure navigation even for unimpaired pedestrians in areas that are not yet covered by “pedestrian” data update it is required to have geometrical continuity between the already existing routable road database(s).

3.2. Requirements from methodologies for navigation of people with special needs

Several methodologies are used for classification of on-route objects according to dimensions and obtrusiveness for the impaired and existing accessibility mappings. These methodologies are cornerstone for creation of a data model for a navigation map. Moreover, the methodologies were created by organizations uniting visually impaired people and mobility impaired people and are used to manually describe their regular routes (e.g. route to work, nearest bus stop, etc.). Methodologies are as follows:
• Methodology for mapping the accessibility of objects from the perspective of persons with reduced mobility www.presbariery.cz
• Methodology of marking routes for of wheelchair routes KCT http://www.kct.cz/cms/turni%C3%A1%C4%8Dka-pro-vsecnyst
• Methodology for labeling the accessibility of routes and roads http://www.presbariery.cz/konference-a-jednani/jednani-trasy-2014.html
• Methodology of accessibility www.vozekmap.cz
• OSM methodology of University of Heidelberg http://wiki.openstreetmap.org/wiki/Wheelchair_routing
• Ordinance of the Ministry for Regional Development of the Czech Republic no. 398/2009 about general technical requirements ensuring barrier-free use of buildings.

By mapping of accessibility we understand a collection of specific information about a particular segment of pedestrian segment in a real world. Evaluation of the information from different user perspectives leads to assessment of overall passability of the segment. Each user group has different passability criteria. The data model is designed to take into account the criteria of all user groups.

3.3. Physical phenomena (elements) suitable for data collection

The selection of phenomena important for route planning and navigation instructions is based on the specific requirements of people with special needs and the results of extensive user research conducted in 2016 [7].

Table 1. Possible elements and attributes of a navigational model for 2 user types* (own study)

<table>
<thead>
<tr>
<th>Movement impaired</th>
<th>Visually impaired*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problematic parameters:</td>
<td></td>
</tr>
<tr>
<td>• lateral slope</td>
<td>• open areas (max 8 m without guideline)</td>
</tr>
<tr>
<td>• longitudinal slope</td>
<td>• objects that cannot be discovered by white cane (e.g. in height from the knees up), waste-bins, side payphones, of stopping shelters</td>
</tr>
<tr>
<td>• horizontal gap</td>
<td>• doorway height</td>
</tr>
<tr>
<td>• grate with gaps in the walking direction</td>
<td>• passage width</td>
</tr>
<tr>
<td>• walking areas surface</td>
<td>• temporary obstacles – e.g. Excavation</td>
</tr>
<tr>
<td>• the coefficient of friction</td>
<td></td>
</tr>
<tr>
<td>• passage width</td>
<td></td>
</tr>
</tbody>
</table>

Longitudinal elements in the data model (segments)*pedestrian road (crossings, sidewalks, pedestrian paths, places for road crossing, passages, overpasses, underpasses, pedestrian zone, shoulder, ramp)

<table>
<thead>
<tr>
<th>Point elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local barrier on a given segment of a maximum length of 3 meters or stairs up to three.</td>
</tr>
<tr>
<td>• ramps to sidewalks – length, width, magnitude and direction of lateral and longitudinal slope</td>
</tr>
<tr>
<td>• ramps to public stops – length, width, magnitude and direction of lateral and longitudinal slope</td>
</tr>
<tr>
<td>• elevators – door width, “cage” width and depth, lift capacity, on-line information about the functionality of the lift, travel (lifting) time, comprehensive assessment of accessibility (availability of controls / buttons, door opening system, availability of controls / buttons inside the cabin – height, offset from the corner)</td>
</tr>
<tr>
<td>• platform – entry width, platform width and depth, load (capacity), on-line information about the platform functionality, travel (riding) time, platform type (vertical, slanted, on a closed track, open, locked)</td>
</tr>
<tr>
<td>• horizontal gaps (rails, rain drainage …) – gap width, distance of two horizontal gaps</td>
</tr>
<tr>
<td>• Vertical gaps (steps) – directionality (entry or exit), distance between two vertical gaps.</td>
</tr>
<tr>
<td>Orientation points mainly.</td>
</tr>
<tr>
<td>• Guidance voice beacons</td>
</tr>
<tr>
<td>• information boards with voice output</td>
</tr>
<tr>
<td>• natural guidelines (minimum length of individual parts 1300 mm) – house walls, retaining walls, fences, greenery edges (with curbs &gt; 6 cm, or without), railings with a stop for a white cane or other compact elements of the minimum width 400 mm height min. 300 mm</td>
</tr>
<tr>
<td>• artificial guide line – signal strip, warning strip, guide road crossing strip, palpable strip, warning strip on dedicated lane (metro), guide line with warning stripe function, sinusoid or trapezoid grooves</td>
</tr>
<tr>
<td>• entrances to buildings</td>
</tr>
<tr>
<td>• Places / objects with a strong sensory potential (sound/noise/scent)</td>
</tr>
<tr>
<td>• passages</td>
</tr>
<tr>
<td>• types of building corners (round, square, polygon …)</td>
</tr>
<tr>
<td>• public stop signs and other landmarks</td>
</tr>
<tr>
<td>• pitfalls (without a stop for a cane) – billboards, trash cans, phone booth, bus stop shelters, information stands</td>
</tr>
<tr>
<td>• information stands with voice output</td>
</tr>
</tbody>
</table>

4. Implementation of Geographical Information Database

All possible elements of the extended data model and general principles for their selection are discussed above and in more detail in the project ROUTE4ALL internal memos. This chapter constitutes of a description of basic procedures and elements that were selected for the creation of geographical information database.

4.1. Data collection

Basic criteria for the selection of attributes / features of an extended data model were:

By identifying users and their requirements for passage of the route, select the real world phenomena that will be collected and define the way of collecting them (either by field work or by deriving data from existing sources). Define the way how the elements will be fitted into the model, for “obstacle type” elements define the criteria which make them a barrier, use this criteria as a precision guidance when collecting these elements.

The navigation model is designated for route planning and guidance along the way. Users, especially in the urban environment, cannot estimate their position with high precision (meters), due to incapability of positional systems such as GPS in urban environments given by especially reflections from buildings.

* People with serious visual impairments, the blind, practically blind
Therefore exact position of phenomena on the path is not important, i.e. supplying user with exact position in units of meters of a specific object brings no information and possibly creates confusion. Experiments [8] with visually impaired participants showed that navigation instructions in form of precise distance (e.g., “in 31 meters turn left”) are less usable than less precise information as the participants were not able to estimate the precise distance.

Furthermore, precise information like exact slope, height or width of an element with an accuracy of centimeters is also unnecessary; only certain limits (from-to) of width, slope, height, are important as they make the route impassable for certain user groups. It is therefore beneficiary to collect them in precision given by those limits.

The above considerations, given by the application of the user perspective, helps to reduce time and work necessary for data collection in contrast to creating a CAD blueprint suitable for construction purposes.

### 4.2. Data elements of geographical information database

Based on user requirements for movement and orientation in space, mainly introduced above, the model of a navigation map is composed as follows.

**Representation of pedestrian segments**

The streets in the road model are represented by linear segments that intersect at a point (node). In the case of the intersection on the Figure 1 four line segments connects. In ROUTE4ALL approach a pedestrian network in the same area have eight line segments one for each sidewalk, four line segments one for each crossing and four corner points. In case of changing of sidewalk geometry in real world, that affects pedestrian behavior, the impaired pedestrian should be notified, this is facilitated in the model by dividing such segment to several parts. So, in such case, even more than eight sidewalk segments might be used.

Fig. 1. Topology of a road (left) and pedestrian (right) network [own study]

**Definition of types of sections / roads**

Movement of people with limited mobility and orientation in an urban area is facilitated mostly on “pedestrian segments”, e.g., sidewalks. Those pedestrian segments are mostly reserved for pedestrians only, but also can be shared with other means of transport – cars and bikes. Car movement on such segments is limited – entry only with permit (pedestrian zone) or by speed limit (residential areas) – or it is a dedicated road, which is the only possible approach to the destination.

<table>
<thead>
<tr>
<th>pedestrian only segments</th>
<th>Segments with shared use with other vehicles</th>
<th>cross roads</th>
</tr>
</thead>
<tbody>
<tr>
<td>sidewalks along the street</td>
<td>cyclists and pedestrians paths</td>
<td>level crossings</td>
</tr>
<tr>
<td>sidewalks off the road</td>
<td>pedestrian zone</td>
<td>underpasses</td>
</tr>
<tr>
<td>trails in parks</td>
<td>residential zone</td>
<td>overpasses</td>
</tr>
<tr>
<td>public spaces</td>
<td>dedicated road</td>
<td>stairs and ramps</td>
</tr>
<tr>
<td>stairs and ramps in a steep terrain</td>
<td></td>
<td>into underpasses or overpasses</td>
</tr>
<tr>
<td>passages</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Segment characteristics**

Each segment has certain characteristics that may affect the travel convenience of users. This may result in lesser speed of users or influence their choice of route. When the characteristics are severe the segment might be impassable for some users. Important characteristics influencing the passability are as follows:

- longitudinal and lateral slope
- width
- the quality and type of surface

Some segments have also important temporal aspect – for example the opening hours of passages, roads in winter, etc.

Not only property of the segment alone, but also the properties of the neighborhood are important for some users. They are mainly used by people with disability to help with their orientation. The most usable are:

- land use and land cover along the segment
- linear phenomena along the segment (railings, etc.)
- sound and olfactory cues

**Crossings characteristics and curb ramps**

To overcome roads, crossing or dedicated paths are used. Because of the differences in height of road and a sidewalk are crossing entry and exit critical points for citizens with impaired movements (wheelchair). Following features of crossing and curb ramp are important for assessing the possibility of passage:

- the height and the type of curb
- slope of reduced or “angled” curb
- slope of the ramp
- size of landing
- width of ramp (where the sidewalk is in the level of the road)

As the curb ramps eliminate the vertical edge of the curb used by visually impaired pedestrians, it is necessary to have a detectable warnings (acoustic signalization, stripes) to mark the boundary between the sidewalk and street.

**Stairs and ramps**

A staircase or even a mere step is problematic for people with limited mobility. Often, there is a possibility to use a ramp along the stairs. In places, where there is a greater height differences an elevator or mobile platform may be used.

**Point barriers and landmarks**

Information about the elements that are located along or at the sidewalk is important. Those elements might be represented as points (within max. 3 m length) or as linear features in the model.
For a mobility impaired person these elements may represent a barrier – e.g. narrowing the width of walking areas below the width of a wheelchair or a high step. For people with impaired orientation these elements improve orientation thus helping to navigate the route.

Tab. 3. Point barriers and landmarks [own study]

<table>
<thead>
<tr>
<th>point objects</th>
<th>linear objects</th>
<th>temporary objects</th>
</tr>
</thead>
<tbody>
<tr>
<td>• objects of urban immobility (benches, bins, boxes ...)</td>
<td>• a fence, wall</td>
<td>• improperly parked cars</td>
</tr>
<tr>
<td>• objects of a technical nature (columns, signs, lamps ...)</td>
<td>• handrails, portico</td>
<td>• excavations</td>
</tr>
<tr>
<td>• gaps, ridges and other obstacles lateral to the walking direction</td>
<td>• trench / slope</td>
<td>• scaffolding</td>
</tr>
<tr>
<td>• entrances</td>
<td></td>
<td>• the front gardens restaurants</td>
</tr>
<tr>
<td>• corners of buildings</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.3. Linking of the model object to a pedestrian segment

Phenomena that are important in terms of route planning and navigation instruction may have one of the following relations to a pedestrian segment:

- phenomenon occurring throughout the pedestrian segment
- phenomenon occurring at specific locations along the pedestrian segment
- phenomenon occurring on the part of the segment
- phenomenon occurring outside the pedestrian segment

The basic pedestrian segment (having geometry) is defined from crossing to crossing. Sometimes the segment are cut even between crossings.

Phenomenon linked to whole pedestrian segment

This is the simplest mode of representation, because it is not necessary to create a new geometric representation of the phenomenon.

Examples of phenomena that can be linked to the entire segment are slope, width and surface quality, described in the model by interval values. For a long segment where some of these phenomena vary outside the interval, it is advisable to split the segment, to two or more homogenous segments.

The assessment of necessity to cut the segment, takes into account the fact that the (wheelchair) user can tolerate for very short stretches certain „worsening” of sidewalk characteristics. So, the section described by the longitudinal slope interval of 4-6 % will have most of the slope in this interval, but on a very short stretch, may have slope of 6-8 %.

Phenomenon linked to a specific location on a pedestrian segment

In this case, a standard approach is to create new geometry – a point described by its coordinates and linkage to the segment to which it belongs. Another possibility is to create just a data item linked to the segment by its relative position from the start.

These “point type” phenomena (shorter than 3 m) can be linked to one segments (typically crossing curb ramp) or more segments (building corner).

Phenomenon linked to a part of a pedestrian segment

Same as above but with extent defining affected part of the segment.

The phenomena has linear representation (extent has to be greater than 3 m). Typical example is railings, landuse, excavations etc. It can also be used as an alternative representation of phenomena that are otherwise related to the whole section, but in terms of data maintenance, it is preferable link it to the segment, e.g. when a part of a section is in desolate condition – after the repair is not necessary to change segment attributes, but only to delete points representing the starting point of the originally desolate part.

Phenomenon outside of a pedestrian segment

In this case, new geometry is created – point described by coordinates and link to segment or by relative position. This is not an own representation of the phenomenon, but only entry point, which links to another object described by its own geometry and attributes. Typically, these represent address points and points of interest. It also serves as representation of public stops – that carries a link to the phenomenon described in an external database of public stops and connections.

4.4. Data collection

Reference base for vectorization of pedestrian segments is a city technical map – segment geometry corresponds to the level of accuracy of the map (see Fig. 2). In nodes (especially in the areas of intersections) the topology has a higher importance than the position accuracy.

Fig. 2. Representation of sidewalks along the streets (grey) and crossings (black) in the model [own study]

Additionally, aerial photographs, street network geographical information database, specific paper maps created mobility impaired, street view and or even on-site reconnaissance can be used for higher precision of the vectorization.
4.5. From an extended data model to routable geographical information database

The extended data model consists of information usable by all groups of users with special needs. However their preferences in finding the route are different, therefore mappings from the extended model to its routable interpretation has been defined:

- ROUTE4ALL model defines a structure for storing all phenomena – i.e. events important for all pedestrians and people with limited mobility and orientation.
- ROUTE4WHEEL model defines a subset of ROUTE4ALL model for the mobility impaired users, and it is built as a specific interpretation of the ROUTE4ALL model.
- ROUTE4BLIND defines a subset of ROUTE4ALL model for the visually impaired and it is built as a specific interpretation of the ROUTE4ALL model.

All specific geographical information databases have to employ multi criteria route planning with regard to all selected routable features. During the project the segment and feature attribute values (width, slope, etc.) were reclassified into 4 categories with different effect on the segment “passability” following figure. In finding a suitable route, each segment used on a route adds up its passability value (acquired by classification) to the overall impedance of the route. The passability value of a segment is not given by the length but by its characteristics impeding user movement and is classified into values 1, 2, and 3. The segments with lower (better) passability value may have small part belonging to more difficult category.

An example of the phenomena (with different passability impact) is the height of the curb, which is particularly important for wheelchair user group. Limit of height value for full passability is 2 cm, height 5 cm may be acceptable for some users (e.g. a wheelchair user with accompaniment), higher curbs already constitutes a barrier to movement for all wheelchair users. From the perspective of a blind person the important height is 8 cm; lower curb height requires existence of a warning strip. Data model therefore has to take into account the requirements of all user groups – from which it derives the classification requirements of individual phenomena.

![Fig. 3. Reclassification of interval attribute width to 4 classes for wheelchair user of different ability (classification: 1 = “novice”, 2 = “apprentice”, 3 = “master”, 9 = “unpassable”) [own study]](image)

Based on user selection the route could be composed of segments classified with value 1, 2 or 3. Classification values relate to:

- 1: full barrier-free accessibility to the entire user group,
- 2: partial barrier-free accessibility, passability only for some users,
- 9: no barrier-free accessibility for the entire user group, i.e. unpassable.

Total impedance of a route is used for the selection of optimal route.

4.6. Evaluation with people with special needs

The extended data model was evaluated in several user studies with visually impaired participants and in one study with wheelchair users. The results showed efficiency of the itineraries based on the model. The studies confirmed that the proposed extended data model and its interpretation improved the feelings of safety and efficiency of the participants during the travel [7].

5. Conclusion

In this paper we have shown that there have been quite a number of project focused on navigating specifically impaired pedestrians and on creation of a map for such purposes. The project ROUTE4ALL we are describing in this paper focused on convergence of different approaches across all users (visually and manually impaired, people with strollers, etc.) thus bringing together knowledge from “both worlds”. We have created one model of navigation map which can be by automatic transformations converted into routable map either for visually or for manually impaired users. Developed model was tried out on 1 square kilometer are in Prague old town and tested in navigation system Naviterier and independently developed application for wheelchair users.

Acknowledgements

The authors acknowledge the financial support provided by the Technology Agency of the Czech Republic through project ROUTE4ALL (TA04031574).

Bibliography


Generation Y Consumer preferences and mobility choices – an empirical approach

A. DEWALSKA-OPITEK
UNIVERSITY OF ECONOMICS IN KATOWICE, Faculty of Informatics and Communication, 1 Maja 50, 40-287 Katowice
EMAIL: a.dewalska-opitek@ue.katowice.pl

ABSTRACT
Automotive industry has been undergoing significant alteration. Innovative technologies change vehicles toward fully autonomous ones, but also change mobility choices of consumers, offering on-demand rides and shared mobility services. Consumers have the power to determine automotive companies’ business models and strategies. The main interest of car manufacturers and mobility service providers is nowadays put on young consumers from generation Y, proficient with latest technology, digital media and electronic gadgets. Their preferences and mobility choices have been described in the paper on the basis of consumer survey conducted on 22 000 Millennials from 17 countries by Deloitte in 2016 and 2017.

KEYWORDS: Generation Y, global trends, mobility choices

1. Introduction
Characteristic features of the contemporary transportation market include essential changes not only in the production activity, consisting in implementing product innovations (i.e. electric or hybrid cars, self-driven vehicles etc.) or system innovations (smart mobility as a part of smart city concept), but mainly in customers’ consumption patterns [1].

Consumption has become more complex nowadays, and is determined by various factors, including economic, cultural and social factors among others. A differentiation of customers' attitudes and behaviours among generations may also be observed. At present, the Y Generation, born in the 80s and 90s is the predominant generation.

Attitudes of young consumers toward transportation products, processes and solutions will give specific directions to enterprises operating in the automotive market in future decades, which make them a subject matter of interest in the paper. The generation Y consumer preferences and mobility choices are identified and described based on literature studies, as well as empirical research conducted by Deloitte in 2016 and 2017. The objectives of the study focused on understanding the factors influencing consumers' mobility decisions such as new transportation models that provide access to transportation (e.g. car-sharing, etc.). The study also sought to assess the customer experience and factors influencing the final vehicle purchase decisions. Results allowed for drawing conclusions for automotive manufacturers and service providers.

2. New era of mobility
In recent years, the world has reached a critical midpoint: over half of the world’s population live in cities. The trend is expected to accelerate, with approximately 70% of the world’s population predicted to live in cities by 2050 [2]. Overcrowding, the realities of traffic, and new capabilities enabled by technology are all leading to more collaborative approaches to transport: for example, the “sharing economy,” driverless cars, etc.

Individuals today have several transportation options, and increasingly their transportation decisions are differing across
3. Generation Y as a predominant group of consumers in the contemporary automotive market

Generation Y members are now highly active in the marketplace. They not only represent the most numerous generation among others, but also dispose of 600 billion USD annually as their purchasing power, in addition to the influence the younger members of this group still exert over parental expenditures [7]. This generation became the subject matter of interest of many companies offering goods and services in the market, including transportation. Their decisions and mobility choices strongly influence business activity of enterprises conducting the so-called “diffusion of innovations” of their marketing, process, or technological nature [8].

Taking into consideration the above comments, it seems important to describe generation Y in more detailed manner. Generation Y covers people born between the 1980’s and the year 1995. This generation has been shaped by the technological revolution that occurred throughout their youth. Generation Y grew up with technology, so they are proficient with the latest technology and gadgets such as iPhones, laptops and tablets. They often referred to as “tech savvy consumers”, “Millennials” or “Millennium generation”, “next generation”, “digital generation” and the “generation of flip-flops and iPods” [9]. They have “tamed” technological innovations and actively apply digital media and digital technologies; they are considered to be audacious generation that is open to new challenges.

This has an immense impact on the way individuals of this generation communicate, study, work, make choices and decisions. Being used to constant access to information, Millennials use various technical devices, including M2M (machine to machine) technology. It enables an active communication between the devices (“machines”) and takes place via wireless or wired connection [10]. Howe and Strauss [11] describe generation Y as optimistic, cooperative team players and rule followers. They present rational minds, a positive attitude and selfless team virtue.

Studies conducted on young consumers of generation Y brought many interesting observations. What differentiates this group from other generations is:

- Millennials are less interested in buying, and more interested in availability. This explains the popularity of services such as “landing”, “joining”, “sharing”, and creates the necessity of developing new services like car-sharing or ridesharing commuting [11], [12]. There is a trend identified by researchers called “deconsumption” and can be described as a conscious limitation of consumption to the reasonable size, i.e. a number of consumed products that results from natural, individual, physical and psychological characteristics of a consumer [13]. Millennials turn to deconsumption more often than other generations;
• They are open-minded, think outside the box and willingly take new challenges. This makes generation Y perfect addressees for innovations in transportation and other fields [14];

• Generation Y have faith and trust in other customers, which explains the development of new trends in consumption, e.g., collaborative consumption – an emerging social and economic phenomenon that is fuelled by development in information and communication technology. Consumers replace exclusive ownership of goods with lower-cost options from within a collaborative consumption. The service may be a source of enjoyment and may also enable gaining reputation among likeminded people [12];

• Young customers are used to constant access to information via mobile devices, they look for and share opinions, thus recommendations or admonishments of other customers strongly influence their decision-making process and purchasing choices [15];

• Millennials are often involved in customer citizenship behaviour (CCB), discretionary and prosocial actions displayed by customers which benefit both the companies and, usually, other customers as well. This behaviour is based on the theory of social exchange where customer reciprocates positive behaviour from a sense of personal obligation or gratitude. Among various dimensions of CCB identified and defined by researchers [16], [17], [18], one seems to play an important role in the context of customer behaviour in passenger transport, i.e. helping other customers while using a mobile app for road navigation (GPS app). Due to data optimization in real time, users are informed, and inform other road users about possible traffic difficulties and burdens, congestions, traffic jams and road works, as well as speed controls, speed detectors and police patrols. All the information about current situation observed on the roads is provided by the application users who build a social network of traffic participants [12].

Young customers representing generation Y are different from others in terms of values, attitudes, and market behaviours. It is very important for companies operating in automotive industry to recognize the key drivers of their most numerous and thus most important consumers.

4. Global trends in young customers’ mobility choices and transportation decisions

To explore consumers’ mobility choices and transportation decisions, a survey was fielded in 2016 and 2017 by Deloitte [19], [20]. In total, about 22,000 individuals – automotive consumers responded to the survey. They represented mainly generation Y, as well as other generations (Baby Boomers and Generation X). The study was conducted in 17 countries, i.e. in: Canada, US, Mexico, Brazil, UK, France, Belgium, Germany, Italy, India, China, South Korea, Japan, Thailand, Indonesia, Malaysia, and South Africa. This allowed for in-depth analysis through multiple lenses, including generational, socio-economic, gender, and many others.

The objectives of the research focussed on understanding the factors influencing consumers’ mobility decisions as new transportation models that provide access to transportation emerge (e.g., car-sharing, etc.). The study also sought to assess the customer opinions on advanced vehicle technology.

Young consumers were asked if they plan to purchase or lease a vehicle – almost three-quarters of Gen Y consumers plan to purchase/lease a car within the next five years. The main reasons for not owning a vehicle is affordability and high operational and maintenance costs. Millennials also declare, their lifestyle needs may be met by public transportation or in other ways. Gen Y opinions are presented in Fig. 1.

42% of young consumers representing Gen Y are willing to use car-sharing, car-pooling or similar services if they were readily available and convenient, and for comparison only 28% of other generations would use these types of commuting.

It is predicted that ride-on demand, shared mobility and other transportation services may disrupt car ownership in future. Some geographical and generational differentiations may be observed, especially in India and China (Fig. 2).

It should be stated, that ride-sharing services are not commonly used in many markets, particularly in Japan, where the regulatory environment discourages the use of mobility services. Use of these services in India and China far outplace other markets. In fact, almost half of consumers in emerging markets like China or India use ride-sharing services at least once a week.

Millennials are more interested in alternative modes of transportation, particularly if they are safe and enabled by technology. Respondents’ opinions on the usage of alternative modes of transportation, especially driven by innovative technologies are presented in fig.3.
Simultaneously, Millennials declare purchasing a vehicle if cars are cheaper and more fuel efficient or if there are also more affordable payment options.

Respondents were also asked to describe themselves as commuters. An interesting conclusion may be drawn of cross-generation nature. Survey participants were supposed to prioritise several descriptors. Generation Y consumers pay attention to low costs of transportation (“My total costs when going somewhere needs to be low and I will choose a transportation option that is cheapest”). The second most important feature is convenience (“When going somewhere, I want to do so in the fastest and easiest way and am willing to use any transportation option to achieve this”). The generation Y respondents also described themselves as driving amateurs (“I look forward to driving because getting there is half the fun”). Elder generations pay most attention to utility (“Getting somewhere needs to fit the demands of my lifestyle”). Low costs and convenience appeared as their second and third choices. What is interesting, the least favourable feature for all generations is luxury (“I value luxury and want to be noticed when I go somewhere. I feel a sense of pride driving a luxury vehicle and am willing to pay more for the features and the brand name”).

More than half of generation Y (59%) would prefer to be driving an alternative powertrain in five years’ time (Fig. 4).

Consumer interest in alternative powertrain technologies could make an opportunity for car manufacturers, particularly in Asian markets like China and Japan where purchasers are significantly more interested in alternative powertrain for their next vehicle. Consumer preferences for various powertrain technology differentiated by country is presented in figure 6.
Enables hands-free interior controls

<table>
<thead>
<tr>
<th>Feature</th>
<th>Convenience</th>
<th>Safety</th>
<th>Self-Drive</th>
<th>Connectivity</th>
<th>Cost Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>16</td>
<td>23</td>
<td>26</td>
<td>29</td>
<td>24</td>
</tr>
</tbody>
</table>

Monitors the physical health of the driver

<table>
<thead>
<tr>
<th>Feature</th>
<th>Safety</th>
<th>Self-Drive</th>
<th>Connectivity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>17</td>
<td>9</td>
<td>13</td>
</tr>
</tbody>
</table>

Enables high-speed, long-distance, highway “auto-pilot” mode

<table>
<thead>
<tr>
<th>Feature</th>
<th>Self-Drive</th>
<th>Connectivity</th>
<th>Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>18</td>
<td>17</td>
<td>11</td>
</tr>
</tbody>
</table>

Enables remote/automatic software updates of the vehicle

<table>
<thead>
<tr>
<th>Feature</th>
<th>Connectivity</th>
<th>Self-Drive</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>19</td>
<td>25</td>
</tr>
</tbody>
</table>

Allows for the use of smartphone applications through the vehicle dashboard

<table>
<thead>
<tr>
<th>Feature</th>
<th>Connectivity</th>
<th>Self-Drive</th>
<th>Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20</td>
<td>28</td>
<td>31</td>
</tr>
</tbody>
</table>

Enables full self-driving capabilities

<table>
<thead>
<tr>
<th>Feature</th>
<th>Self-Drive</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>21</td>
</tr>
</tbody>
</table>

Coaches the driver to drive safely

<table>
<thead>
<tr>
<th>Feature</th>
<th>Cost Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>22</td>
</tr>
</tbody>
</table>

Makes available adjustable settings to enhance vehicle performance

<table>
<thead>
<tr>
<th>Feature</th>
<th>Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>23</td>
</tr>
</tbody>
</table>

Assists in locating, reserving, and navigating to a parking space

<table>
<thead>
<tr>
<th>Feature</th>
<th>Service Enabler</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24</td>
</tr>
</tbody>
</table>

Enables the use of self-healing paint

<table>
<thead>
<tr>
<th>Feature</th>
<th>Miscellaneous</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25</td>
</tr>
</tbody>
</table>

Provides passengers with customized entertainment while driving

<table>
<thead>
<tr>
<th>Feature</th>
<th>Convenience</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>26</td>
</tr>
</tbody>
</table>

Provides notifications when places of interest are nearby

<table>
<thead>
<tr>
<th>Feature</th>
<th>Service Enabler</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>27</td>
</tr>
</tbody>
</table>

Automatically pays parking and toll fees

<table>
<thead>
<tr>
<th>Feature</th>
<th>Service Enabler</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>28</td>
</tr>
</tbody>
</table>

Empowers customer to personalize vehicles

<table>
<thead>
<tr>
<th>Feature</th>
<th>Miscellaneous</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>29</td>
</tr>
</tbody>
</table>

Allows the driver to control automated home systems

<table>
<thead>
<tr>
<th>Feature</th>
<th>Service Enabler</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30</td>
</tr>
</tbody>
</table>

Enables low-speed urban “auto-pilot” mode

<table>
<thead>
<tr>
<th>Feature</th>
<th>Self-Drive</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>31</td>
</tr>
</tbody>
</table>

What is not perceived useful is also noteworthy. For example, features that provide customized entertainment, notification of places of interest and technologies that enable low-speed urban “autopilot” mode are universally viewed as least useful – an important finding for producers considering investing resources to offer these features in future vehicles.

As far as modern technologies are concerned it is interesting to recognize generation Y consumers’ opinion on autonomous vehicles. Research shows there is a lack of consensus among consumers in terms of advanced vehicle technologies. First, interest in various levels of autonomous vehicle technology varies across global markets. Consumers in India and China appear most interested – probably due to high number of accidents and road fatalities caused by human error. Geographical differentiations of consumers’ preferences toward various levels of vehicle automation is presented in Fig. 7.

What is not perceived useful is also noteworthy. For example, features that provide customized entertainment, notification of places of interest and technologies that enable low-speed urban “autopilot” mode are universally viewed as least useful – an important finding for producers considering investing resources to offer these features in future vehicles.

Across the presented countries (i.e.: US, Germany, Japan, China, and India), four technologies delivering advanced, predictive safety capabilities were consistently ranked as the most preferred when compared to a variety of advanced technology features. These technologies are: object recognition on roads to avoid collision, information system on dangerous driving situations, immediate communication in case of emergency or accident and prevention for drivers in case of engaging in dangerous driving situations.
It is noticeable that consumers from developed markets, like Japan or Germany trust traditional car manufacturers, while customers from emerging markets – mainly from China relay on new autonomous companies.

What may also be observed is a considerable decline in stated consumers’ willingness to pay for advanced automotive technologies. Even Japan and China, where consumers tend to pay extra money for the latest technologies posted an average 50% decrease of possible accepted payments. The change in expected prices which young customers are willing to pay for advanced technologies in 2014 and 2016 is presented in Fig. 9.

![Graph showing overall expected price which consumers were willing to pay for advanced technologies in 2014 and 2016 (in USD) [20]](image)

Millennials from US declared in 2016 to pay 33% less for advanced technologies than in 2014. But the most significant decline is observed in Germany – customers were able to pay 77% less in 2016 comparing to 2014, which makes them the most sceptical young nation among all 17 researched.

The majority of consumers representing generation Y spends more than 10 hours researching, and considers 3 or more brands before they purchase or lease a vehicle. They are active in gaining information from the market and other consumers. The main sources of information impacting Millennials’ buying decisions are: car reviews on independent websites, other consumers’ opinions and social media, manufacturer websites, news articles and media reviews, as well as salesperson at the dealership. As the generation Y is described as a “connected” generation, they need constant infl ow of information. Automotive companies, offering both vehicles and mobile services, need to keep in touch with young consumers to build and maintain close relation with them as main customers and purchasers.

### 5. Conclusion

Many automotive companies have been undergoing massive changes in response to innovative technologies and new models for mobility that are coming to market at an exponentially faster pace and fundamentally transforming the movement of people and goods unlike anything seen since the dawn of the 20th century.

One of the reasons is the noticeable acceleration of advanced technologies applied in automotive sector. They vary from basic level, through safety technologies, cockpit technologies, to fully autonomous vehicles. The main question concerning the popularization of new technologies is not “if”, but “when”, and the answer depends on customers. They are at the heart of automotive value chain, which generates trillions of dollars for auto manufacturers, suppliers, dealers, financial institutions, oil companies and a host of other organizations [20]. Automotive companies focus mainly on Millennials, whose preferences and mobility choices have a noticeable impact on automotive sector. Studies conducted on generation Y consumers demonstrate that they are less focused on possessing a car, and mainly interested in affordable and convenient mobility in general. It makes them the most numerous group of customers of rides-on-demand, ride-sharing and other mobility services.

Millennials as commuters pay attention to low cost of transportation, convenience, and the pleasure of driving a vehicle. When they have made their decision to purchase a car, they present enthusiastic attitudes toward an alternative powertrain and advanced technologies. Generation Y consumers believe there are significant benefits from new vehicle technologies, like: connectivity, cyber security or fuel efficiency, but the most important technologies for them are safety technologies enabling recognizing objects on road and avoiding collision, informing of, and preventing from dangerous driving situations, as well as taking steps in medical emergency or accidents. What is interesting, these appreciated technologies help drivers; they do not take the full control over the vehicle. Although generation Y is far more comfortable with autonomous vehicles than other generations, only 47% of Millennials declare they would have a full self-driving car.

Another interesting finding is the geographical differentiation of young consumers. Millennials from Asian emerging markets (China and India) are far more devoted to new technologies than other young customers, especially from developed countries. Attitudes and behaviours of Chinese and Indian Millennials indicate future preferences of young customers from other countries. Automotive companies should recognize consumer preferences in this part of the world to notice distinct consumption patterns which will appear in the future in other parts of the global market.

### Bibliography


[8] KUCHARSKA B.: Innowacje w handlu detalicznym w kreowaniu wartości dla klienta [Innovations in retail trade in creating the value for customer], UE, Katowice 2014, pp. 43-44
Clusterization methods in detecting the restricted areas for sea transport

M. DRAMSKI
MARITIME UNIVERSITY OF SZCZECIN, Faculty of Navigation, Waly Chrobrego 1-2, 70-500 Szczecin, Poland
EMAIL: m.dramski@am.szczecin.pl

ABSTRACT
Clusterization is one of the data mining techniques which is responsible for classifying data. Selection of the proper parameters leads to some desired clusters behavior. This fact can be used in detecting the restricted areas for ships and other units. The allowed area can be marked as a data cluster and vice versa. The other advantage is the fact that each cluster consists of the set of points which can be used to find the shortest path in given area. In this paper the use of clusterization in detecting restricted areas is described. Few methods are analyzed and the conclusions presented.

KEYWORDS: data mining, clusterization, restricted area, shortest path

1. Introduction
Each point in the Euclidean metrics has it's coordinates [1]. If two points or more have the same coordinates, they are considered as the same point. From the other side it can be said that these points are different but similar. Human senses are able to orientate in 3 dimensions. In theory even n-dimensional space may be considered where . Two similar points are easy to imagine, but there is a question how to do it in n dimensions. Luckily, mathematics gives such tools. Two or more points are considered as similar, when they lie in the closest space from each other. In other words the metrics describing the similarity is the Euclidean distance:

\[ d(x,y) = \sqrt{(x_1 - y_1)^2 + (x_2 - y_2)^2 + \cdots + (x_n - y_n)^2} \] (1)

This metrics is common used in optimization problems where the distances are compared.

Clusterization is the task of grouping a set of points or objects in such a way that objects in the group are more similar to each other than to those in other groups. These groups are called clusters. In Euclidean metrics the geometric distance is used as a main criterion of grouping.

In this paper the use of clusterization in detecting the restricted areas for sea transport is described. The aim of navigation is to safely conduct the ship from the start point to it’s departure. Usually it is solved by creating a graph of possible paths and projecting it on the electronic map. Then the shortest path algorithms such Dijkstra or A* are used. It is not a big deal in wide areas free of any obstacles (moving or stationary). The problem becomes more complicated, when the restricted areas are considered. The restricted area may contain some obstacles like shallows, rocks, reefs etc. natural or artificial origin. It is necessary also to take into consideration that our ship is not the only one moving object in the given area. Some other objects may appear in almost every moment. So, there is a need to update the situation from time to time. This time could be estimated e.g. by decision support system.

2. Clusterization
As mentioned in the introduction of this paper, clusterization is an automatic grouping of similar objects into sets. In this paper two methods were applied: k-means and mean-shift algorithms. In both the metrics is distance between the points. K-means is used the most common used approach, the clusters size is even. Mean-shift lets create more clusters and supports uneven cluster size.

K-means algorithm [2] aims to choose centroids that minimize the inertia or within-cluster sum of squared criterion:

\[ \sum_{i=1}^{n} \min_{\mu_j \in C} \left( \|x_j - \mu_j\|^2 \right) \] (2)
This algorithm may have some problems if the incorrect number of clusters is set as the parameter. The distribution of data points is important too. The aim is to obtain the given number of clusters with equal (or almost equal) number of points in them.

In mean-shift algorithm [3] the bandwidth is given as the parameter. The number of clusters is determined during the calculations. Given a candidate for iteration, the candidate is updated according to the following equation:

$$x_i^{t+1} = x_i^t + m(x_i^t)$$  \hspace{1cm} (3)

Where \(x_i\) is the neighborhood of samples within a given distance around \(x_i\) and the \(m\) is the mean-shift vector computed for each centroid according to the equation:

$$m(x_i) = \frac{\sum_{j \in N(x_i)} K(x_j - x_i) x_j}{\sum_{j \in N(x_i)} K(x_j - x_i)}$$  \hspace{1cm} (4)

The mean-shift algorithm stops the search when the change of centroids is small.

Using clusterization methods makes possible easy decoding all the points from the digital map. In three-dimensional space there are three variables describing the coordinates.

### 3. The experiment

#### 3.1. Theoretical description

As mentioned above, each point in three-dimensional space has three coordinates: \(x, y,\) and \(z\). First two describe the position of the point in two-dimensional projection. In sea transport this is the visible aspect of coordinates. It is impossible to see the third dimension which means e.g. the depth but also can be used to store some other type of information. Sailing is possible if the depth in given area is enough to avoid hitting in the bottom of the sea or other obstacles which are located shallowly. Anyway, there is no need to store the precise information about the depth or other facts. The most important thing for the navigator is if sailing is possible or not. And this is the way of the experiment’s construction. Three hypothetical areas were generated (Area 1, Area 2 and Area 3). Then on each area, the random set of points was created. The number of samples was: 100, 1200 and 2500. Each point had three coordinates. The third coordinate stored the information if the given point is available for sailing. Two methods of clusterization were applied, and the final result was to divide the area into two subsets: points allowed and points disallowed. Of course, the area can be divided into more parts if more detailed information is needed. All the experiments showed that both clusterization methods can be used in detecting the restricted areas.

#### 3.2 Practical part

Fig. 1. illustrates the Area 1 and 100 generated samples. Clusterization results are shown in the bottom subplots. Detection of the restricted areas wasn’t successful perfectly. This number of samples is not enough for this area size. Fig. 2. confirms this fact in the Area 2 and Fig. 3 in the Area 3.

Clusterization has sense if the total number of samples is ensured. If it’s too low, there is a need to get more data.

Fig. 4, 5 and 6 show the experiment results in the case of 1200 random samples. Now it can be seen that due to the increasing the total number of samples, the clusterization is much more clearer. The shape of allowed and restricted areas is visible even without any calculations.

In the case of 2500 samples due to the pages limit of this paper, only the Area 2 is illustrated (Fig. 7).

All experiments were carried out using scikit-learn library for Python programming language.

Both clusterization methods gave almost the same result. In k-means method the target number of clusters was set to 2. Mean-shift algorithm calculated the number of clusters by itself and it was also set to 2.
The other experiments were carried out too. This time the average time of execution was measured (only the time of clusterization was taken – not time needed for drawing the plots). The results are illustrated in the Table 1.

Table 1. Average execution times [own study]

<table>
<thead>
<tr>
<th>Number</th>
<th>Area</th>
<th>No. of samples</th>
<th>K-means [ms]</th>
<th>Means-shift [ms]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>100</td>
<td>0.005</td>
<td>0.003</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>100</td>
<td>0.006</td>
<td>0.003</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>100</td>
<td>0.006</td>
<td>0.003</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>1200</td>
<td>0.007</td>
<td>0.011</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>1200</td>
<td>0.007</td>
<td>0.010</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>1200</td>
<td>0.006</td>
<td>0.010</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>2500</td>
<td>0.009</td>
<td>0.024</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td>2500</td>
<td>0.009</td>
<td>0.023</td>
</tr>
<tr>
<td>9</td>
<td>3</td>
<td>2500</td>
<td>0.008</td>
<td>0.022</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>5000</td>
<td>0.013</td>
<td>0.048</td>
</tr>
<tr>
<td>11</td>
<td>2</td>
<td>5000</td>
<td>0.012</td>
<td>0.046</td>
</tr>
<tr>
<td>12</td>
<td>3</td>
<td>5000</td>
<td>0.012</td>
<td>0.045</td>
</tr>
</tbody>
</table>
4. Conclusion

It has been proved that clusterization algorithms can be applied to detection of the restricted areas. Two methods were used and the comparison between them was done. In all the cases the two final clusters were identical and it was consistent with the assumptions.

The number of samples has a big influence on the final result. It is necessary to cover with samples all the most important map’s parts to avoid any wrong classification. Moreover, there is a possibility to store a lot of additional data in the coordinates.

Although both clusterization algorithms gave the same observable results, the execution times weren’t similar. The higher number of the samples causes the increase of the average execution time, which fact is of course obvious, but k-means algorithm showed less complexity. In the case of 5000 samples was even four times faster than mean-shift. It leads to the conclusion that knowing the final number of clusters would be an advantage.

Clusters centers can be also used to create a graph which would make possible finding the shortest path in restricted area. The other approach could be only connect these centers and find the suboptimal path in this way. Anyway, further research should be done.

Bibliography

The efficient management of railway sidings in terms of a safety criterion – selected aspects

A. JABŁOŃSKI
OTTIMA PLUS SP. Z O.O., Południowy Klaster kolejowy, 40-594 Katowice, ul. Gallusa 12
EMAIL: adam.jablonski@ottima-plus.com.pl

ABSTRACT
The dynamics of the changes in the railway sector requires a system approach. Adopted management mechanisms are created by new regulations, for example a new Directive of the European Parliament and the Council 2012/34 / EU of 21 November 2012. New law presents a new categorization of railway sidings and proposes their way of functioning in terms of a safety criterion. Ensuring the supply chain with regard to safety is determined by specific operating rules on the railway sidings. At the same time this requires intensified supervision of the railway sidings, especially in the case of rail events. A railway siding is a very important component of the rail system and a railway siding user is a special case of an infrastructure manager. The aim of this article is to present the selected aspects of the efficient management of railway sidings in terms of a safety criterion. The scope of this article includes the issue of railway siding management in the context of a new division of railway infrastructure arising from changes in legislation.

KEYWORDS: Safety, railway siding, management

1. Introduction
The dynamics of the changes in the railway sector requires a system approach. Adopted management mechanisms are created by new regulations, for example a new Directive of the European Parliament and the Council 2012/34 / EU of 21 November 2012 on establishing a single European railway area (O.J. EU L 343, 14.12.2012, p. 32). At the same time a new, the required categorization of railway sidings changes their way of functioning in terms of a safety criterion. This also requires the intensified supervision of sidings, especially in the case of possible occurrence of rail events. At the same time a new division of railway infrastructure has appeared.

A railway siding is thus railway infrastructure and a railway siding user is a special case of an infrastructure manager.

In such an approach, the business model of a railway siding and its operationalization is particularly important in organizational, operational and technical terms, taking into account safety criteria. The aim of this article is to present the selected aspects of the efficient management of railway sidings in terms of a safety criterion. The scope of this article includes the issue of railway siding management in the context of a new division of railway infrastructure arising from changes in legislation.

2. Implementation of the EU Directive 2012/34 on the creation of a single railway area - amendment to the Act on rail transport
The modern principles of rail transport operation are based on the mechanisms of risk and safety management in rail transport. Every decision is burdened with some kind of risk, hence the concept of risk begins to set a new dimension of railway undertakings management. It is important to approach risk in rail business analytics in a
systemic way, so as to make it an indispensable factor influencing the organizational behaviour of managers in railway undertakings. Then business analytics enables management supported by forecasting and planning processes, based on the mutual synthesis of cause and effect relationships [2]. In this context, the Directive of the European Parliament and the Council 2012/34 / EU of 21 November 2012 [3] on establishing a single European railway area is to standardize the provisions contained in the three directives on the development of the railway sector, the issuance of licenses and capacity allocation and charging principles, which have been significantly altered. The primary objectives of the new Directive is to increase the integration of rail transport in the European Union, to intensify rail freight and passenger services and increase the efficiency and competitiveness of railways compared to other forms of transport. The main areas regulated by the Act refer to the separation of infrastructure management from transport, financing infrastructure managers, licensing railway undertakings, the principles of charging for access to infrastructure and capacity allocation, independence and the functions of a regulatory body and access to services for railway undertakings. A new definition of railway infrastructure has appeared. In new regulations, the definition of railway infrastructure has been changed. The definition of infrastructure is uniform with the definition in the Directive of the European Parliament and the Council 2012/34 / EU. Reference to the new Addendum I to the Act has been made, which defines the components of railway infrastructure in a more structured way than the Directive.

Railway infrastructure consists of the following components, provided that they form part of a railway line, siding or other railroad, or are designed to be managed, transport things or people, or maintained:

1. railway tracks, including turnouts and crossings and their constituent rails, grooved rails, steering wheels, rub rails, tracks, switches, crossings and other elements of turnouts, sleepers and fastenings, small parts of a railway track, ballast, including rubble and sand;
2. turntables and traversers;
3. control centres, railway traffic control devices, including security, signalling and communications devices on railway routes, in stations and in marshalling yards, devices for generating, transforming and distributing electric current for signalling and communications; buildings for such installations or devices; trackside control devices for a safe ride of trains and detecting failures in passing rolling stock; retarders; equipment for heating turnouts;
4. engineering structures: bridges, viaducts, culverts and other bridge structures, tunnels, passes over and under tracks, retaining walls and strengthening of slopes;
5. platforms including the infrastructure enabling passengers to reach them on foot or by vehicle, from a public road or a railway station;
6. freight ramps, including those in freight terminals, along with freight delivery and pick-up roads to and from public roads;
7. technological roads and walkways along tracks, enclosure walls, hedges, fences, firebreaks, and snow screens;
8. rail-road crossings and railway level crossings, including devices and systems to ensure the safety of road traffic and pedestrians;
9. lighting installations for rail traffic and safety;
10. devices for processing and distributing electricity for traction power supply: sub-stations, power supply cables between sub-stations and contact wires, overhead contact lines along with supporting structures such as catenary masts, and the third rail with supporting structures;
11. land, marked as record parcels, where the items listed in Sections 1-11 are located [8].

According to a new division, railway infrastructure is divided into a railroad, railway line, railway siding, private infrastructure and service infrastructure facilities. According to the new law, a railway siding is a railroad designated by the infrastructure manager, connected directly or indirectly with a railway line, used for loading, maintenance or parking activities, or moving railway vehicles and entering them into traffic on the rail network. It should be noted that only maneuvers are possible at the railway siding. A railway siding is railway infrastructure and its user is a special case of an infrastructure manager. A railway siding user is an infrastructure manager who manages only a railway siding and not other railroads [7]. An applicant is a new entity in the process of making railway infrastructure available. An applicant is a railway undertaking, an international grouping of economic interests, including railway undertakings or other entities interested in obtaining railway infrastructure capacity, in particular the organizer of public rail transport, freight forwarder, and the shipper or operator of combined transport.

3. Preparation of the railway network charter as a new duty of a service infrastructure manager

According to the new Act on railway transport, within one year of the day the Act entered into force, a manager is obliged to draw up a railway charter defining railway lines, railway sidings and other railways that he manages, as well as specifying which of them are disused or private infrastructure. The manager also includes information about railway infrastructure components belonging to the railway line, which are managed by another manager. No railway network charter means that the manager decides that the railway infrastructure managed is disused. The Act provides for a penalty if there is no charter, if the railway network is used only for its own needs. Establishing a railway line, a manager specifies railway infrastructure components included in it, the starting and end points and stations belonging to it, the sections the line is divided into, and the number of lines. A railway siding is established by defining its elements. It is made available to railway undertakings on a non-discriminatory basis under Chapter 6 of the Act. A railway siding is railway infrastructure. A railway siding user is a special case of an infrastructure manager. In many cases, access to a service infrastructure facility is at the railway siding. A new definition of railway infrastructure capacity does not associate this concept only with a train ride. Railway infrastructure capacity can be allocated to an applicant also for maneuvers or rail vehicles stops. The obligations to make infrastructure available do not apply to private infrastructure. A public railway siding includes the
railway siding that is an access road to a service infrastructure facility. The manager is obliged to make a railway siding available to each applicant under the terms set out in the Act. The manager prepares: a network charter, network rules, pricing charges for access to railway infrastructure (the principle of direct cost), a draft agreement on making railway infrastructure available, a draft agreement on the use of railway infrastructure capacity, and procedures for resolving disputes related to the allocation of capacity. Real estate included in the railway siding are exempt from real estate tax and fee for perpetual use. A railway undertaking cannot be a public railway siding manager. A manager makes a private railway siding available only to such railway undertakings that carry out transportation for the needs of the railway siding owner or manager. A manager covers the costs of transportation (he commissions transportation to railway undertakings). A manager draws up the railway network charter. Real estate included in the railway siding is not subject to tax exemptions. A railway undertaking can be a manager of a private siding. It is not allowed to operate a rail service on the disused railway siding. Real estate included in the railway siding is not subject to tax exemptions. A railway undertaking can be a manager of a disused railway siding. The following are the possible options of the functioning of a railway siding in light of the new legislation, according to the assumptions:

1. A railway siding subject to availability
2. A service infrastructure facility
3. Private infrastructure is shown in Fig.1.

Fig. 1. Possible options of the functioning of the railway siding in light of the new legislation [own study]

In the options presented, a railway siding user develops a draft pricing list specifying, among others, the manner of determining the unit basic rate or a system of charging for access, and a network charter. The user of a service infrastructure facility develops the rules of access to the facility, referred to as "Facility regulations" and the charter of the facility. A private infrastructure user requires the extension of provisions in the Work Rules of the Railway Siding on the status of private infrastructure and reporting changes to the President of the Rail Transport Authority (UTK).

4. New requirements related to the procedure for dealing with accidents at railway sidings

The Regulation of the Minister of Infrastructure and Construction of 16 March 2016, [4] on serious accidents, accidents and incidents in rail transport (Journal of Laws 2016 Item 369) changes the conditions of safety management at the railway sidings. A key change is an obligation to report serious accidents to the State Railway Accidents Investigation Commission. It should be noted that the Regulation of the Minister of Transport of 30 April 2007 on serious accidents, accidents and incidents on railway lines (Journal of Laws 2007, No. 89 item. 593) [5], considered repealed, indicated no obligation to report serious accidents to the State Railway Accidents Investigation Commission by railway siding users. The Regulation of the Minister of Infrastructure and Construction of 16 March 2016 on serious accidents, accidents and incidents in rail transport (Journal of Laws 2016 Item 369) requires the reporting of events that took place on the user’s “railway siding tracks” (i.e. those on which in-house transport is not run). The Regulation (Journal of Laws 2016 Item 369) defines how to notify of serious accidents, accidents and incidents, appoint a railway commission chairman and conduct the proceedings and how railway commissions should work. Pursuant to the new regulation, a threat is within the meaning of Art. 3 Section 13 of Regulation No 402/2013 [6]. A threat means a condition that could lead to an accident. This event is a serious accident, an accident or incident. An accident is any occurrence other than an accident or a serious accident, associated with rail traffic and affecting its safety. According to the Regulation, an accident is an unintended sudden event or a sequence of such events involving a railway vehicle, resulting in adverse consequences for human health, property or the environment; accidents include, in particular:

- collisions,
- derailment,
- events at level crossings,
- events involving persons, caused by a rail vehicle in motion,
- railway vehicle fire.

To the Regulation, a serious accident is any accident caused by a collision, derailment or other event having an obvious impact on railway safety or safety management:

- with at least one fatality or at least five people injured, or
- causing significant damage to a railway vehicle, railway infrastructure or the environment, which can be immediately assessed by the commission investigating the accident as at least two million euro damage [4].

A railway siding user is obliged to notify of a serious accident, accident and incident involving in-house transport vehicles to the Commission and the President of the Rail Transport Authority in a situation when:
Polish experience may apply to include:
examples of various changes which the requirements based on the
of change management, pursuant to the Regulation 402/2013. The
operational and technical aspects. It also refers to the mechanisms
that should be conducted, taking into account the organizational,
safety criterion, it is necessary to determine essential activities
Volume 10 • Issue 1 • February 2017

5. The operationalization of a
railway siding business model
in terms of a safety criterion

In order to effectively manage railway sidings in terms of a
safety criterion, it is necessary to determine essential activities
that should be conducted, taking into account the organizational,
operational and technical aspects. It also refers to the mechanisms
of change management, pursuant to the Regulation 402/2013. The
examples of various changes which the requirements based on the
Polish experience may apply to include:
• Technical changes (the modernization of railway traffic
control devices - replacing relay devices with digital ones, the
modernization of rolling stock construction, reconstruction of
railway lines).
• Operating changes: (change in service-repair cycles of rolling
stock, changing rules of organizing railway traffic).

Organizational change (outsourcing of train dispatchers, the
acquisition of railway infrastructure maintenance processes by
external companies based on their original approach) [1]. This
can also be interpreted for the needs of efficient railway siding
management.

Table 1 below presents organizational activities at the railway
siding in terms of a safety criterion.

Table 1. Organizational activities at the railway siding in terms
of a safety criterion [own study]

<table>
<thead>
<tr>
<th>No.</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Showing a model of railway siding operation and maintenance, in accordance with changes in the railway law, effective since 29 December 2016. Models should contain possible layouts of the status of railroads forming sidings, including the creation of areas that meet the requirements for rail transport.</td>
</tr>
<tr>
<td>2.</td>
<td>Developing the complete documentation on railway siding safety, in particular the documentation including the conditions of rail traffic operation and signalling; railroad infrastructure maintenance conditions, rail traffic control and communications devices; the rules of operating railway crossings; the rules of conduct at the railway transport of hazardous materials; the rules of conduct in the event of rail accidents and events; instructions for riding trains or railway vehicles only within the railway siding and acquiring the necessary instructions on the maintenance of traffic control devices.</td>
</tr>
<tr>
<td>3.</td>
<td>Developing the Work Rules of Railway Sidings with updated schematic plans of railway sidings with the development of: • the rules of work and cooperation of railway sidings with railroads and railway infrastructure that have different status; • the rules of service infrastructure facilities; • price lists for making such infrastructure and service infrastructure facilities available; • determining the Work Rules of Railway Sidings with the managers of the non-railway infrastructure connected with railway infrastructure; • submitting all necessary applications to the competent authorities; • support in the process of obtaining necessary administrative decisions in the course of application proceeding by the Railway Transport Authority.</td>
</tr>
</tbody>
</table>

Table 2 below presents maintenance activities at the railway
siding in terms of a safety criterion.

Table 2. Maintenance activities at the railway siding in terms
of a safety criterion [own study]

<table>
<thead>
<tr>
<th>No.</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Conducting audits twice a year (spring/summer, autumn/ winter) reviewing railway siding management. Checking the correctness of activities performed by organizations involved in the operation of a railway siding, i.e. traffic technique, vehicles, staff competencies, and infrastructure maintenance.</td>
</tr>
<tr>
<td>2.</td>
<td>Representing the company before the State Railway Accidents Investigation Commission by an appointed representative</td>
</tr>
<tr>
<td>3.</td>
<td>Introducing periodic reporting on accidents at railway sidings</td>
</tr>
</tbody>
</table>
4. Acting as a railway siding coordinator on constant standby, which involves monitoring of the legal area in order to seek changes and propose making specific modification of internal rules or the work rules of the railway siding. Conducting training once a year on legal aspects related to the functioning of a railway siding. The thematic scope of training will include, first of all, accidents, legal aspects and a rail system.

5. Cooperation with or supervision of the work of the railway commission when an event occurs.

6. Ad hoc inspection (at least quarterly) of the functionality of railway siding operation

The above tables present the proposal for the operationalization of an effective business model of a railway siding in terms of a safety criterion. The typology is consistent with the Regulation 402/2013 and therefore refers to the common safety methods. Such a multi-dimensional approach can ensure the ability of a railway siding to perform its basic functions while ensuring an acceptable level of railway safety.

### Bibliography


4. Regulation of the Minister of Infrastructure and Construction of 16 March 2016 on serious accidents, accidents and incidents in rail transport (Journal of Laws 2016, item 369).

5. Regulation of the Minister of Transport of 30 April 2007 on serious accidents, accidents and incidents on railway lines (Journal of Laws 2007, No. 89 item 593).


Improvement of energy balance in automotive vehicle, based on combustion engine losses

P. OLSZOWIEC, M. LUFT, Z. ŁUKASIK
UNIVERSITY OF TECHNOLOGY AND HUMANITIES IN RADOM, Jacka Malczewskiego 29, 26-600 Radom, Poland
EMAIL: p.olszowiec@uthrad.pl

ABSTRACT
The paper presents an innovative method to increase the overall efficiency of the internal combustion engine. The presented method is based on the kinetic energy derived from the flow of exhaust gases in the exhaust system of the internal combustion engine. This energy is used to drive a high speed turbogenerator which is integrated with the gained energy system management. Such a system, which uses energy otherwise lost in the engine exhaust system, allows the acquisition of additional electrical energy. As a result, it improves the energy balance of a motor vehicle. This is particularly important in a situation of constantly expanding system of electric receivers in vehicles. The paper presents an analysis of the research results of the system of energy recovery, carried out on turbo supercharged engine with spark ignition. The article also gives the research results on the impact of the proposed system on the environment.

KEYWORDS: recuperation, turbogenerator, exhaust system

1. Introduction
Visible demand growth for electricity on board a vehicle is associated with a continuous increase in the amount of electronic devices installed. They are both part of the equipment increasing the comfort of the vehicle, and also the instruments to ensure active and passive safety of the car. For the sake of environmental standards of today's vehicles, many car companies have introduced electronic systems into the By-Wire technology. An example of such solutions is a commonly used system: Steer by-wire or Brake by-wire. This is illustrated by vehicles with functioning electric refrigerant fluid pumps, electric air conditioning systems, or electronic thermostats actively regulating the temperature of the engine. However, the increase in the number of devices powered by electricity translates into a power source, which directly translates into a degree of thermal unit load. On the market there are already Premium class vehicles, where the demand for electricity amounts to 15 kW. Therefore, there is a need for battery charged from other sources of electricity. Electrical energy in the vehicle is used mostly in systems increasing the driver's comfort and safety, but also in the components responsible for the propulsion system management of the vehicle.
Power consumption in the vehicle varies, depending on the function of the electrical devices in the car. The highest energy consumption is visible in the devices boosting driving comfort. Here you can include air conditioning 1000 W, a blower 300 W, electric seat adjustment 400 W, etc. Relatively little amount of power is used by the devices which increase driving safety, including the ABS 50 W, ESP 50 W, the lighting of 150 W (Fig.1). The increase in demand for power on board a modern vehicle, directly contributed to the search by the industry for solutions dealing with recuperation and energy savings. The main area of research is directed at the source of the combustion engine losses, thus the optimization of the cooling system, exhaust system and a reduction in friction losses of engines. The subject literature indicates that there are some solutions that use the exhaust gas stream in the exhaust system as a source of energy. These include the following solutions: Turbocompound, Tigers and ElectricTurbocompound.

2. Recuperation Energy System with Turbogenerator – REST

The presented project of energy recovery system (REST) is based on application of a high speed turbo generator into the exhaust system of the combustion engine (Fig.2). It is the result of an analysis of a continuous growth in energy demand in contemporary vehicles, as well as a disproportionate increase in the improvement of the efficiency of combustion units. The nominal specifications of the generator used in the project are the following: the power of 1 kW, variable three-phase voltage 187V and the maximum speed of 100,000 rpm.

![Fig. 2. Block schema of System REST (own study)](image)

Theoretical considerations on the use of the turbogenerator in the process of electric energy recovery from the exhaust system, indicate the possibility of improving the balance of electrical energy on board the vehicle. Therefore, it is proposed for the power supply system with the use of the turbogenerator, to create a system of management and disposal of energy from two sources. These are: a classic alternator and a high speed turbogenerator which is used depending on the load unit, operating conditions, the demand for energy and attention to environmental standards. A control unit connected with the main controller of the drive unit, acquires information of the current power consumption. On this basis, it controls the operation of one or both energy sources adding up their operations. The system is also responsible for storing of the appropriate level of energy, taking into account such variables as the outside temperature affecting the capacity of the battery, the number of switched on receivers and the average speed of the vehicle. Resource management is performed by adjusting the generator load current and switching the excitation current to the alternator. The basis of the REST system is a high speed brushless electric generator with permanent magnets. Due to the number of windings, these machines can be divided into 2-phase and 3-phase. Mechanical parameters do not distinguish them from the brush electrical machines. Their significant advantages include: high durability, possibility of precise speed control, possibility of use in adverse operating conditions (high temperature). The discussed generator consists of a stator, on whose surface drains of the heat removal were milled, and a rotor with a permanent magnet. As a protection against damage to the magnet, the flange of a titanium alloy was applied to the rotor, and its task is to carry the partial stress at high operating speeds. The material for the rotor shaft is made from structural steel S235 JRG2. Taking into account the specific conditions of the generator work, especially in terms of temperature transferred from the exhaust system used to integrate the power source to the turbine, a housing centering the shafts of both elements was created. The housing contains channels which use the flow of air entering the compressor, as a refrigerant for the generator. Small torque of the brushless electric generator enables it to work with a flue gas turbine. The measured torque of the generator at approximately 2 Nm ensures that the flue gas turbine will not be held back by its operation. Three-phase voltage generated by the generator G is sent to the six pulse bridge. Therefore, the PWM system was used on the filter output through capacitor C 470 μF to minimize ripple voltage circuit 0,1μF.

3. Management module

EvB 5.1 set is a runtime system based on widely available microprocessors ATME32, the Atmel Company (Fig.4). The board is equipped with a number of peripheral elements whose control terminals are led onto pin header. This allows the user for quick implementation of any project without creating a dedicated board. All headers are labeled, and are located near the peripheral devices,
to which they are connected, which allows intuitive connection of elements without the need to read the documentation.

Fig. 4. Controller EVB performing the functions of the REST module [own study]

To create algorithms - commands for the REST system, C++ programming language was used with the help of the Eclipse platform (Fig. 5). Therefore, the platform enriched with plugins is becoming a very popular tool used in the fields of information technology irrespective of whether we work in Java, C++ and PHP. The integrated development environment built on the Eclipse platform provides opportunities for work and development of applications in a very friendly and user-friendly conditions.

Fig. 5. Window of the Eclipse application [own study]

In the design of the functioning of the system, the following conditions were assumed to enable proper interaction of the turbogenerator with a driving unit:

• the system is activated by rotating values of 1500 rev / min,
• the controller enables loading the generator only in a situation when the engine obtains the operating temperature of 840°C,
• REST module constantly monitors the level of demand for energy in the vehicle, among other things by measuring the battery voltage,
• the system takes into account the stabilization period of the generator rotation, and therefore allows generator full load after 2 seconds of stabilized rotation
• the module will not be running in a situation when the engine control unit activates MIL control,
• the controller deactivates the functions of the REST system when the pressure drops in the intake manifold - a leak in the channel boost.

4. Research

The Project is based on four variants of testing energy recovery system. The first is a series of studies on the internal combustion engine without an alternator. This variant is intended to indicate what impact on the engine has its cooperation with the alternator. In this study, the ignition system is powered by the external power source. The second variant of the experiment is a test on the internal combustion engine working with an 700W alternator. This power is defined on the basis of the total load power of electric receivers in the car from which the examined petrol unit comes (Renault Clio III generation 2012). The next variant of the study is an analysis of the parameters of the engine cooperating with the implemented REST system. During the above test the motor and generator parameters were determined accompanying the maximum electric power obtained by the turbo set in specific load values and rotational speed. Knowledge of extreme values of electric power in the individual operating points of the engine, allowed for testing the fourth variant – cooperation of the engine with the alternator and the REST system. The alternator was subsequently charged with powers analogous to those obtained by the turbogenerator at the same measuring points. This study allowed to make a comparison which of the energy sources saves fuel.

5. Results

As part of the metering operations of the turbogenerator, such parameters as current and voltage were recorded in order to calculate the power subsequently. During the study, these parameters were varied in order to determine the generator power for different operating states of the internal combustion engine. This experiment was repeated for each case of the studied rotational speed and for all assumed load points of the engine. The graph shows the power waveforms as a function of torque (Fig.6). For speed of 1500 rev / min (Fig.7), power measurement of the system for all torques was carried out, while, at each measuring point the generator was loaded with three different current values, in which different power values were obtained. Analogously for the moment, the powers were the following 0.6W, 0.9W and 1.3W.

Fig. 6. The graphs of power of the system REST for different rotation speeds of the internal combustion engine [own study]
With a torque 30Nm, the currents transferred to the turbogenerator had a value of 0.115A, 0.13A and 0.045A for the power 4W, 3.18W, and 2.5W. With a torque 45Nm, the obtained voltage is: 45V, 66V, and 79.5V for the power 14.5W, 13.2W, and 7.95W. For the above speed of 1500 rev / min, the highest values of the observed parameters were recorded at the engine load with a torque 75Nm. At that point, the following values of power were obtained: 41W, 46.5W and 41.2W, analogously to the current 0.51, 0.4A and 28.3A. For the speed 2000 rpm / min, the highest parameters were recorded at the moment of 75Nm for the 61.7V, 127.3V and 143.2V for power values 70.3W, 76.4W, and 28.6W.

The speed of 2500 rev / min and an engine load of 75Nm were accompanied by the following electrical parameters of the turbogenerator (Fig. 9). The required current 0.73A, 0.5A and 0.2A. Powers obtained with these currents are analogously 53.6W, 57.6W and 29.8W. Another investigated value of rotational speed is 3000 rev / min which is, as in previous studies, the highest power of the system REST which was recorded with a load of the order of 75Nm (Fig. 10). The electric power obtained by the generator with such a torque is 223.3W, 250W and 208W for the current 2.9A, 1.79A and 1.2A.

The highest electric power gained during the experiment, generated by the system REST, was obtained at a speed of 3500 rev / min, and with a torque 75Nm (Fig. 11). The generator had values: 104V, 2.9A and power of 303W. In addition, the required current was at 2.1A with 140V and the obtained power was 294W, and also the required current was at 1.6A with 180V and the obtained power was 288W. However, the resulting maximum electrical power is not sufficient enough to replace the traditional alternating current alternator. On the other hand, these studies show that it is possible in certain operating conditions of the engine and the vehicle, disconnect the alternator. This solution also allows to use smaller nominal generator power, which enables the reduction of electricity.
Bibliography


Analysis and generation of messages in an automatic communication system at sea

Z. PIETRZYKOWSKI, P. BANAŚ, P. HATŁAS, P. WOLEJSZA
MARITIME UNIVERSITY OF SZCZECIN, Faculty of Navigation, Wały Chrobrego 1-2, 70-500 Szczecin, Poland
EMAIL: z.pietrzykowski@am.szczecin.pl

ABSTRACT
The development of unmanned remotely controlled and autonomous vehicles necessitates seeking new and improving existing systems of communications between such objects themselves and control or monitoring centers. This applies to maritime transport and other areas of transport. The article characterizes communication processes between the navigators on ships taking place via VHF in view of their automation. Some of the issues concerning analysis processes of message reception and generation of outgoing messages resulting from automatic reasoning are discussed. We also consider selected operations: message parsing, interpretation of data concerning the context and generation of outgoing message. An example is given of the analysis of the received message and corresponding answer.

KEYWORDS: automatic communication, message interpretation, navigation

1. Introduction
Increasing the scope of the automation of ship control and conduct is one of the actions aimed at reducing human error, a frequent cause of accidents at sea. The subprocesses subject to automation are: data acquisition, collection, processing and sharing. Increasingly, the automation also comprises the generation of solutions to collision situations in navigator’s decision support systems. The automation of ship control processes applies to all modes of transport. It is particularly evident in air and land (road and rail) transport. One effect of automation is work on unmanned remotely operated vehicles and autonomous vehicles.

To make correct decisions, the decision maker has to have access to information, in this case navigational situation at sea. The sources of this information are both internal and external systems and devices. Internal systems, such as radar or ECDIS, make the operator independent of external sources, which is crucial for the security of vessels. External sources, complementing the available information, include GNSS, AIS, GMDSS. They can also serve to verify information from internal sources. These are systems and equipment gathering and providing information about vessels located within their coverage area. These systems and equipment for automatic data exchange acquire standardized sets of data in predefined formats (standardised scope and form of information). Solving a solution may require additional information or arrangements. In this approach, navigators on ships (with crew on board) are an additional important source of information. Voice communication provides a channel of communication allowing to obtain additional information, and to make arrangements, if necessary. The automation of verbal communication helps to avoid errors perpetrated by navigators such as mere lack of communication, or wrong communication, e.g. misunderstanding of a message. The same method of communication between vessels can be implemented on unmanned or autonomous vehicles. In this connection, an essential complement to the systems of automatic data exchange can be automatic communication systems based on the principles used in verbal communication.
2. The system of automatic communication at sea

2.1. The purpose and scope

Processes of communication can be considered as exchange of information, perception of a message and interaction, e.g. negotiations [1]. Communication occurs in various areas of human activity, also in navigation processes at sea. Processes of communication at sea include [2]:

- acquisition, processing, transmission and sharing of information by using standard navigational equipment and systems,
- selective acquisition of information for enhancing situational awareness through the determination or specification of description, interpretation, assessment of current and/or projected situation, and intentions of traffic participants,
- negotiations, including co-operation, to ensure safe ship conduct, avoid hazards and prevent or minimize consequences of accidents.

At present, the automation of communication involves mainly the first group of processes, whereas in the other two groups the process of automation is less advanced. This is partly due to difficulties in the automation of verbal communication. The basic premise herein assumed is that automatic communication system will be based on the principles obligatory in or characteristic of voice communications.

The principles of ship-to-ship and ship-to-shore communication are governed by regulations (SOLAS Convention, performance standards for AIS and GMDSS, Admiralty List of Radio Signals, Standard Marine Communication Phrases [3, 4]) as well as good sea practices. The need for automation of verbal communication stems from the fact that those principles and other factors do not eliminate dangerous situation from occurring, resulting from failure to establish communication or erroneous communication: incomprehension of received messages, wrong choice of message or bad interpretation of exchanged information. It has been accepted that for encounter situations, where only one vessel has the said system, its functionalities will be limited to selective information acquisition from other available sources of information.

The development of automatic communication system calls for working out, inter alia:

- the necessary ontology of the field concerned (marine navigation) for the unification and unambiguous interpretation of navigational information,
- ontology of communication, taking account of the principles, forms, standards of communication, including verbal communication,
- methods of generating and interpreting messages,
- user interface,
- methods of interference.

The methods of generation and interpretation of messages are considered.

2.2. Modes of communication

Given the scope of the automation of communication, in particular selective information acquisition and negotiations, and the tasks necessary for (Chapter 2.1) the transformation of man-to-man communication to fully automatic communication between systems on ships and in land-based centres can be done in different modes (Fig. 1):

- man-to-man via a computer system; applies to manned vessels
- man-computer system (in both directions, any range); applies to encounters of vessels, in which only one is equipped with the system under consideration,
- computer system-computer system; applies to all types of vessels, including manned, unmanned, autonomous.

The modes of communication for the proposed system of communication for the sender - recipient relation is shown in Figure 1.

3. Processes of communication

3.1. The scope and form of messages

Determining the scope and form of messages, we adopted the division used in the Global Maritime Distress and Safety System (GMDSS). It includes rules and procedures of priority communication: distress (collisions, fire, grounding, man overboard etc.), urgency (technical failure, ice damage etc.) and safety (navigational and meteorological reports and warnings, environmental protection etc.). GMDSS System also enables routine communication. This
applies, for example, to situations, when ships report their position in traffic separation schemes or reporting system areas. Routine communication, unlike priority messages, has no specific structure or defined circumstances, in which communication must or should be performed. The attention was also drawn to messages formulated by navigators during VHF communication.

In [6] the authors proposed this message format: a header with a unique identifier, sender, recipient, body of message transmitted to the recipient. We assumed that transmissions consist of either a single message or a sequence of messages.

Three basic forms of communication: <Question>, <Answer> and statement <Tell>) and their attributes, defining what a single message refers to: 'Warning', 'Information', 'Request', 'Intention', 'Expectation', 'Demand' and 'Permission'. The message body is supplemented with items of the message, specifying the message content (Fig. 2).

Fig. 2. Structure of message body [6]

It is assumed that these elements are defined in the ontology of the field concerned (marine navigation) for the unification and unambiguous interpretation.

3.2. Ontology in the system of automatic communication at sea

Ontology deals with discovering and describing ‘what is’- in reality, in our minds, or observations. It is ontology that allows us to formalize knowledge and describe concepts hierarchically in order to establish the semantic relations within the field [7].

One of the first definitions was introduced by T. Gruber, who characterized ontology as a specification of a conceptualization [8]. For any broad field we can create different ontologies, describing that field in a different way.

The ontology referring to marine navigation may be used to describe communication between participants of the transport process, e.g. ship navigators. The need arises to comprehend a specific fragment of reality, and the said ontology, understood as the formalization of the knowledge of marine navigation, permits to unify the meanings of the concepts used.

The description of vessel traffic and communication between vessels makes use of the ontologies of navigation and communication and an interface. The ontologies were built with the Protégé program, which is used for object modeling, and supports designing of ontologies, data bases and complex formal models (Fig. 3).

The ontology of navigation distinguishes navigational information, manoeuvres, events, wheel and engine orders and objects created on the basis of Standard Marine Communication Phrases [4]. They make up main classes, to which instances, containing appropriate values, are assigned.

Communication ontology takes into account actual information acquisition and sharing processes and negotiations between traffic participants. It defines the message structure, distinguishing a header and message body.

The interface contains functions for interpreting messages, and semantic criteria. One of the functions is function $f$, responsible for generating messages (1). Function $f$ combines elements of set $X$ with one element from set $Y$, creating the message body.

Function $g$ is responsible for message interpretation, understood as the identification of the meaning of the information sent and of actions that must be undertaken in conjunction with the received message (2). This function assigns to the received message $K_i$ a combination of entities from sets $X$ and $Y$. The functions $f$ and $g$ are expressed by the formulas:

$$f: X \times Y \rightarrow K$$

(1)

$$g: K \rightarrow X \times Y$$

(2)

where:

- $X$ - a set of navigational concepts (entities contained in the navigation ontology),
- $X_k$ - set of entities in $k$-th sequence of messages,
- $k$ - numeral of a message sent ($k \in N$),
\[Y\] - a set of types of messages,
\[K\] - a set of messages,
\[K_i\] - \(i\)-th message from set \(K\),
\[K_j \equiv \{s_{i,1}, s_{i,2}, ..., s_{i,j}\}\] - individual words in a message, where:
\[s_{i,j}\] - \(j\)-th word in message \(K_i\),
\[i, j \in \mathbb{N}\]

Function \(g\) can be described by the following algorithm:
1. For every word \(s_i\) contained in message \(K\), its assignment should be searched for in one of the defined ontologies: navigation or communication,
2. Words assigned to the ontology of navigation are collected in a set \(X\),
3. The words attributed to the ontology of communication are collected in a set \(Y\),
4. If the cardinality of set \(Y\) is more than one, the words contained in this set should be examined for contradiction; if they are contradictory, and one of them is not a word requesting for information, the function returns an error indicating a wrongly worded (unintelligible, ambiguous) message, otherwise it returns the pair of sets \((X, Y)\).

The combination of communication and navigation ontologies with an interface (in the oval structure) is shown in Fig. 4.

**Fig. 4. Fragment of an ontology in the oval structure [own study]**

This ontology construction allows its extension to other modes of transport (Fig. 5).

**Fig. 5. Fragment of the ontology of navigation [own study]**

A graphical display of the process of communication at sea is shown in Figure 6. It encompasses the discussed earlier assumptions, scope, modes and forms of communication in the system of automatic communication at sea and a description the message built on the created ontology.

**Fig. 6. A diagram of automatic communication [9]**

### 3.3. Representation (record) of a message

In the presented solution, transmitted messages are encoded using the XML language. A single message consists of two basic parts: a header containing control information and the body encoding the message proper. Its components are shown in Figure 7.

```xml
<?xml version="1.0" encoding="UTF-8"?>
<ontology xmlns="http://am.szczecin.pl/zitm"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://am.szczecin.pl/zitm ontology.xsd">
  <message>
    <header>
      MessageID="13AD129E"
      MessageReapeted="0"
      ConfirmationRequired="true">
      The header defining message parameters:
      MessageID - unique identifier of the message,
      MessageRepeated - a tag of second transmission of message,
      ConfirmationRequired - obligation to acknowledge the message receipt
    </header>
    <sender>
      MMSI="9213911"
      name="GDYNIA"/>
    </sender>
    <receiver>
      MMSI="9056002" name="FU SHAN HAI"/>
    </receiver>
    <sent date="2003-05-31" time="12:09:02"/>
  </message>
</ontology>
```

A tag (markup) of an XML file

A reference to the XML schema describing the ontology used

The header defining message parameters:
- MessageID - unique identifier of the message,
- MessageRepeated - a tag of second transmission of message,
- ConfirmationRequired - obligation to acknowledge the message receipt

Definition of message sender

Identification of the sender’s ship

Definition of message recipient

Identification of the recipient’s vessel

Date and time of message transmission
4. Generation, analysis and interpretation of messages

4.1. Collision at sea – case study

The case concern a collision of two ships [10], where one of the recognized causes was lack of VHF communication between the ships' navigators. The collision between the m/v Fu Shan Hai and the m/v Gdynia occurred on 31st May 2003 north of Bornholm in daylight, with visibility over 10 Nm. The distance from the place of collision to the nearest navigational danger, shallow water, was about 3 Nm. There were also a few fishing vessels in the area, the traffic parameters of which did not constitute immediate threat of collision with any of the vessels.

The only signal transmitted during the collision situation was five short blasts (doubt signal) from the Fu Shan Hai. At 1205 hrs local time the vessels were in a distance of 2.9 nm from each other and the CPA according to ARPA was 0.4 nm. In the subsequent (06-08) minutes CPA rose to 0.5 nm, although it was actually on the level of 0.3 nm. Only at 1209 hrs, when the CPA started decreasing, did vessel “Gdynia” begin to alter course to starboard. At 1210 hrs vessel “Fu Shan Hai” issued 5 short blasts; she must have not noticed that “Gdynia” started altering course. At 1213 hrs, when “Gdynia” had altered her course by about 150° this fact went unnoticed on vessel “Fu Shan Hai”, which is why the master decided to stop engine. He did not notify other vessels about it; the manoeuvre could not be noticed neither visually nor by radar. At 1215 hrs the vessels were at a distance of 1.1 nm from each other. Two minutes before the collision “Gdynia” continued turning to starboard and was on a course of 320°. “Fu Shan Hai” was decreasing her speed. A minute before the collision “Gdynia” continued altering course to starboard (at the moment of collision she was on a course of 3500), and “Fu Shan Hai” continued to reduce her speed. From collision avoidance point of view both manoeuvres were neutralizing each other and eventuated in “Gdynia” striking the port of the other vessel making it sink.

Figure 8 presents both vessels’ position from 1200 hrs up to the moment of collision.
The give way vessel did not undertaking proper measures according to the situation (non-compliance with rules 8, 15, and 16 of COLREG). This may have been due to erroneous estimation of the situation, based mainly on ARPA information (breaking rules 5 and 7), which eventuated in undue nervousness of the other party, resulting in miss-judged decisions (action non-complying with rule 17) and leading to collision.

Massages, which enable to avoid collision:

Gdynia:
At 1209 “I’m altering course to starboard. My final course is…….” – or one short blast on siren/whistle

Fu Shan Hai:
At 1213 “I stopped my engine” – or three short blasts on siren/whistle

Fu Shan Hai did not perform a proper lookout and radar observation, this is why she did not noticed that Gdynia was altering course to starboard.

In short, if ships had notified each other of their intentions, they would not have carried out ineffective manoeuvres that neutralized each other.

### 4.2. Generating a message

In the case described above the two ships collided (with each other). One of the identified causes was a lack of communication between the ships’ navigators. We have examined the possibility of preventing that collision by using a system of automatic communication at sea. We have formulated messages that, if exchanged, could lead to collision avoidance.

Let us skip the phase of interference during message creation, and present the processes of message generation and interpretation in the system.

Here is how the collision could have been avoided:

**Gdynia**: ‘I am altering course to starboard. The final course is……’. 

**Fu Shan Hai**: ‘I stopped my engine’

Figures 9 and 10 illustrate those messages written in the ontology (oval structure).

![Fig. 9. Message from the ship Gdynia in an ontological record (own study)](image)

![Fig. 10. Message from the ship Fu Shan Hai in the ontological record (own study)](image)

Listed below are the messages generated on the basis of the ontology and formula (1).

The ship Gdynia

**Message:**

\[ f(X_1, Y) = K_1 \]

\[ X_1 = \{x_1, x_2, x_3\} \]

\[ Y_1 = \{T_{\text{information}}\} \]

The ship “Fu Shan Hai”

**Message:**

\[ f(X_1, Y) = K_2 \]

\[ X_2 = \{x_2\} \]

\[ Y_2 = \{T_{\text{intention}}\} \]

As mentioned in Chapter 2.2 messages may be generated in different modes. It has been adopted that the process of message generation is carried out in the manual mode.

### 4.3. The analysis and interpretation of the message

If we use the previously introduced message format using XML language, the interpretation of a message consists in the parsing of received messages in accordance with the indicated types of
messages. Since the defined message types clearly indicate a context, further interpretation of the message content is unambiguous: depending on the indicated type of message, it is interpreted as sending information on the present situation (information) or its probable change (intention), which requires updating of the knowledge base (data base) on navigational situation. When another type of message is identified (permission, question, request), the message is interpreted as the need of performing operations using indicated navigational data, e.g. sending indicated information or performing a manoeuvre.

An interesting issue in this context is the interpretation of messages transmitted in the form of a simple text, which should be analyzed in terms of syntax and semantics, and not in the coded form using XML.

Interpreted messages, displayed in the program window, have the form as shown in Figure 11.

Interpreted messages, displayed in the program window, have the form as shown in Figure 11.

**5. Conclusion**

The automation of communication processes, including verbal communication between navigators on board ships, can be one of the ways to reduce the number of collisions at sea.

The authors have presented the assumptions, modes and forms of automatic communication at sea and some problems of outgoing messages generation, resulting from the automatic inference, analysis and interpretation of incoming messages. One specific case of ships’ collision is given, where the navigators failed to establish contact on VHF radio. One of the ways to prevent that collision could have been sending messages about actions taken by both ships. The authors also describe the process of generation and interpretation of messages coming in the automatic system of communication specifically for the collision case considered.

The automation of communication processes, including verbal communication, is crucial for ships with crews as well as unmanned and autonomous vessels. The same observation applies to other types of transport.

**Bibliography**


[10] WOLEJSZA P., BANACHOWICZ A.: Advances in marine navigation and safety of sea transportation, pt. The analysis of possibilities how the collision between m/v Gdynia and m/v Fu Shan Hai could have been avoided, Gdynia 2007

Intraregional transport accessibility of Łódź province in terms of data on theoretical and real travel times

S. WIŚNIEWSKI
UNIWERSYTET ŁÓDZKI, Faculty of Geographical Sciences, 90-142 Łódź, Kopcińskiego 31, Poland
EMAIL: szymon.wisniewski@geo.uni.lodz.pl

ABSTRACT
The article presents results of research devoted to comparison of intraregional transport accessibility of the Łódź province in the light of theoretical and real travel times by individual car transport. The article has two aims: methodological and cognitive. The first one comprises assessment of utility of presented data for research into transport geography, in particular those devoted to accessibility. The latter concentrates on analyzing differentiation (also spatial) of differences in travel times resulting from adopting the theoretical and the real variant. Data on theoretical travel times include the author's own calculations whose key assumption is that car vehicles move on a network of roads at maximum speeds allowed by law with exclusion of all other variables. The second source of data (on real travel times) is Distance Matrix Responses provided by Google Maps APIs. Due to the use of the isochrone method and the potential method it was stated that data obtained from Google servers is highly useful for accomplishment of research into transport geography, including time accessibility analysis. One may not, however, treat the regularities presented in it uncritically and use them for unrestricted analysis. In relation to the cognitive aim it should be pointed out that differentiation (also spatial) of differences in travel times resulting from adopting the theoretical and the real variant for connections between settlement units of the Łódź province is considerable.

KEYWORDS: time accessibility, potential accessibility, theoretical travel time, real travel time, Łódź province

1. Introduction

The reason for the research is the necessity to analyze, from the perspective of car transport, differences in time transport accessibility which result from basing calculations on two sources of data referring to travel times to the same matrix of (source and destination) points. The first source includes the author's measurements whose key assumption is that vehicles move on the road network at maximum speeds allowed by law with the exclusion of all other variables (such as congestion, weather conditions or the driver's personal features). A detailed description of measurements can be found in the part of the article devoted to the methodology. Another source of data is Distance Matrix Responses provided by Google Maps APIs. Due to this service it is possible to obtain data on real travel time between any two points on the Earth which can be reached by the given transport mode, i.e. as long as they are connected by an adequate transport network. The application algorithm will be explained later in the article.

Obtaining data from both sources for the same matrix of points allows to carry out comparative analyses considering travel time, its average speed and potential if the component of land use is considered.

The area on the basis of which the research was conducted is the Łódź province and the data included in the research is valid as of August 2016.

The article has two aims: methodological and cognitive. The first aim comprises assessment of utility of the presented data for research in the field of geography transport and that of accessibility in particular. The latter aim focuses on research into differentiation (also spatial differentiation) of differences in travel times resulting from adoption of the theoretical and the real variant.
Considerable interest of scientists in the topic of transport accessibility is reflected in numerous Polish and foreign publications. It is worth mentioning research conducted by Hansen [1], Ingram [2], Spiekermann and Neubauer [3], Guzik [4], Komornicki and others [5], Rosik [6], Stepiński and Rosik [7], Kosiak [8] or Wiśniewski [9]. Research is also accomplished with the use of data on vehicle traffic transmitted in real time but there are far fewer publications in this field. These include, however, publications by, for instance Rose [10], Bar-Gera [11], Backer and others [12], Calabrese and others [13], Gao and Liu [14], Iqbal and others [15] or Bartosiewicz and Wiśniewski [16].

A major research problem today in the field of transportation geography is finding means of obtaining data that would enable in-depth research to be conducted on transport accessibility based on actual automobile traffic. The only reliable source of information currently available for analysis of road load is General Traffic Measurements, which are conducted on regional and national roads every five years (the latest two took place in 2010 and 2015), and which allow total vehicle traffic on a given road can be determined. Analyses of transport accessibility (in terms of automobile traffic) enable us not only to diagnose the movement of goods and people, but also help to clarify a number of spatial socio-economic problems, and – perhaps most importantly – encourage the adoption of appropriate transport policies. For this reason, such analyses have proven extremely important. The conclusions drawn from accessibility analysis can be useful for decision makers and planners on various levels of management, from the local to national echelons [17].

The impact of transport accessibility on specific areas and locations, and transport strategies formulated on their basis are often evaluated by means of methods that decision-makers and scientists studying accessibility and mobility can easily be put into operation and whose results can be easily interpreted, such as travel speed, which, however, generally do not meet the criteria for use in theoretical research. More advanced tools for measuring accessibility increase the complexity and effort involved in calculating and interpreting the results. Current practices in this area can be significantly improved by introducing more sophisticated means for operationalization accessibility based on modern computer systems, using mobility data transmitted in real time [18]. This article responds to the ongoing need for theoretical and empirical research on the relationship between accessibility and the speed of their movement. Achieving good transport accessibility and evenly distributed transport services is one of the main objectives of transport policy. The data source presented in this paper is a response to several constraints to measuring accessibility with other existing models used in planning practices. It offers an alternative and practical tool to help planners and decision-makers analyse the strengths and weaknesses of the transport infrastructure. Studying transport accessibility has been of interest for a long time, and in this sense, the research hereby proposed is a continuation of search on effective and ergonomic ways of measuring this phenomenon. At the same time, in comparison to existing methods, the methodological approach hereby presented is innovative on a wide scale. Creating a method for measuring actual transport accessibility will have a considerable impact on the approaches currently used in transport geography to measure this phenomenon, and will simultaneously indicate the possibilities for applying modern information technology in this field of study. By applying modern technologies and using widely available data the method allows for a precise and current description of phenomena such as flow and average automobile traffic speed without the need to conduct expensive direct studies.

The data obtained by the method described herein can help improve the quality of representations of the spatial effects of interactions on the demand for transport in model studies, which are often based on generic curves that have little grounding in empirical data [19]. In terms of applicability, the research results provide diagnostic material for institutions dealing with the design and realisation of transport infrastructure, as well as for regional governments at all levels responsible for drafting spatial policy and strategic documents on i.e. the functioning of transport systems.

Information and communication technologies allow users to access a virtual space without having to physically travel the distance and spend time travelling. Developments in technology, including those used in measuring accessibility, mean that distance recorded by means of different indicators is taking on new meaning. In physical space, accessibility is measured based on the spatial distance between sites or between possibilities and those seeking them [20]. From a virtual perspective, spatial distance loses its meaning. The study below makes it possible to incorporate the virtual component into existing available models. In general, the impact of the use of information and communication technologies in the field of accessibility cannot be overestimated.

2. Source materials and research methods

In order to accomplish the adopted research assumptions it was necessary to collect data in reference to the road network of the Łódź province as well as distribution of its settlement units and demographic potential. The information about the course and allowed maximum speed on individual sections of the road network was obtained from the resources of the General Directorate for National Roads and Motorways (GDDKiA), Province Roads Authorities as well as OpenStreetMap (OSM) databases so as to calculate theoretical travel time. OSM is a community project which allows to use and edit data under the Creative Commons license [21].

Besides, the author included into the research data on the distribution of all settlement units in Poland together with the number of their inhabitants. A central point was generated for every out of 4,968 settlement units and it was given the number of the unit’s inhabitants in accordance with the data of the Ministry of Internal Affairs and Administration, the Main Statistical Office and City and Municipality Offices (fig. 1.).

To compare theoretical and real travel times it was necessary, in the first place, to construct a matrix of sources and destinations. Both groups comprise all settlement units of the region. In this way a matrix of 4968 per 4968 was obtained.

The following formula allowed to calculate theoretical travel times. The first step consisted in construction of a transport network on the basis of which travel times were subsequently calculated. At this stage every segment of the road network was ascribed the maximum allowed speed depending on which type of road it represents. This, in
Obtaining data concerning real travel times requires more commentary. Firstly, the use of the term “real” needs to be explained. In accordance with the instruction presented by the service provider, travel time between any two points is defined as perennial (since 1 January 1970) average travel time of vehicles between these points. It is necessary here to show how Google gets data on travel routes. Data is obtained from sensors located on roads, information from taxi corporations, government services, private database distributors and on an anonymous basis from users of the mobile version of Google Maps for Android, IOS, Symbian, Windows Phone and others which give access to their location data. The service provider collects data concerning the courses of device movement and is able to specify how long the travel between two specific points normally is in real conditions in which traffic takes place through averaging them.

Before embarking on downloading data from the service provider it is necessary to accept license requirements and obtain a suitable API key. Application parameters include, for instance, starting and finishing points (it is possible to feed one or more locations in the form of geographic coordinates), movement mode (means of transport), exclusions (exclusion of travels made on infrastructure of certain parameters) or traffic model (adopting the perennial average transport), external potential (exclusion of travels made on infrastructure of the form of geographic coordinates), movement mode (means of transport), and settlement travel time between settlement unit i, or when the location of unit i is notably remote from other relatively large units j, or when the passenger is highly sensitive to extending travel distance or if the destination attractiveness decreases rapidly.

Potential accessibility is an approach which is frequently used in research into transport accessibility [22, 23]. In the group of models referred to as "potential accessibility", there are variants of accessibility measured by means of potential indicators. Those variants assume different parameters and function types. Their common feature is the fact that they take into account two interrelated components: land use component and transport. The most characteristic feature of potential accessibility is the fact that the attractiveness of destination increases together with its size (component of land use) and drops together with an increase in broadly understood distance [6].

Potential can be divided into three elements in the form of own, internal and external potential [24]. This division was used in this work to calculate potential accessibility of settlement units on the area of the Łódź province. The external potential, however, was not accounted for due to the number of data necessary. The problem is posed by license restrictions implemented by the service provider. Assuming the linear function to describe the attractiveness of weight and time distance as a selected element of space resistance, the general formula for potential accessibility used in this work assumes the form of:

\[ A_i = M_i f(t_{ii}) + \sum_j M_j f(t_{ij}) \]  

where:

- \( A_i \) – potential accessibility of settlement unit i,
- \( M_i \) – own weight (number of population) of settlement unit i,
- \( M_j \) – weight of settlement unit j located within the boundaries of the Łódź province,
- \( t_{ii} \) – internal travel time in settlement unit i,
- \( t_{ij} \) – travel time between settlement unit i and settlement j.

Own potential was included into analysis to specify the impact of own weight of a settlement unit on its general transport accessibility. According to Rosik [25] it is of great importance in relation to internal and external potential if the own weight of unit i is relatively big in relation to other weights j, or when the location of unit i is notably remote from other relatively large units j, or when the passenger is highly sensitive to extending travel distance or if the destination attractiveness decreases rapidly.

The best solution of problems connected with appropriate assessment of own potential is a low degree of data aggregation during the research. Consequently, it seems adequate to adopt settlement unit as the basic unit of the analysis. While calculating travel times within the researched unit researchers tend to adopt average speeds lower than those in travels between units, which turn, allowed to estimate the segment’s travel time and finally choose the quickest routes between adopted points in accordance with the Dijkstra’s algorithm.

![Fig. 1. Distribution of settlement units and demographic potential against the background of the region's road network (own study)](image)
is can be attributed to the fact that internal travels to a large degree are accomplished on local roads where one may achieve notably lower average speeds. The length of average travel in this perspective is often defined on the basis of the length of the radius if the unit surface is generalized to the circle [25]. It may be assumed that it is exactly half the length of the radius. This distance was assumed, for instance, by Rich [26] or Gutiérrez and others [27]. In this analysis the travel time within the unit is defined as theoretical (convergent with the Traffic Code articles) or real travel time between the farthest points in the settlement space connected by hard-surfaced roads. The internal potential, in turn, defines the impact of weights of units distributed in the Łódź province on general accessibility of settlement unit i.

Admittedly, potential accessibility has many advantages. This method outdoes accessibility measured by distance or cumulative accessibility as it accounts for correlations between the aforementioned component of land use and the transport component.

One disadvantage of potential accessibility is high sensitivity of results to the choice of the functional form and parameters of space resistance function, the assumed speed and travel distance within the transport region (used while calculating own potential), the understanding of the notion of weight attractiveness or the way of delineating space (also ascribing weights to nodes or centroids). Even small differences in the level of parameters may result in considerable differences in final results. It is vital to model the function of space resistance in an adequate way. Another problem is that results of the potential model are not easy to interpret, which results mostly from the fact that potential accessibility has no units. Because of this, research results are often given in the relative form, i.e. in the form of percentage changes in accessibility of individual researched items in relation to the adopted starting level. The basic issue determining the results of potential the accessibility model is the space resistance function. The work uses the exponential function, i.e. one with basis e (natural logarithm), which is often used in empirical research. The formula of the exponential function of space resistance assumes the following form when used in research into potential accessibility:

\[ f_{st} = \exp\left(-\beta t_{ij}\right) \]  

where:

- \( f_{st} \) – space resistance function,
- \( t_{ij} \) – travel time between settlement unit i and settlement j,
- \( \beta \) – beta parameter.

This research uses two different indicators of space resistance depending on travel destination. The aim of this is to reflect the rationality of decisions made by travellers as it should be assumed that the attractiveness of the given destination drops together with an increase in (differently understood) distance or, more generally, effort which the traveler is forced to make to reach this destination.

As it is shown by numerous research into traffic modelling (conducted, for instance, by the Stanislaw Leszczynski Institute of Geography and Spatial Organization of the Polish Academy of Sciences), the indicated decrease in attractiveness is characterized by diversified spatial distribution depending on, for example, the purpose of the journey (e.g. shopping, visiting someone, business trips) which may be identified with travels in specified distance or duration intervals. This is why travels within settlement units were qualified as very short and in accordance with research into Poland’s land transport accessibility [6] the beta parameter equalling 0.0347 was used in them. Travels between settlement units within the Łódź province were identified as short travels and the parameter beta equaling 0.0154 was used in the function of space resistance.

Potential accessibility of settlement units for both theoretical and real time distances was calculated in accordance with the above method. Subsequently, the relative change in potential was assessed, adopting theoretical potential as 100%.

Subsequently, interpolation of the value of change in accessibility was accomplished on the basis of data on changes in potential accessibility for 4,968 settlement units the Łódź province.

### 3. Time accessibility

Juxtaposition of theoretical and real travel times (from the topological perspective) between settlement units of the Łódź province allows to generalize that travelling around the region lasts longer than it is indicated by traffic law (fig. 2.). A different conclusion seems impossible if it is assumed that drivers observe articles of law. Results of comparisons in single connections show, however, that drivers are capable of covering the given route in a much shorter time than that permitted by law.

An increase in topological travel time (either theoretical or real) connected with moving away from the region’s geometrical centre naturally results from the fact that time accessibility was analyzed solely within the province: its administrative border was a barrier for travels. If research into transport accessibility of settlement units of the province were to be subject to research in general, the introduction of this kind of barrier would have to be considered a mistake. It is of key importance in this research, however, that there are differences in travel times and their distribution within the province boundaries.

Analysis of spatial differentiation of theoretical travel time allows to highlight an important role of the region’s motorways and expressways in shaping transport accessibility of the province settlement network. Isochrones clearly “follow” the course of A1 and A2 motorways and S8 expressway, ”stretching” the area of the best transport accessibility both latitudinally and longitudinally. The course of isolines of identical travel time based on data concerning real movements appreciably levels this positive aspect. Admittedly, it is still visible yet its interpretation is not so explicit.

This clear difference can be interpreted twofold. First, one may conclude that there are factors which interrupt travelling on the network of roads of the highest parametres in a smooth and quick manner. Examples include congestion at toll booths or slip roads to motorways or weather conditions which do not allow to drive at speeds permitted by law.

Another explanation, in turn, is connected with the data on travel time itself. The service provider presents averaged perennial results, and a large part of the network of roads of limited accessibility (motorways, expressways) has been constructed on the area of the Łódź province in the last few years. Real shorter travel times resulting...
from implementation of this infrastructure still represent such an
insignificant percentage of all measurements that their impact on the
average result is limited.

Consequently, it is interesting to observe the spatial differen-
tiation of differences in topological theoretical and real travel
time (fig. 3.). It is possible to see time losses in the case of travels
commenced from settlement units located in the stripe between
Wieruszów - Wieluń - Belchatów - Lask - Aleksandrów Łódzki
and Uniejów. With respect to the number of connections (over 12
million) these losses seem insignificant, even though their differen-
tiation is rather considerable.

Superimposing the course of isolines of identical time differ-
ence on the settlement network and distribution of the province's
population allowed to specify which part of the region's society
is concerned with individual accelerations or delays with regard to
theoretical travel times (tab. 1.).

The above breakdown shows that over 30% of the region's
population (and picture no. 3 shows that it is the province centre)
reaches their destination slightly quicker than it is set out by
traffic regulations when they move between different localities.
The vast majority of this group is comprised by Łódź inhabitants.
The remaining inhabitants of the province make their local and

---

Table 1: Area surface, settlement units and number of population
of the Łódź province in individual isolines of differences in
topological travel time [own study]

<table>
<thead>
<tr>
<th>difference in topological travel time (hrs)</th>
<th>area surface [km²]</th>
<th>share [%]</th>
<th>settlement units</th>
<th>share [%]</th>
<th>number of population</th>
<th>share [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>-193.3 – -124.1</td>
<td>65.9</td>
<td>0.4</td>
<td>15</td>
<td>0.3</td>
<td>1398</td>
<td>0.1</td>
</tr>
<tr>
<td>-124.1 – -81.3</td>
<td>174.7</td>
<td>1.0</td>
<td>35</td>
<td>0.7</td>
<td>8808</td>
<td>0.4</td>
</tr>
<tr>
<td>-81.3 – -54.9</td>
<td>1 990.8</td>
<td>10.9</td>
<td>536</td>
<td>10.8</td>
<td>113 397</td>
<td>4.6</td>
</tr>
<tr>
<td>-54.9 – -38.5</td>
<td>3 799.0</td>
<td>20.9</td>
<td>1 041</td>
<td>21.0</td>
<td>229 648</td>
<td>9.3</td>
</tr>
<tr>
<td>-38.5 – -28.3</td>
<td>4 118.3</td>
<td>22.6</td>
<td>1 078</td>
<td>21.7</td>
<td>300 707</td>
<td>12.2</td>
</tr>
<tr>
<td>-28.3 – -22.0</td>
<td>2 301.9</td>
<td>12.7</td>
<td>654</td>
<td>13.2</td>
<td>207 233</td>
<td>8.4</td>
</tr>
<tr>
<td>-22.0 – -18.2</td>
<td>1 474.1</td>
<td>8.1</td>
<td>439</td>
<td>8.8</td>
<td>301 791</td>
<td>12.2</td>
</tr>
<tr>
<td>-18.2 – -11.9</td>
<td>2 765.9</td>
<td>15.2</td>
<td>782</td>
<td>15.7</td>
<td>306 382</td>
<td>12.4</td>
</tr>
<tr>
<td>-11.9 – -1.7</td>
<td>1 124.7</td>
<td>6.2</td>
<td>333</td>
<td>6.7</td>
<td>215 055</td>
<td>8.7</td>
</tr>
<tr>
<td>-1.7 – 14.6</td>
<td>375.4</td>
<td>2.1</td>
<td>55</td>
<td>1.1</td>
<td>785 037</td>
<td>31.8</td>
</tr>
<tr>
<td>sum</td>
<td>18 190.8</td>
<td>100</td>
<td>4 968</td>
<td>100</td>
<td>2 469 456</td>
<td>100</td>
</tr>
</tbody>
</table>

---

Fig. 2. Spatial differentiation of theoretical (upper map) and real
(lower map) travel time for Łódź province settlement units
from the topological perspective [own study]

Fig. 3. Spatial differentiation of the difference between real and
theoretical travel for Łódź province settlement units time in
topological terms [own study]
intraregional journeys longer than is allowed by infrastructure conditions.

Looking at theoretical and real travel times in the case of individual connections (fig. 4.), it should be concluded in general that the longer the journey, the bigger time losses in relation to theoretical possibilities. At the same time it is worth stressing really considerable changeability of this correlation since the linear function characterized by the highest determination ratio accounts for it in merely about 30%.

4. Travel speed

The data obtained on theoretical and real travel times allowed to analyze discrepancies between average travel speeds in both variants of the research (fig. 5.).

This feature of intraregional translocations is also characterized by clear spatial differentiation. Its mean value from all analyzed connections is not dependent on the distribution of settlement units in relation to geographic centre of the province.

A breakdown of results (fig. 6.) shows clear, if relatively small, areas of concentration of settlement units from which it is slower by 19 km/h on average to travel around the region than it is allowed by traffic law. These include the neighbourhoods of Tomaszów Mazowiecki, Opoczno and Drzewica. On the other hand, there are patches of areas from which travels within the boundaries of the province are on average over 11 km/h faster than those allowed by law. It is difficult to see any regularities in their distribution.
5. Potential accessibility

The research is complemented by potential analysis. Acting in accordance with the aforementioned algorithm, the potential of Łódź province settlement units was calculated adopting theoretical values in the first variant and real values in the latter as space resistance. The weight (number of population) of the locality remained unchanged (fig. 7).

Fig. 7. Spatial differentiation of settlement network potential of the Łódź province with the assumption of theoretical (upper map) and real (lower map) travel time [own study]

Taking into account both the transport component and the land use component allows to assess the scale of impact of differences in travel time on the region’s potential. If calculations in absolute terms allow to evaluate spatial differentiation of the phenomenon in both variants, then the scale of changes is better illustrated in relative terms (percentage) since distribution of potential is a derivative of the aforementioned distribution of topological travel time as well as the distribution and weight of settlement units. As the Łódź region (notwithstanding new structural investments) is characterized by a road layout close to the concentric one with a core which is over six-time larger than the second biggest centre considering the number of inhabitants, the distribution of potential refers to the concentric one to a certain extent.

Substituting real travel times between Łódź province settlement units to the formula for their potential results in, generally speaking, considerable changes in the value of potential and its considerable spatial differentiation within the province (Fig. 8.). Real potential represents only a small share of theoretical potential on a considerable area of the region. The opposite situation may occur only occasionally in the neighbourhood of Złoczew, Radomsko, Wolborz and Przedborz. A decrease in potential concerned a markedly larger part of the region.

Fig. 8. Spatial differentiation of potential relations of Łódź province settlement network with the assumption of theoretical and real travel time (theoretical potential = 100%) [own study]

6. Conclusion

The conducted research proceeding seems to have accomplished the aims adopted at the beginning of the article. In relation to the methodological aim it should be considered that data obtained from Google servers was really useful for accomplishment of research into transport geography, including time accessibility analysis. One may not, however, be indiscriminate in relation to the regularities presented by the research and use them for any kind of analysis. One invaluable feature of the research is the fact that results are averaged, which is also its big disadvantage. Data on average travel time between any two points on the Earth collected for many years is undoubtedly an abundant research material which has no distortions of results connected with untypical occurrences on the road. Averaging results “flattens” all extremely long or short travels on the given road network section. Consequently, the impact of any
random events, seasonality or changes in traffic connected with, for instance, all types of holidays, remains insignificant. Consequently, these data are ideal for research into transport behaviour which is aimed at detecting general features of travels on the given area. At the same time it does not apply at all to analysis of dynamic phenomena. For instance, it does not reflect changes in travel time resulting from adding a new motorway or expressway section or closing a road in the city for repair. Admittedly, the service provider will detect shorter or longer travel times but averaging perennial results will make these changes imperceptible. They will become apparent only after some time when the number of new travel time measurements will represent an adequate share of a whole set of measurements. License restrictions concerning the number of researched connections pose certain inconvenience while using data on real travel times. Their number is unlimited only upon paying an adequate charge, which is why it may be problematic if it occurs that research requires a number of data which considerably exceeds the number of „free” records and no funds have been allocated for this purpose in one tranche. The data needed may be naturally obtained for a longer period of time since every 24 hours the limit of free downloads is renewed. However, during every 24 hours servers collect a great number of data which in a way influence the final value of average travel time on the given section. Consequently, the situation varies slightly every day when data is downloaded. These differences for individual connections are, of course, insignificant. However, if the research assumes the format of topological relations and the group of starting and finishing points is very large, these differences may presumably affect the final results.

Considering the article’s cognitive aim, it must be pointed out that differentiation (also spatial) of differences in travel time resulting from the adoption of the theoretical and real variant for connections between Łódź province settlement units is rather considerable. The adopted aim assumes a universal form whereas the research was conducted on a relatively small area but it was accomplished for a rather large number of connections amounting to 12 million. Naturally, it seems justified that similar research be conducted for other spatial scopes (e.g. city, country) and areas of different characteristics of the settlement network or road network layout. Nonetheless the research includes connections of different travel times leading through a very diversified area as far as land development is concerned and running through the road network of the Łódź province which is very diversified in terms of parameters and technical condition. Hence it may be assumed that the results obtained will not be characteristic of the Łódź province only but instead they show regularities which may be encountered also in the case of research conducted on other areas between different reference points.

Based on this diagnostic data, guidelines for documents authorizing transport policy could be drafted. Thanks to the information on the weak spots in local and regional transport networks, it may be possible to choose which development paths are optimal and which regions need the most attention – that is which regions have such poor transport networks that they remain ‘excluded’ from transport.

Further studies based on data relating to actual transit times should be developed in two directions. Firstly, the data that are already available, should be widely applied in the field of analysis of transport - even for calibrating models of traffic. Secondly, researchers should make efforts to gain access to the source data that are aggregated by the supplier. Information about the location of the vehicle and its current speed would allow for numerous analyzes of mobility. Of course, data of this nature can be purchased, however, the barrier is the price and the protection of personal data. Suitable process of anonymization of data and providing development tools in this area would open up wide possibilities for research in many fields of science and practice issues.

Bibliography