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CONCEPTUAL MODEL OF PROVIDING TRAFFIC NAVIGATION SERVICES TO VISUALLY IMPAIRED PERSONS

ABSTRACT

In order to include people of reduced mobility in the traffic system it is necessary to provide accessibility and information of the users to all the facilities surrounding them. By analysing the currently available information and communication technologies a new conceptual model of providing navigation services to the visually impaired persons has been proposed. This model is based on Cloud Computing platform, and this research describes the method of navigating the users based on accurate and updated data. The users' requirements have been analysed according to the needs of the movement of visually impaired persons along the traffic network. The information and communication solutions with the function of informing these groups of users have to provide accurate and updated data, which is made possible by the proposed model. This research was conducted on the most frequent routes in the city of Zagreb. With the review of model efficiency user's sense of security is increased in the amount of 87%.

1. INTRODUCTION

Persons with reduced mobility can be divided into several categories which depend on the level of their impairment. The main classification of these persons is into the persons with impaired vision, speech and hearing. In this research the defined group of users are persons with impaired vision (partially sighted and blind persons). According to the latest available data there are 1,985 visually impaired persons in the City of Zagreb [1]. Out of this figure, 171 users are permanently employed, and this figure is defined as a relevant sample in carrying out this study (the mentioned persons move daily along the traffic network).

The visually impaired persons (further in the text "users") in their independent movement along the traffic network use the basic aids, white cane or guide dog. By using one of the aids the user obtains information within a radius of up to 1.50 [m]. The drawback of such a form of information is other information which includes: better perception of the surroundings, orientation, possibility of faster decision-making, and better mobility. The mentioned information can be substituted by the application of information and communication (IC) technologies and services, which defines the concept of assistive technologies in traffic [2]. One of the applications of assistive technologies is reflected in the use of IC solutions for the guidance and navigation of the users along the traffic network. The mentioned solutions are based on global navigation satellite systems (GNSS), systems for data transfer in mobile networks (GPRS, EDGE, UMTS, etc.) and geographic information systems (GIS) [3]. The user interface is an important component in such solutions because it has to be adapted and fully available by its functions. By analysing the availability of GPS systems the main problem in such solutions are errors in information about the user's location [4]. The mentioned drawbacks can be substituted by the application of other technologies in the function of locating and navigating the users, as well as informing purposes [5]. The identification of traffic intersections as parts of the traffic network is possible by the application of points of interest (POI) within mobile applications [6, 7]. POI markings have the role of informing the users about a certain facility, which is in their vicinity.

Information on the user's location and environment represents the basic parameter in defining the

user's request for route planning. The collection of all relevant data into one information system is possible by applying the proposed conceptual model based on *Cloud Computing* (*CC*) platform. *CC* is used as a platform in case of services for identification of traffic intersections, but also in case of identifying pedestrian crossings [8, 9, 10].

2. METHODOLOGY OF RESEARCH

The problem of research is indicated through the absence of accurate and updated information that surround the user while moving along the traffic network. The research included 101 users who move independently and daily in the area of the city of Zagreb, which is 59% of the predicted number (171). Apart from this, also the users who use guide dogs – 14 (100%) and student population – 29 (100%) participated in the study as well. The users participated in the survey independently by means of on-line questionnaire, and per telephone in the form of interview.

As part of this research, one of the authors attended the training of orientation and movement with an authorized peripathologist in the duration of six months, satisfying all the training methods. The results of the training are reflected in the definition of the picture (perception) of the surrounding, feeling of safety, orientation, identification of elements of the traffic intersection and determining of the method of traffic control at a traffic intersection.

When calculating the duration of the green phase for the pedestrians in the Republic of Croatia the average speed of the users of $v_r = 1.2$ [m/s] to maximum 1.5 [m/s] is taken (in places with extreme traffic a lower value is taken as well) [11]. For persons of reduced mobility this speed should not be lower than 1.0 [m/s], whereas the research results show that the mean users' speed is 0.55 [m/s].

In evaluating the accessibility of mobile terminal devices and availability of certain services the research [12] has been used. The research shows that

143 users use mobile terminal devices, which is important when designing this conceptual solution.

3. CURRENT STATE

In the City of Zagreb, on 31 October 2012 there were 76 traffic intersections equipped by audio signalling devices, and a total of 698 signalling devices. Audio and tactile information represents currently the only method of informing the visually impaired persons while moving along the traffic network. The users evaluated by means of a survey the methods of information (audio and tactile) at the most frequently used traffic intersections. In the carried out analysis, as presented in *Figure 1*a and 1b, there is great dissatisfaction by the users with current audio and tactile information.

The users assessed five most used traffic intersections at the same time assessing their own level of safety (feeling when moving through it). This means that the user, when moving, cannot fully use the methods from the training of orientation and mobility. According to the mentioned criteria the users assessed the traffic intersection of Zvonimirova Street – Šubićeva Street as the least secure one (72 users). The mentioned traffic intersection was used for experimental implementation of the proposed model.

The importance of the current method of information is related to the operation of the control system of the traffic intersection for the pedestrians. For this purpose *Figure 2* shows current method of operation of the traffic light system presented in *Unified Modelling Language* (UML) notation.

The figure shows that when moving the user enters the area of red phase, when the mode of operation changes and audio information endangers the safety of the user. While moving the user is provided with the information by the use of senses, as well as aids such as white cane or guide dog. The significance of the green phase duration was assessed by the users in
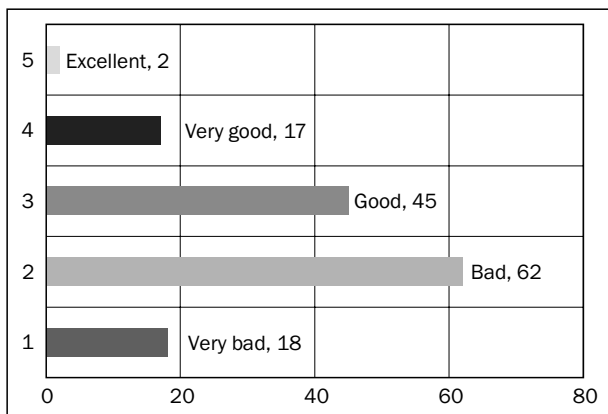
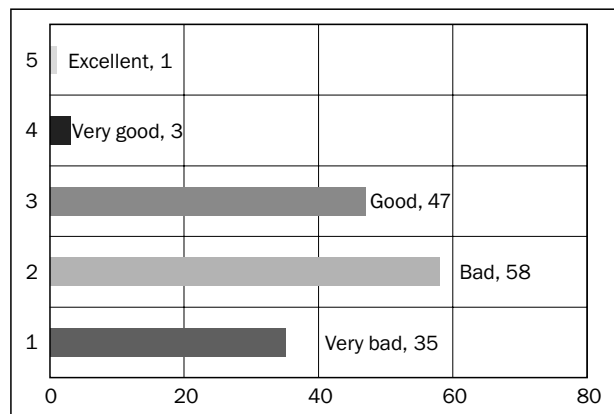*Figure 1a) Satisfaction of users with audio information*

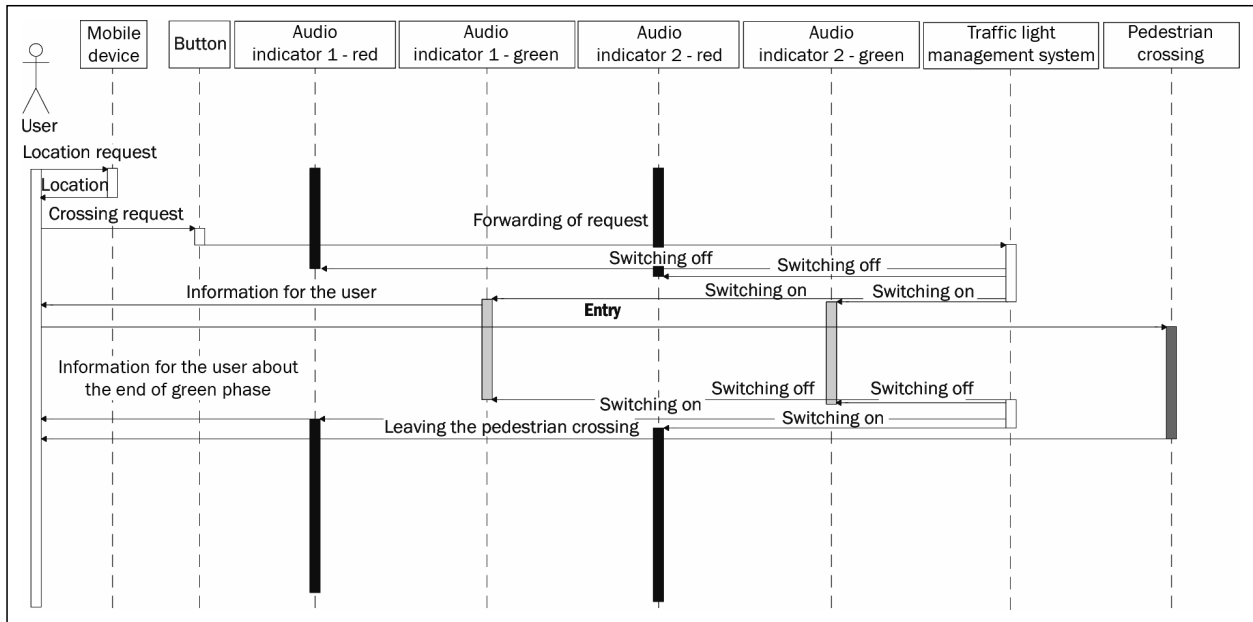*Figure 1b) Satisfaction of users with tactile information*

Figure 2 – Movement of users through traffic intersection (current method)

the survey, with 99 users (69%) stating that the current duration of the green phase is too short.

The analysis of the availability and adaptability of IC services to visually impaired persons shows that a large number of users use new technologies. There are 136 (94%) users using computers, whereas *Figure 3* shows the assessment of managing abilities in using the Internet.

The carried out analysis of the availability of the Internet contents and possibilities of using the mobile terminal devices is important when creating the user requirements. The results of the analysis of the traffic light system show the importance of single elements in the function of informing the users (green phase, surroundings, perception). Green phase i.e. information during which the user can be safely directed through a part of the traffic intersection increases the user mobility safety level.

4. CLOUD COMPUTING ARCHITECTURE FOR THE BLIND

In designing the new conceptual model it is important to define the requirements of the users who move or plan to move through the traffic network. The user requirements can be categorized into two groups: by implementing the applicative solutions based on new technologies and the classical method of using the aids.

4.1 Cloud computing platform

CC platform can be described through five basic characteristics, three models of services and three different implementation models [13]. Five basic characteristics are described as follows:
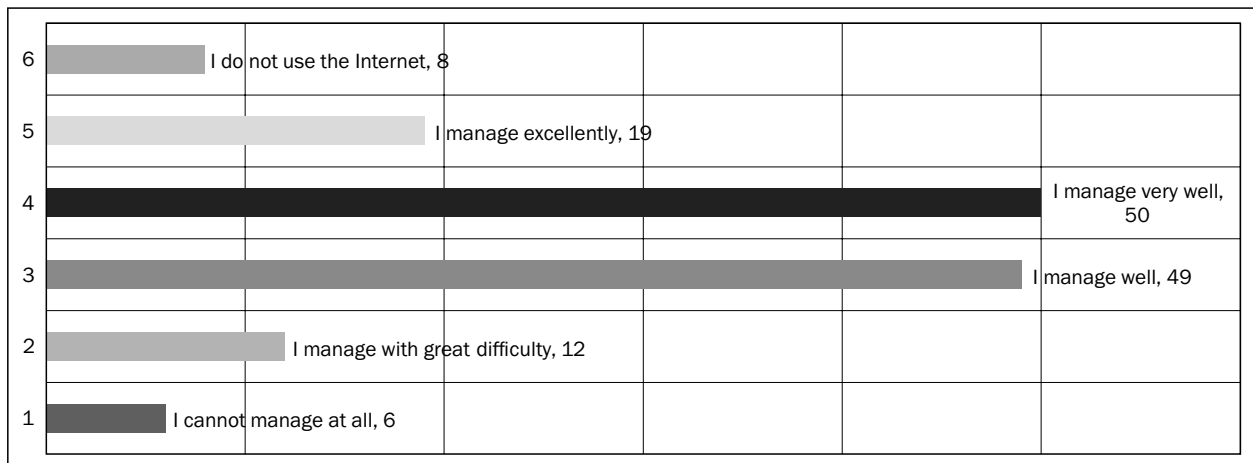

Figure 3 – Assessment of accessibility of Internet contents

– *On-demand self-service*. A consumer has unilateral provision of computing capabilities, such as server time and network storage, as needed automatically without requiring human interaction with each service's provider.

– *Broad network access*. Capabilities are available over the network and accessed through standard mechanisms that promote use by heterogeneous thin or thick client platforms (e.g., mobile phones, tablets, laptops, and workstations).

– *Resource pooling*. The provider's computing resources are pooled to serve multiple consumers using a multi-tenant model, with different physical and virtual resources dynamically assigned and reassigned according to consumer demand. There is a sense of location independence in that the customer generally has no control or knowledge over the exact location of the provided resources but may be able to specify location at a higher level of abstraction (e.g., country, state, or data centre). Examples of resources include storage, processing, memory, and network bandwidth.

– *Rapid elasticity*. Capabilities can be rapidly and elastically provisioned, in some cases automatically, to scale rapidly outward and inward commensurate with demand. To the consumer, the capabilities available for provisioning often appear to be unlimited and can be appropriated in any quantity at any time.

– *Measured service*. Cloud systems automatically control and optimize resource use by leveraging a metering capability at some level of abstraction appropriate to the type of service (e.g., storage, processing, bandwidth, and active user accounts). Resource usage can be monitored, controlled, and reported, providing transparency for both the provider and consumer of the utilized service.

The most significant possibility in case of *CC* platform are the models of delivering the service. The mentioned models allow delivery of the defined aspect of computing as service. According to the mentioned literature three basic architectures of service delivery are defined: Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS). The mentioned service models have the following definitions:

– *Software as a Service* (*SaaS*). The capability provided to the consumer is to use the provider's applications running on a cloud infrastructure. The applications are accessible from various client devices through a thin client interface such as a Web browser (e.g., Web-based email), or a program interface. The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, storage, or even individual application capabilities, with the possible exception of limited user-specific application configuration settings.

– *Platform as a Service* (*PaaS*). The capability provided to the consumer is to deploy onto the cloud infrastructure consumer-created or -acquired applications created using programming languages and tools supported by the provider. The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, or storage, but has control over the deployed applications and possibly application hosting environment configurations.

– *Infrastructure as a Service* (*IaaS*). The capability provided to the consumer is to provision processing, storage, networks, and other fundamental computing resources where the consumer is able to deploy and run arbitrary software, which can include operating systems and applications. The consumer does not manage or control the underlying cloud infrastructure but has control over operating systems, storage, deployed applications; and possibly limited control of select networking components (e.g., host firewalls).

CC platform can be implemented in three basic scenarios of service delivery:

– *Private cloud*. The cloud infrastructure is provisioned for exclusive use by a single organization comprising multiple consumers (e.g., business units). It may be owned, managed, and operated by the organization, a third party, or some combination of them, and it may exist on or off premises.

– *Public cloud*. The cloud infrastructure is provisioned for open use by the general public. It may be owned, managed, and operated by a business, academic, or government organization, or some combination of them. It exists on the premises of the cloud provider.

– *Hybrid cloud*. The cloud infrastructure is a composition of two or more distinct cloud infrastructures (private, community, or public) that remain unique entities, but are bound together by standardized or proprietary technology that enables data and application portability (e.g., cloud bursting for load balancing between clouds).

In navigation along the defined route, the user uses applicative solutions and mobile terminal devices. The services of accurate navigation are carried out on the *CC* platform.

4.2 Elements of system architecture

Conceptual model of directing is based on *Cloud Computing for the Blind* (CCfB) architecture (*Figure 4*). CCfB architecture allows consolidation of all informa-
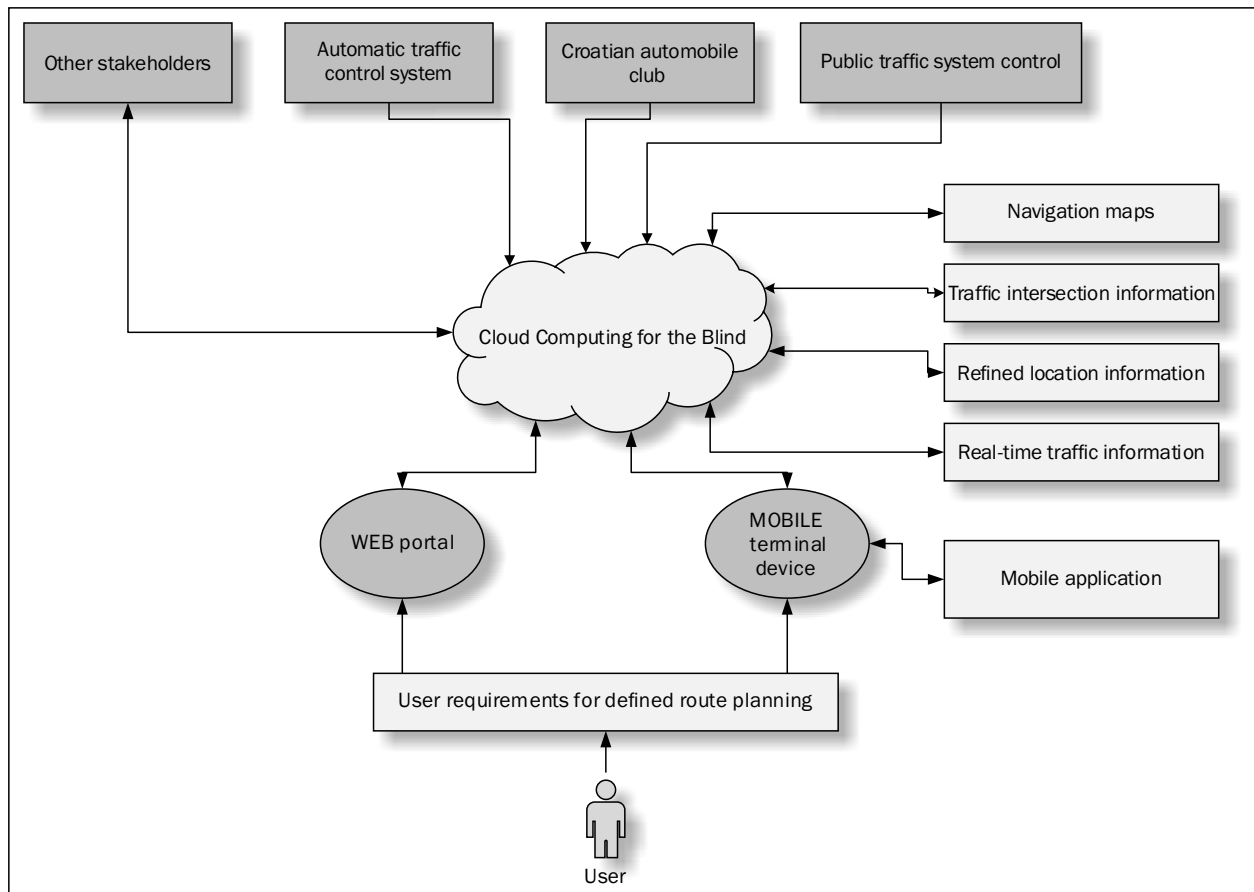
Figure 4 - Simplified architecture of the Cloud Computing for the Blind system

tion into one shared system with the aim of providing updated and accurate information to the end user. Specified architecture illustrates CCfB system on the example of signalized intersection in the city of Zagreb (Zvonimirova Street – Šubićeva Street), with all stakeholders involved.

Based on the defined user requirements the user selects the model of assistive technology to create their routing plan. The user requirements consist of all the relevant information that the user receives from the service of accurate navigation. The information of accurate navigation consists of: data about the user location (maps), information on traffic management (audio or tactile), real-time information and information about the environment. All these pieces of information can be found in the CCfB database which can be assessed by means of the Web portal or by using the mobile application on the mobile terminal device. It is important here to satisfy the criteria of accessibility of the contents for the users, according to Standard guide for designing web sites (WCAG 2.0) standards and recommendations [14].

The functionality of the conceptual model based on *CC* platform is presented in *Figure 5*. The CCfB architecture is based on IaaS service model which is described by the UML diagram of *Use case*. The IaaS model provides the possibility of storing the data and computer

capabilities as standardized service via network. The data that are in the IaaS architecture are created and updated by the users, service provider and the third party (stakeholders). This makes it possible to deliver the service in SaaS or PaaS architecture in the public scenario, which is defined depending on the user requirements.

The implementation model used in this solution is *Public Cloud*, where apart from the users the infrastructure in CCfB is available also to other stakeholders (Croatian Automobile Club - HAK, traffic light control system...). *Public Cloud* represents the model of open usage by the public; the infrastructure may be controlled by, used and in the ownership of one or several business, public or government organizations (it exists at the location of the service provider). With the mentioned approach i.e. by using CC platform in consolidating the described data the dynamic system scaling is possible depending on the needs of the users as well as of the system itself.

The mentioned architecture elements (*User tracking, Points of interest*) allow the creation of the user knowledge base and thus the system in its further operation can feature the processes of independent decision-making.
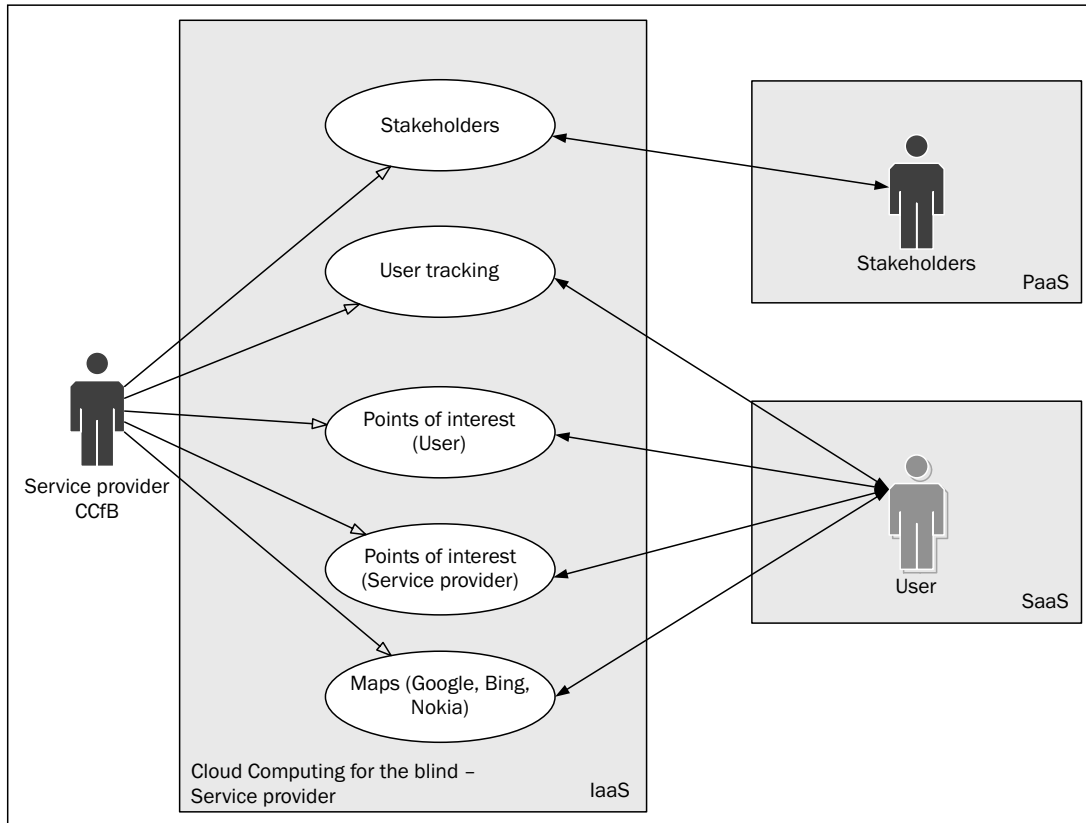
Figure 5 – Functionality of conceptual model based on Cloud Computing platform

4.3 Defining of data for accurate navigation along traffic network

The basic data that define the information of the users' requests are the result of the analysis of traffic parameter importance while moving along the traffic network. The users analysed their own needs, i.e. how important is the speed and the time of movement, as well as precise information. The speed is important in case of 88% of users, time of movement in case of 93% of users, and precise information on the location and environment is important to 97% of users. The processes of defining the plan of movement and information of users are presented in *Figure 6*, and all the relevant information is stored in CCfB database. Based on their own needs and available access technology the user defines the plan of movement. Depending on the degree of visual impairment the users define their requirements, where it is important to satisfy the user movement speed and precision of information requested by the users. Also the time during which the user will manage the traffic intersection depends directly on the speed of movement. The green phase duration for the pedestrians is important information during the implementation of the methods of crossing. The user's speed will increase during crossing, which means that also the density on the pedestrian crossing will be important, which may additionally interfere with the users' movement.

The points of interest which the user has the possibility to use have to provide precise information on the objects they describe. Apart from the information on the objects the points of interest may inform the user about approaching the point of interest, during which the users alone define the distance of information. After the definition of all the information which the user wants to have available by the information services, a verification and updating of the data with the CCfB database is made.

While moving along the traffic network, the user receives all the relevant information about their environment. The user environment refers to the identification of traffic network elements when the user creates the perception of intersection that they have to manage on their route of movement.

For the identification of the users the available technologies such as WiFi, GPS or RFID are used. The user information is provided by the application of NFC technology and mobile application. The mobile application has the possibility at any moment, if desired by the user, to update the data for the defined movement plan. At that moment the user is provided with real-time information thus raising the safety level. After user identification the information is forwarded to the signalized intersection management system through CCfB platform. The traffic light control system changes its operation mode, which refers to the activation of the audio information and extended duration of the
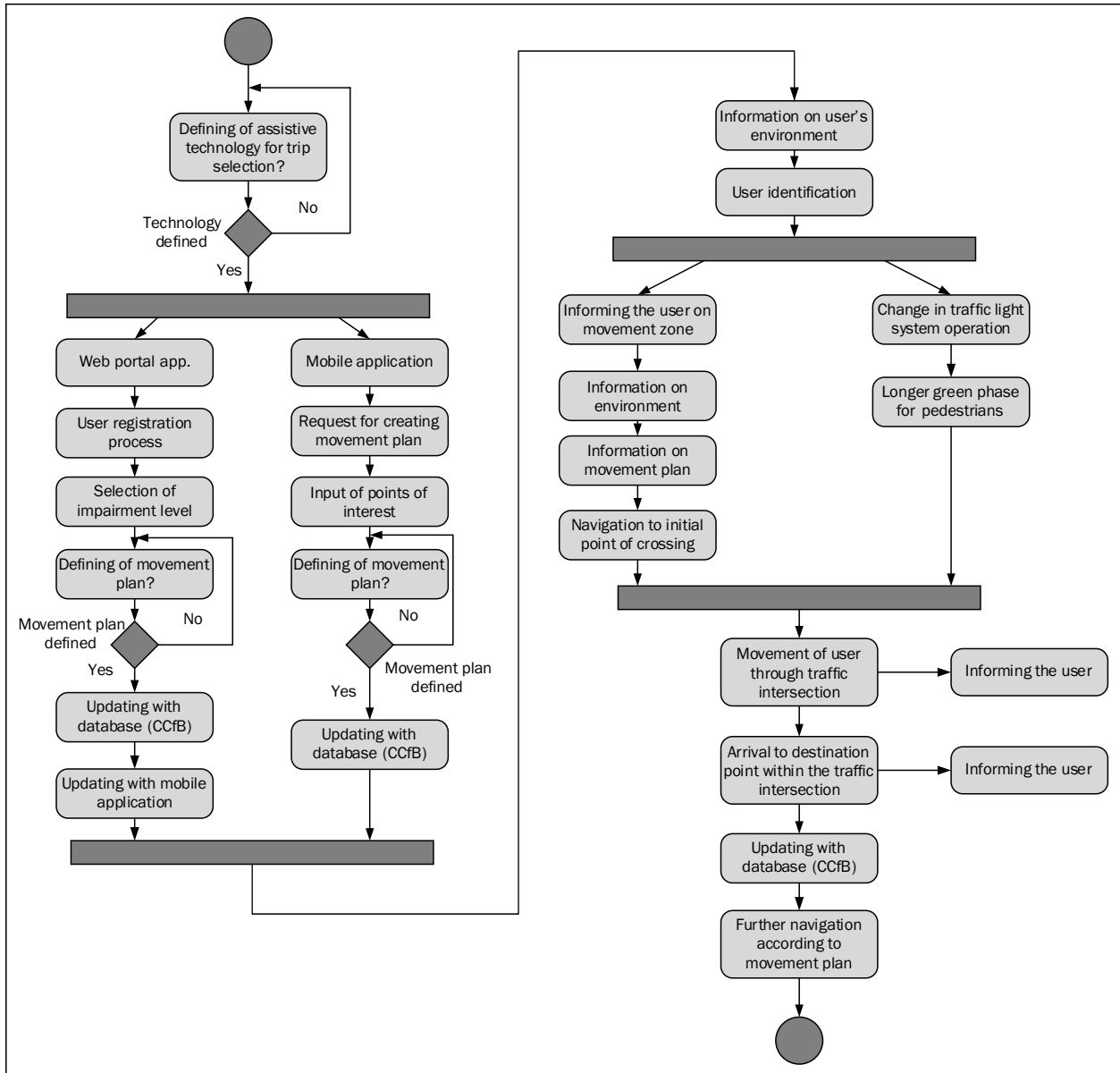
Figure 6 – Methods of informing the users about the traffic intersection

green phase. The duration of the green phase (minimum length) is calculated according to the following formula:

$$t_z = \frac{s_r}{v_k} \text{ [s]}$$

where:

t_z – green phase duration [s];

s_r – total length of traffic lanes which is necessary for managing the crossing [m], and

v_k – average movement speed – 0.55 [m/s].

In the mentioned calculation the average speed obtained from the performed measurements at the analysed intersection is used. Users, which were using mobile guidance and navigation application, were involved, with starting and end points defined as points of interests (POI).

At the moment of identification the user receives all the information: about the location, objects that surround them, position of the descending and ascending curb, traffic control mode (tactile line, traffic light system or something else), time of the right moment to cross the street, time of arrival to the destination, and information on the system operation (failure of the system or upgrading). The user routing after identification towards the initial point of crossing is provided in a safe and coordinated way.

At the moment of waiting to cross the traffic lane, the user receives all information about the size of the traffic intersection (how many lanes and in which direction), street names (defined according to the geographical direction), existence of landmarks, tactile elements of accessibility, tramway lines, and possible directions of movement. If the pedestrian crossing is at

an angle (example of the intersection of the analysed intersection), the user also receives this information and aligns the body to the respective position. For example: *Direction of movement North–South, Šubićeva Street, position of body at 30° to the right*. After confirmation of the audio information for crossing the traffic intersection, the user arrives to the destination point. Upon arrival the user gets the information that they have arrived to the destination, and the information about the possibility of further moving by using the movement directions according to the geographical directions.

All data on the navigation of the user are forwarded to the CCfB system. By collecting these data the user base is created which is presented in *Figure 7*.

The implementation of IC services in the generalized model contributes to the increase in the level of safety and obtaining of accurate information on the users' movement and environment. The CCfB architecture allows unification of all relevant data in one database with the aim of providing accurate and updated information to the end user. Based on the obtained information the user can move in a coordinated manner through the traffic network thus regulating their speed and automatically their time of movement.

5. DISCUSSION

The results of applying the mentioned conceptual model are reflected in the efficient manner of navigating users along the traffic network. The members of the Croatian association for promotion and development of Tiflotechnic (HUPRT) participated in checking the efficiency of navigation which includes also the user information, with the users using the *loadstone* mobile application.

During user education their walking speed to the initial point of crossing amounted to 0.55 [m/s] which was also the mean speed in several carried out measurements. Besides the measurement of user's speed, minimal green light duration was also measured, and its duration was 48 [s]. The length of southbound pedestrian crossing is 33 [m]. Therefore, if user is moving with average speed, there is no enough time for safe crossing. Also, it is essential to adjust signal control with the average user speed.

While defining all the data that compose the user information system, and traffic light system management, the users tested the described solution (87% of users felt an increased level of safety). After the educational passing of the users with the peripathologist,
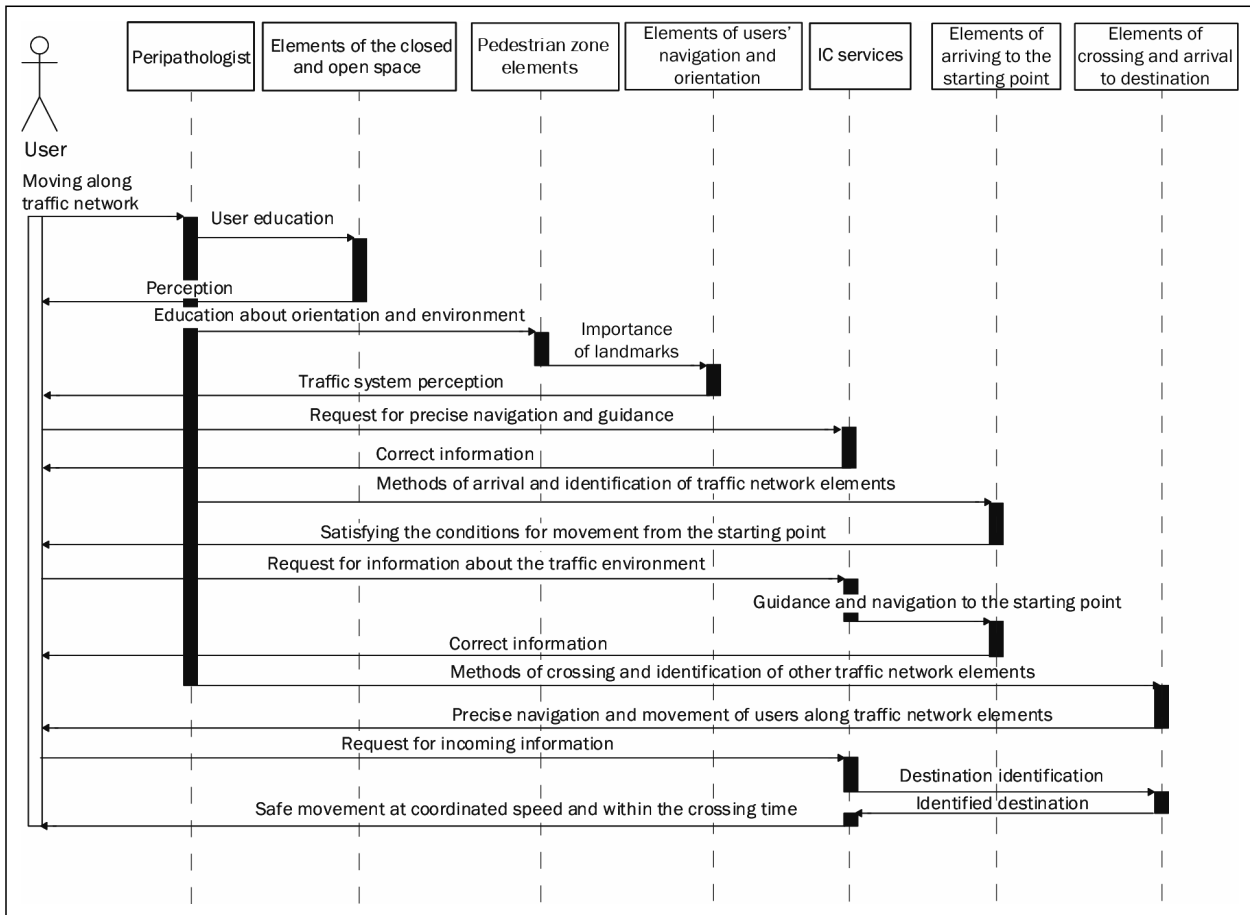

Figure 7 - Generalized model of creating the user knowledge base

the user passed independently the entire movement route with the walking speed amounting to 0.66 [m/s], which is according to the carried out analysis in recording the initial state higher by 0.16 [m/s]. By exact information about the location and further navigation the user is provided with better perception of the environment thus achieving greater independence and better coordination during movement.

As the architecture proposed for processing and location of data *CC* makes it possible for the described system to learn from the collected data which are available at any moment both to the applications and to the very system and the users. The advantages are also indicated in the availability of data at any moment independent of location.

There are no costs related to the purchase of hardware, licenses for server operating systems, databases, e-mail servers, their installation and configuration, and subsequent maintenance. All this is in the hands of service providers, rather than system users. The system user, as well as the third party, contribute by models SaaS and PaaS to the accuracy and updatedness of the data which define information for the end users.

6. CONCLUSION

By analyzing the current condition of availability of the IC services to persons of reduced mobility in the traffic environment the base for new solutions has been set. The proposed conceptual model of providing the service of navigation on a defined case gives the user accurate and updated information. The visually impaired persons who create their movement plan by means of the web interface have to obtain real-time information via mobile terminal device and mobile application. This method of information raises the user's level of safety during movement.

The CCfB architecture represents the method of collecting, processing and storing data that are always updated and available 24(hours)/7(days), with all the participants taking part in the creation, updating and checking of data. IC technologies available today to a greater extent are adapted to the users' requirements, which does not limit the described solution, for other participants in the presented architecture as well.

This conceptual model facilitates improved control of managing the traffic intersection, precise navigation and better perception and orientation of the users. More efficient use of the currently available technology and its functionality makes it possible for the users of reduced mobility an improved level of the quality of living.

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SAŽETAK

KONCEPTUALNI MODEL PRUŽANJA
USLUGE PROMETNOG USMJERAVANJA
OSOBA OŠTEĆENOG VIDA

Za uključivanje osoba smanjene i otežane pokretljivosti u prometni sustav potrebno je osigurati pristupačnost i informiranost korisnika svim sadržajima koji okružuju samu osobu. Analizom trenutno dostupne informacijsko-komunikacijske tehnologije predložen je novi konceptualni model pružanja usluge usmjeravanja osoba oštećenog vida. Navedeni model temelji se na Cloud Computing platformi, te je u ovom istraživanju opisan način usmjeravanja korisnika, na temelju točnih i ažurnih podataka. Korisnički zahtjevi analizirani su prema potrebama kretanja osoba oštećenog vida prometnom mrežom. Informacijsko-komunikacija rješenja u funkciji informiranja navedene skupine korisnika moraju omogućiti točne i ažurne podatke, što se i omogućava predloženim modelom. Istraživanje je provedeno na najčešće korištenim rutama kretanja na području grada Zagreba. Provjerom učinkovitosti modela kod korisnika je zabilježen porast osjećaja sigurnosti u iznosu od 87%.

KLJUČNE RIJEČI

računalstvo u oblaku; stvarno-vremenske informacije; pomoćne tehnologije; prometna mreža; mobilnost

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