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# Possibilities of Applying ICT to Improve Safe Movement of Blind and Visually Impaired Persons

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Additional information is available at the end of the chapter

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## Abstract

Today's level of the development of information and communication technologies enables the implementation of assistive technologies that can contribute to improved mobility of the persons with impaired vision (users that move along the traffic network). The user in this research has the role of a pedestrian moving along the traffic network, using information and communication technology (ICT) solutions and services for the purpose of information about the surrounding and navigation. In order to achieve greater information and safe movement of the user in the environment, one has to identify and define the relevant parameters necessary to define the user's requirements, as the basic precondition for the design of new information and communication services. The analysis of the most used application solutions for mobile terminal devices showed the failure in providing precise information to the user, designing of functionality, structure of information and education of the users about the new solutions and services. The downsides of the current applications have served as the basis in defining the recommendations for the development of future applications, with the aim of increasing the user safety. Proper structure of information allows the user a faster and easier search of relevant information and information methods while moving along the traffic network elements. Therefore, the recommendations in designing future solutions and services based on possible technologies of short coverage area (RFID, NFC, Bluetooth, WiFi, RTLS) have been defined. These technologies allow communication connectivity of the users, other traffic entities and the entire traffic surrounding into a unique whole by using the principle of Internet of Things (IoT).

**Keywords:** Internet of Things, Assistive technology, Cloud computing, Mobility, Navigation

## 1. Introduction

According to the data of the World Health Organisation, there are today 285 million people in the world with impaired vision, out of which 39 million are regarded as blind while 246 million are regarded as partially sighted [1]. According to the latest report about the disabled persons in the Republic of Croatia, there are 17,428 persons with impaired vision, which is 3.4% of the total number of persons with disabilities [2]. According to the mentioned literature, there are 1,961 persons with impaired vision in the City of Zagreb. Out of this number, 185 blind persons (users) move every day using the white cane aid. This paper presents the analysis of implementing the information and communication (IC) technologies and services with the aim of improving the quality of living and the mobility of the users. The user is in the role of a pedestrian moving along the traffic network and their aim is to get precise information about their location and environment. From the definition of the pedestrian and categorisation, the disabled person represents the more endangered group in the traffic system, which includes also persons of impaired vision [3]. Independent moving of the users is based today exclusively on the use of aids such as: the white cane and guide dog. Infrastructure such as the traffic network element is also an important parameter in the function of user orientation and navigation. The accessibility elements are part of the infrastructure which can also be implemented into the intersections and public urban transport stops (trams, buses, taxi stands) [4]. Today's time of new technologies and services may provide the users better information, as well as adjustment of the traffic environment to the users' requirements. The implementation of information and communication technology according to the user's requirements allows the user to overcome social and infrastructural barriers which is the basic aim and purpose of the assistive technology [5, 6]. Some of the implementations of the assistive technologies are reflected in the use of IC solutions for navigation and guiding of the users along the traffic network. The mentioned solutions are based on the global navigation satellite systems (GNSS), data transfer systems in mobile networks (GPRS, EDGE, UMTS, etc.) and geographic information systems (GIS). The user interface is an important component in such solutions because it has to be adapted and completely accessible through its functionalities. The analysis of availability and characteristics of the GPS systems reflects the basic problem in such solutions, the error in the information provided to the user about the location [7–9]. The drawbacks can be compensated by the implementation of other technologies (RFID, WIFI, NFC, Bluetooth, RTLS) for the sake of locating and navigating the user [10–12]. Recognising the elements of traffic intersections as part of the traffic network can be done by implementing the points of interest (POI) within the mobile applications. POI marks have the role of informing the user about a facility which is located in their vicinity [13]. The information about the location and the environment of the user represents the basic parameters in defining the user requirement for the route planning. By collecting all the relevant data into a single information system can be done by implementing the conceptual model based on Cloud Computing (CC) platform [7]. CC is used as a platform in services for the recognition of traffic intersections, as well as in recognising the pedestrian crossings and informing of all stakeholders [14, 15]. The described research results in this paper will form the basis for the definition of recommendations and guidelines for the introduction and implementation of new user-tailored IC technologies and services.

## 2. Models of assistive technology systems

The development in technology in the past two decades has opened new possibilities for the persons with impaired vision who successfully compete with visually healthy persons in all life segments [5]. This competition could not be achieved without using assistive technologies. One of the most acceptable definitions of assistive technologies was provided by the Faculty of Medical Sciences, University of Campinas, Campinas, Brazil, which says that assistive technologies are an interdisciplinary field of knowledge which encompasses products, means, methodology, strategies, skills and services whose aim is the development of the functionality of the persons with impaired vision regarding autonomy, independence, quality of living and social inclusion. Similarly, the US Technology Related Assistance for Individuals with disabilities Act (1988) defines assistive technologies as any item, part of equipment, i.e. system whether acquired commercially, modified or adapted, that is used for upgrading, maintenance or improvement of functional abilities of the persons with disabilities.

The role of assistive technologies in levelling the possibilities of accessing information to handicapped pupils lies primarily in reducing the effect of sensory impairments, and within the frame of the social model the aim of assistive technology is to overcome the gap between the things that the persons with disabilities want to do and the things that the current social infrastructure allows them to do [19]. Assistive technologies consist of the equipment, devices and systems that can be used to overcome social, infrastructural and other barriers encountered by the persons with disabilities and those that prevent them from having equal participation in all aspects of the society [5].

The widely accepted overview of the assistive technology is represented by ISO-classification of technical aids (ISO 9999 Technical aids for the disabled), which has been adopted by CEN (European Committee on Normalisation) for information exchange about technical aids. This classification includes:

- aids during treatment and therapy;
- orthoses and prostheses;
- aids for mobility which enable personal mobility or transport;
- home aids and equipment;
- equipment intended for adjustments in the house;
- aids for communication, information and signalisation;
- aids for handling other items;
- aids and equipment for environmental improvement; and
- recreation aids.

Access to information is becoming all the more important in the life of any person, and it is especially important in case of persons with impaired vision. The majority of information is

obtained through visual and auditive channels, and if information is not available in alternative formats and/or technology does not allow access to the information, the persons with sensor impairments experience reduced access to information.

In spite of all technological advancement, accessing information remains an almost unreachable aim for visually impaired persons, limiting thus their opportunities for employment, education, leisure and independence [16] [17]. Constant barriers prevent independent, reliable and timely access to information. The same authors state that the majority of sources of information (such as, e.g., newspapers, magazines, and TV programs, PCs) rely on visual channels and visual accessibility such as black print or application of video displays. In their opinion, the design and implementation of assistive technologies would provide equal access to information for the visually impaired persons.

The technology is one of the strongest allies to the visually impaired persons in overcoming the negative effects of visual impairment [18]. The technology is related to successful education and positive change in attitudes and has potential in reducing the influence of certain negative consequences brought by visual impairment. Closely connected with education, assistive technology makes it possible for the visually impaired persons to become more successful, function as equal members of the society and develop their personal self-respect.

The main strength of assistive technologies is balancing of the possibilities of accessing information as well as other social possibilities on equal level like the visually healthy persons. The way they will manage the information and use them depends on the users of assistive technologies themselves.

The users of assistive technologies also differ regarding their characteristics, interests, skills, values and level of impairment. As a result of great diversity in the requirements of end users, applications and context, there is need for a simple, efficient and unique framework.

The aims of the framework are as follows:

- implementation in any assistive technology system;
- classification of the assistive technologies system;
- defining the basic structure of assistive technologies system and its implementation in further analyses in device specification;
- development of new assistive technologies systems in order to satisfy the end users;
- support to the process of providing assistive technologies to a certain user with the aim of the user accepting the solution, and
- possibility of understanding the method of functioning of the system for researchers and engineers in social context.

Due to a very complex situation in the real environment in which the end user is often present, the access during modelling of the assistive technology system model often cannot satisfy all the aims of the framework; therefore, the focus is on two main approaches. The first is satisfying the requirements of the end user with adequate assistive technology and measuring the

outcomes of using assistive technology and the second is development of general framework for device analysis.

The satisfying of user requirements of the end user with adequate technology is related to the methodologies of the quality of living. Today's studies place greatest emphasis on the development of technologies whereas very little is written about the very evaluation of their effects. Measuring the outcomes of applying assistive technologies requires consideration of technology and the users who use it which means that the traffic and technological solution for the navigation and guidance of the blind and visually impaired persons need to be placed in the context in which it is used. The assessments of the effects of assistive technologies can be divided into two categories: objective assessment (measuring characteristics, how fast the user can overcome a barrier or find data using the screen reader, etc.) and subjective assessment (survey of the user satisfaction with the proposed technology).

Methods for the assessment of the quality of living of the blind and visually impaired persons:

- method of assessing adequate technology and user (matching person and technology – MPT);
- method of assessing individual efficiency of assistive technology (individually prioritised problem assessment – IPPA).

The mentioned methods allow the defining of the currently available information and communication technology and services, whose purpose is to determine the location of the user, as well as precise guiding and navigation of the user to the destination.

Method of assessing the adequate technology and the user is a procedure used to determine the outcomes of implementing adequate technology to the user in a defined environment. It consists of three main components: user, technology and environment.

The assessment procedure is carried out together with the user through six steps out of which three steps refer to the questionnaire, and other three to the discussion about the outcomes and activities that need to be undertaken.

The method of assessing individual efficiency of assistive technology or IPPA assesses the efficiency of implementing assistive technology by determining the level to which the problems and barriers the user encountered in everyday activities have been reduced. The assessment is based on identification of the seven barriers by the user in performing everyday activities, which could be reduced by using assistive technology.

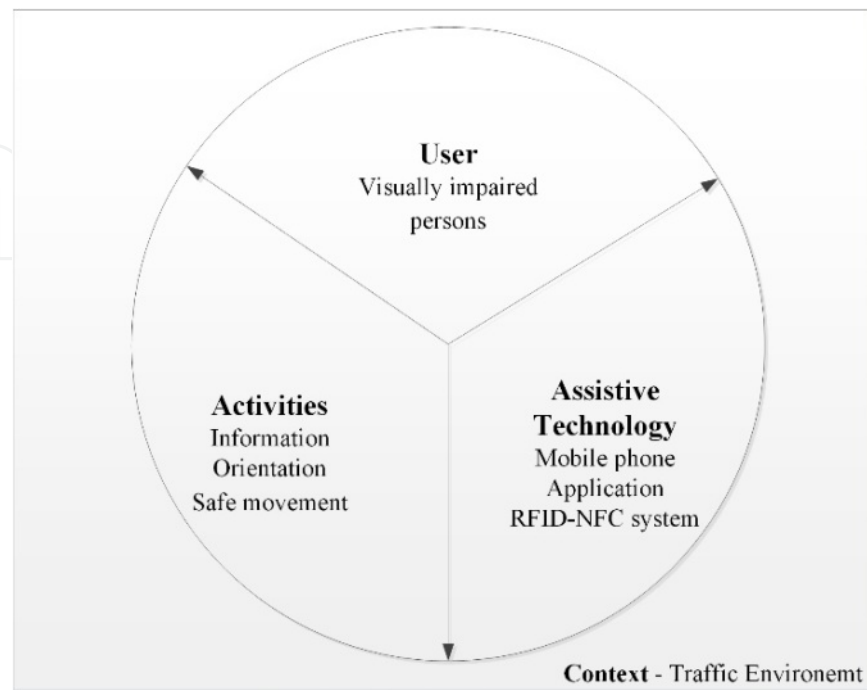
To design the assistive technology system, it is necessary to know the basic models such as: HAAT (human activity assistive technology) model and CAT (comprehensive assistive technology) model [5].

## **2.1. Human Activity Assistive Technology (HAAT) model**

This model, according to Cook and Hussey (2002), is an example of development of the general structure which is used for the analysis, synthesis and development, but it excludes connection of the device and the user. The definition of the assistive technology system allows the user to



perform activities in the context of social environment with possible assistance of some of the assistive technologies.



**Figure 1.** HAAT model according to Cook and Hussey

Figure 1 presents all the components of the model with the user who is in the centre of the system. The HAAT model system consists of four components:

- Context – social frame and physical surrounding in which the person and the assistive technology are functioning;
- Person – user in the centre of the model, which has the characteristics of a sensor input, and the power of central processing and motoric output;
- Activities – procedure, work or task performed by the user (the entire model depends on them), and
- Assistive technology – external assistance used to overcome contextual barriers and hindrances.

## 2.2. Comprehensive Assistive Technology (CAT) model

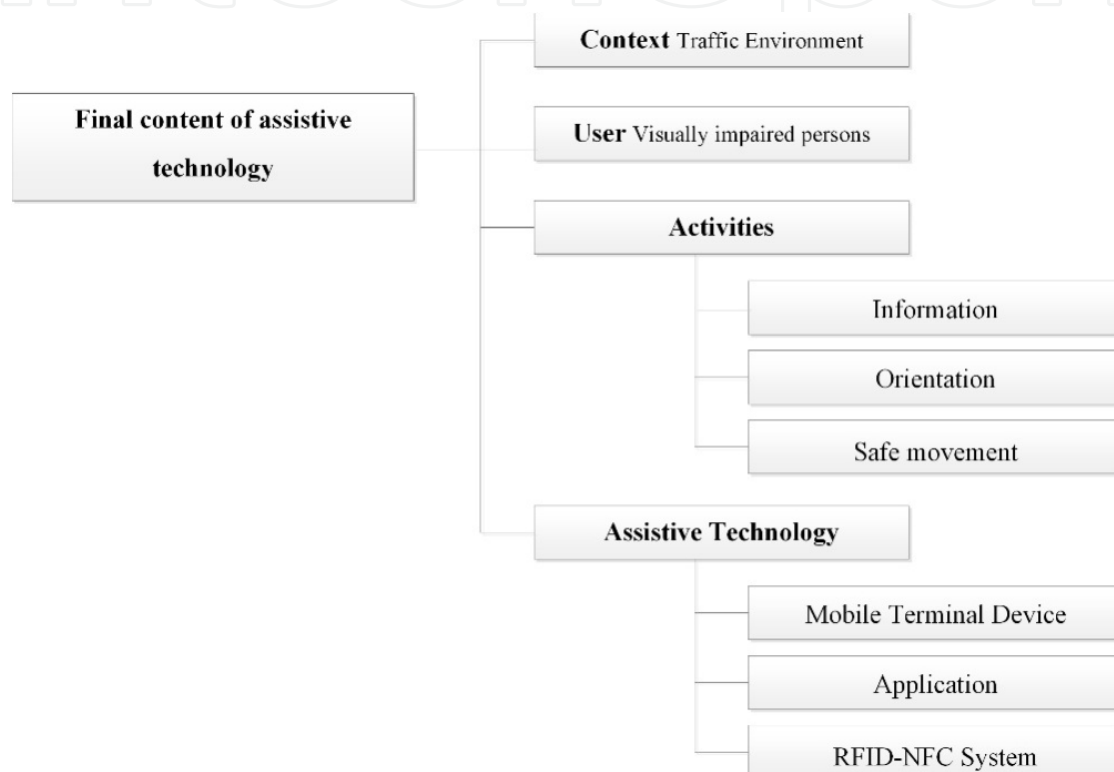
The model of final (more detailed) assistive technology has come out of the HAAT model. The structure of the model is in the shape of a tree, with limited number of variables on each branch. This display makes the model extremely understandable (Figure 2).

The highest level consists of four components that define the system of assistive technology:

- User – centre of the system;

- Context – environment in which assistive technology is used;
- Activities – which are to be used, and
- Technology that is used.

The aim of this model is to identify the drawbacks of implementing assistive technology. The result of this is the development of a system in the areas in which there is currently no elaborated approach or increase in the capacity of the existing system so that the user would have more options.



**Figure 2.** Presentation of CAT model

As an example one can mention the failure of installing audio signals at all signalised intersections, but rather only on some of them, making thus this system an assistive technology system. If all signal-controlled intersections were equipped with audio signalling devices, this would then represent a standardised solution.

### 3. Study of implementation of assistive technologies for the purpose of informing and navigating the users

Movement of the blind or visually impaired person is almost impossible today without the aids (white cane), which is not just an aid in moving, but also a symbol of the blind or visually



impaired person. The idea for the usage of a white cane as the aid for moving was first invented in 1921 by James Biggs from Bristol (Great Britain). A decade later, the white cane was recognised in the society as an aid for the blind. In the USA, the implementation of this aid started in 1930 (Lion's Clubs International) with a black cane. After a lot of criticism because the persons using it were not sufficiently conspicuous, a white coloured cane started to be used. Since then, the white cane has become the most used aid in the function of orientation and movement of the blind and as such it has become the main element of assistive technology. The performed analyses of development of the current technology and devices have defined the relevant parameters for independent moving and information about the environment of the user moving along the traffic network. The presentation of the analysis of availability of mobile terminal devices and applications included participation of the users of the association HUPRT (The Croatian Society for Promotion and Development of Tiphlo technology<sup>1</sup>). The procedure included participation of 16 users from the Society who use mobile navigation applications in their movements along the traffic network of the City of Zagreb. Testing of applications and mobile terminal devices (MTD) was carried out in the duration of 14 days at the traffic intersections in the City of Zagreb.

The presented research results included also, apart from the users of applications for guiding and navigation, the participation of other users from the HUPRT Society, with the aim of assessing the availability and adjustment of MTDs.

### 3.1. Analysis of availability of mobile terminal devices

In the analysis of MTD availability, the users have assessed the following: currently used operating systems, type of GPS receiver, input-output units, possibility of voice management of applications and the device itself. Table 1 shows the analysed characteristics of MTDs; the selected devices represent the most used group of currently used MTDs.

According to the analysed data, the most important parameter for the users in the hardware part of the equipment is the existence of a keyboard as input unit. The output units (voice) mostly used are TTS applications such as: Mobile Speak, TalkBack, Talks and those integrated in the operating system. The operating systems that have been analysed are important from the aspect of accessibility of applications used by the users.

The applications are analysed according to parameters that are listed in Table 2. The users have evaluated the importance (1 – not important, 5 – very important) of individual functionalities.

Loadstone GPS – application is free, i.e. it represents open-source variant GPS navigation application, which has been specially made for the blind or visually impaired users. The application operates with Symbian platform of series 60 and it can be connected with different GPS modules, either external ones or those installed in the mobile device. Loadstone does not use ready-made maps for movement and navigation, but rather the users themselves need to define the maps and movement routes that, after having been defined, can be sent to Loadstone central server so that other users may also use the made maps or routes. The application can

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<sup>1</sup> Joint term for all aids used by the blind and visually impaired persons

DEVICE MODEL	OPERATING SYSTEM	APPLICATION	GPS RECEIVER	INPUT UNITS	OUTPUT UNITS
Nokia E51	Symbian OS 9.2	Loadstone	A-GPS external – Iblue 737A	Keyboard	Talks
Nokia 6220 Classic	Symbian OS 9.2	Loadstone Nokia maps	BT-Q818XT 66-channel	Keyboard	Talks
HTC Mozart	Microsoft Windows Phone 7	Outdoor navigation	Integrated, A-GPS	Touch screen	Voice navigation
Sony Ericsson Xperia mini pro	Android OS, v4	Intersection Navigation WalkyTalky	BT-Q818XT 66-channel	Touch screen	TalkBack
Nokia C7	Nokia Belle OS	Nokia maps	Integrated, A-GPS	Touch screen	Mobile speak
HTC Vario 4	Windows Mobile 6.5	MobileGeo	Prestigio Bluetooth GPS	Combined	Mobile speak

Source: [20]

**Table 1.** Presentation of analysed characteristics of mobile terminal device components

operate off- or online for which the connection to Internet is necessary, so that the decision of the usage lies on the end user. The advantage of this application is the language support (Croatian) and functioning with Symbian screen readers that include Talks and Mobile Speak.

Outdoor Navigation – Windows phone 7 application has the possibility of selecting the maps (Google maps, OpenStreetMaps or OpenCycleMaps) for usage. The application also supports offline/online operating mode, which is extremely important for the users (social aspect). A large number of possibilities such as the possibility of independent input of points of interest (import KML<sup>2</sup> and Geocaching of LOC files), defining of SOS calls that may be in the form of SMS message or e-mail contact, sharing of defined routes of movement by means of online Facebook account or by sending e-mails. The application is additionally equipped by trip computer which enables measuring of the average movement speed, distance travelled, measuring of the altitude and integrated digital compass. The downside of the application is the impossibility of using any screen readers and the price.

Mobile Geo – application can be installed on any mobile device supported under Windows Mobile platform. Mobile Geo cooperates directly with the screen reader Mobile Speak for smart phones and enables users to use mobile phones with installed GPS modules or to connect them with other commercial modules. Using GPS solutions developed in the Sendero group, enables

<sup>2</sup> Keyhole Markup Language – files read by Google Earth application

	APPLICATIONS					
	LOADSTONE GPS	OUTDOOR NAVIGATION	MOBILE GEO	INTERSECTION EXPLORER	NOKIA MAPS	WALKYTALKY
Language – HR	Yes	No	No	No	Yes	No
Operating mode (offline/online)	Yes	Yes	Yes	No	Yes	No
Type of map	Google maps	Bing maps OpenStreetMaps OpenCycleMaps	TomTom	Google maps	Nokia maps	Google maps
Automatic recognition of usage (pedestrian/vehicle)	No	No	No	No	No	No
Voice management	No	No	No	No	Yes	No
Input of points of interest (POI)	Yes	Yes	Yes	No	Yes	No
Starting mode	Slow due to external GPS	Fast	Slow	Slow due to external GPS	Fast	Fast
Multitasking <sup>1</sup>	Yes	Yes	Yes	Yes	Yes	Yes
Method of creating the route	External (using computer)	Yes	Yes	No	No	No
Possibility of automatic creation of return route	No	No	No	No	No	No

Source: [20]

**Table 2.** Presentation of analysed functionalities of navigation applications and their accessibility

the Mobile Geo user great portability and flexibility in providing diverse information, using the installed maps in the memory of the mobile terminal device and at the same time enabling the formation and 100% control of new routes or upgrade of the existing ones. The user has the possibility for central transfer of licences which means that, if the user wants to change the mobile terminal device, the licence can be transferred to the new one without additional costs. The downside of the application is the unavailability of the digital map of the Republic of Croatia, and Mobile Speak for smart phones which operates on Windows mobile platform also has no voice support for the Croatian language.

Intersection Explorer – application which is exclusively intended for the blind and visually impaired users, does not have the function of user navigation, but rather provides the user with information about the location of the traffic intersection. It operates on the principle of Google tools Street view which provides the users virtual research of the locations and orientation by means of panoramic images recorded at the street level. A blind or visually impaired person with this study has the possibility of easier perception of the environment

(traffic intersection) which surrounds them. The application operates exclusively on mobile terminal devices that use the operating system Android.

WalkyTalky – application which is also intended for the blind and visually impaired persons, operates together with the application Intersection Explorer (Android). The intention of the application is to guide and navigate the users to the final destination by using Google maps. The application allows the search of points of interest, but has no possibility of their input. The advantages of the application are voice support integrated in the application.

Nokia maps – application which is mainly used by the newer generations of Nokia mobile devices (Nokia Belle OS and Nokia Anna OS), but its maps can be loaded today also for iOS and Android operating system. Nokia maps allows storing and sharing of routes used by the user via social networks or by sending electronic mail. A detailed overview of the points of interest and their input is defined according to the user's requirements. Information about public transport is a possibility not provided by any of the analysed applications, and they are of great assistance to the blind and visually impaired persons. The application can be downloaded to the mobile terminal device by creating a user profile which is also a great advantage in relation to the applications that are charged.

The analysis of applications has identified the drawbacks such as the impossibility of automatic creation of return route and language voice navigation in Croatian if the user has no installed voice application. The method of starting and configuration in some applications is very complicated which makes it difficult for the blind or visually impaired person to use the application. Automatic recognition of the mode of usage, e.g. if the user goes on foot along one section and after that enters the public transport vehicle, is not enabled by any of the analysed applications.

### **3.2. Analysis of current technologies in the function of locating and informing of users**

In the closed spaces and premises which disturb the GPS signal, i.e. where the possibility of determining the position of the user by implementing the GPS system is difficult or almost impossible, the positioning may be performed by the application of the mentioned technologies:

- RFID;
- Bluetooth;
- NFC - (Near field communication);
- Wireless LAN;
- RTLS; and
- **Locating by means of base stations:**
  - GSM – Global System for Mobile Communications;
  - UMTS – Universal Mobile Telecommunications System, and
  - LTE – Long Term Evolution.

The main characteristics in user positioning of the mentioned technologies are presented in Figure 3. The technologies are analysed with the aim of obtaining precise position of the user using it. The basic data about RfID technology is maximal working distance, which affects the advantage of this technology [22]. Technology of connecting Bluetooth and NFC have their advantages and are recommended to obtain information up to a maximum of 0.20 [m], and their advantage is low energy consumption. Wireless technology is also reflected in the advantages of the transfer speed and the security of data transfer [23, 24]. Locating by means of base stations has no significant advantages in this group of users, and the disadvantage is insufficient precision in determining the location.

Important characteristic of individual technologies is the capacity of data stored in tags (RFID, NFC), which is important from the aspect of user information. In case of RFID technologies, the mentioned data depend on the performance mode, therefore in case of Passive tag the data capacity is from 48 to 736 bytes. Active tag has the capacity of 64 to 32 KB, and Read-only which has the capacity of 20 bits.

Bluetooth technology depends on the version on the mobile terminal device, and it is exclusively used for information transfer to the user. The transfer speed depends on the versions, the latest version Bluetooth SIG (V 4.0LE) allows speed of 25 Mbps. NFC technology allows data transfer speed of up to 424 kbit/s, parallel to RFID technology represents Point-to-Point communication, and a scope smaller than 0.2 m. Wireless technology provides transfer speeds depending on the protocols; standard protocols operate at frequencies of 2.4 GHz (802.11b and 802.11g) and 5 GHz (802.11a) and allow transfer speeds of up to 54 Mbit/s.

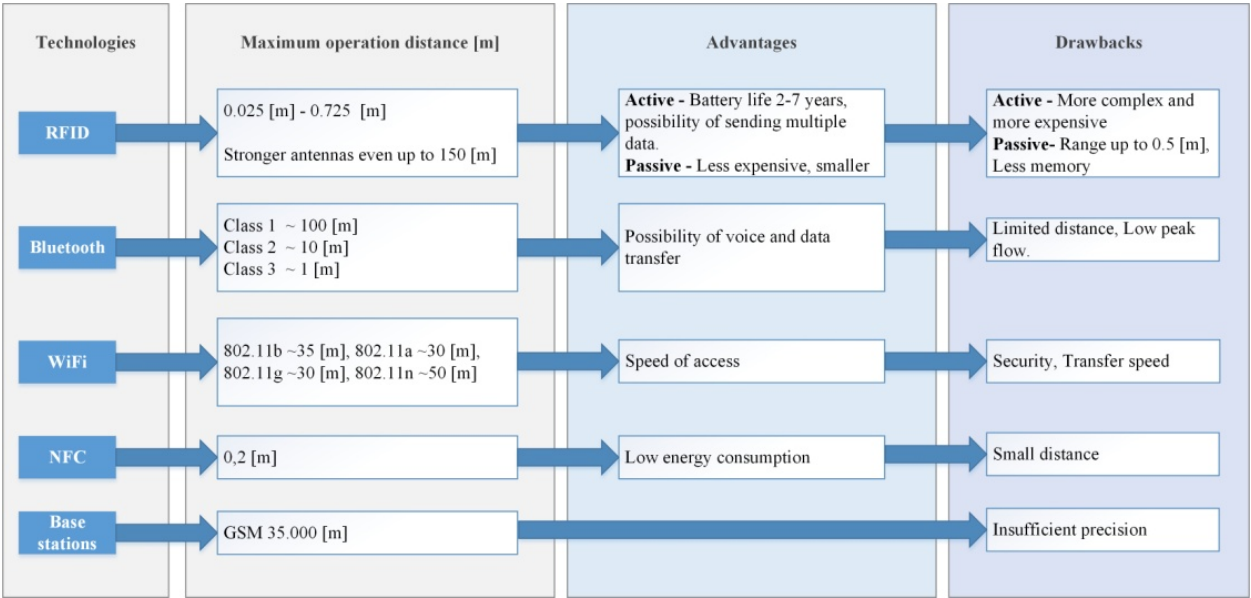
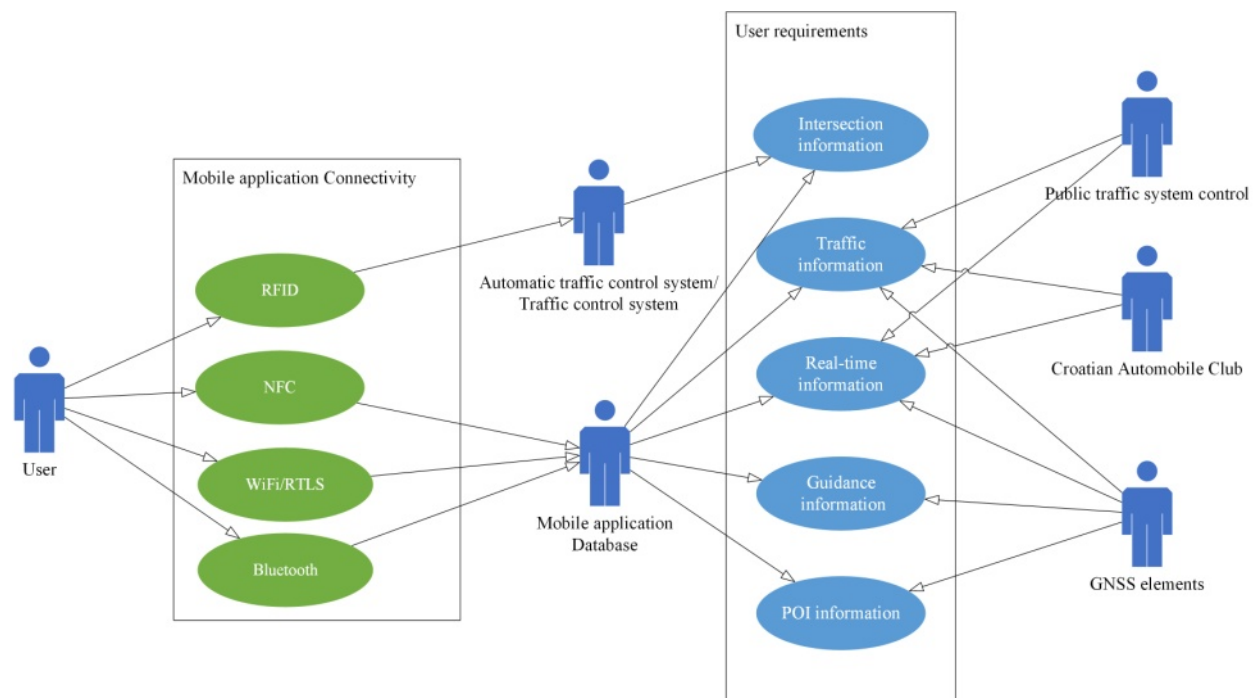


Figure 3. Characteristics of other technologies in positioning of the user [21]

Mobile terminal devices that have been adapted to the visually impaired persons are equipped with analysed technologies. The basic functionalities are used independently by 84% of interviewed users, whereas 16% of users have the problem due to lack of adaptation. The mentioned data are important since the most used mobile terminal devices equipped with the mentioned technologies (Bluetooth, Wireless, NFC, GPS) have been analysed.



For more precision in obtaining information about the user location who moves along the traffic network, it is recommended to use RFID technology. The mentioned technology is used to identify and inform the user about the state and environment of the traffic intersection. The user receives information by using the mobile terminal device.



**Figure 4.** Preview of fulfilling of user requirements based on different mobile application connectivity [21]

The possibilities of applying individual technologies are presented in Figure 4, which presents in detail the connectivity between the user (user law) and all the stakeholders.

## 4. Defining of user request in the function of realising the aim of the assistive technology

The movement of users along the traffic network depends on a number of key parameters. The solutions that are today used in the function of guiding and navigation of users and information (according to user requests) have not sufficient presence of relevant parameters. The role of key parameters is to enable the adaptation of the model to users' requests providing the user with safe movement.

### 4.1. Identification of relevant parameters of guiding and navigating

The systemic approach enables identification of the key parameters which result from two scientific areas: field of technology of traffic and transport and the field of education and rehabilitation science.



For model optimisation, i.e. adjustment of individual elements of the traffic system, it is necessary to optimise function  $Pz$ , i.e. to evaluate single function variables:

$Ku$  – quality of service;

$Sr$  – contribution to solution standardisation;

$Zp$  – implementation of law and regulations, and

$E$  – education of users about new solutions.

From the mentioned conditions, the function of satisfaction is formed:

$$Pz = f(Ku, Sr, Zp, E) \tag{1}$$

By studying the needs of the users moving along the traffic network, the traffic parameters have been defined (field technology of traffic and transport), whereas the parameters from the scientific area of social sciences (field of education and rehabilitation science) were studied by the implementation of training of education and movement. The training of orientation and movement satisfy the following elements: moving across the open space, movement on internal polygon, and moving along the traffic intersection.

The results of the mentioned training are the definitions of relevant parameters which are the basis of further research in the area of designing models of guiding, navigation and information of users. Table 3 shows certain parameters depending on the scientific field.

Field of traffic and transport technology	Field of educational and rehabilitation science
Speed	Perception
Safety of movement	Orientation
Precise information	Independence
Time	Mobility
Landmark	Education of users

Source: [25]

**Table 3.** Parameters of guidance and navigation of the blind and visually impaired persons within the traffic network

Definitions of parameter from the presented table:

- speed – notion that defines the speed of user movement along the desired route (depending on the route and time);
- time – notion which describes the duration of the user movement along the desired route;
- safety of movement – undisturbed movement, so that the user acquires confidence in the proposed solution and gets the feeling of safety;

- precise information – information which raises the user's feeling of security, because if information is not precise, the movement of the user may be endangered;
- landmark – data which may give the user the information in which direction to continue moving, information about their location;
- perception – recognition of the environment in which the user is positioned due to which the information is memorised;
- orientation – managing in space (not equally expressed in all persons);
- independence – feeling that the proposed model allows the user moving with minimal assistance by another person;
- mobility – free movement of the user, i.e. ability of walking in a safe and coordinated way, and
- user education – education of the users about the method of using the system.

The conceptions that surround the user while moving along the traffic network are an important segment in the creation of the knowledge base. The relevant parameters of guidance and navigation of users while moving along the traffic network can be presented as the life-cycle of knowledge.

#### **4.2. Defining user requests**

By using the aids in the function of movement, the blind and visually impaired persons want to arrive from point A to point B in a safe, simple, efficient and independent manner. For that purpose, it is important to define users' requests that are based on relevant parameters. The users' requests can be divided into two categories:

- Basic information (use of current aids) and
- Expanded (additional information by using assistive technologies).

The basic users' requests consist of the following:

- Information on location;
- Information on guidance and navigation;
- Information on facilities surrounding the user;
- Information of audio character;
- Information about descending and ascending kerbstone;
- Information about the traffic intersection;
- Information on the method of traffic control (tactile line, traffic light system or something else);
- Information of the right moment to cross the street;

- Information on the system operation (breakdown of the system or upgrade); and
- Information of arrival to the destination.

The notion of identification of the user is defined within the zone of identification (their location) – depending on the size of the traffic intersection, the zone of user identification is defined. Informing the user about the location and navigation (shape of the traffic intersection and all its elements) includes an example when the user obtains from the system precise information about their location in the form of audio or voice information. The system navigates the user by tactile or voice information. Information of users about the facilities that surround them includes facilities that surround the user and which have to be in the identification zone. The facilities may be state institutions, banks, hospitals, cultural facilities of significance and other facilities that can be found in the user's surrounding. Enabling the actuation of the audio signalisation contributes to the raising of the level of the quality of living of citizens into the environment with the solution, mostly due to the noise produced by audio signalling devices at traffic intersections, the system allows actuation of audio information after user identification. At the moment of audio signal actuation, the user has to have enough time to orientate themselves towards their target. The management of the real-time information of the user is a service that informs the user with audio or voice information about the changes on their movement route. Example: if there are works on the pedestrian crossing and there is no possibility of crossing it, the user receives information about this, and receives suggestions about the alternative routes for safe movement. Provision of information according to a greater number of criteria and special points of interest is used if the user uses navigation application in their movement, the system provides information such as: selection of the shortest route, information input on the navigation map about the user environment, pre-announcement when arriving to the input point of interest (example: how many metres the user has to go to the defined point).

Provision of information about the direction of movement using tactile and voice information is possible by using the elements of accessibility during which the user receives information about their direction of movement. Voice information provides the user with the information about the size of the intersection, its elements (the number of lanes in which direction), existence of bus and tram stops. By applying the basic and secondary geographical parts of the world, the user gets information about navigation along their route. This is voice information and the user receives information in the following form: movement in EAST–WEST direction along the Harambašieva Street.

The logic structure of information allows the user a more suitable method of using the service; according to the most frequently used information, logic structure of the system allows easier approach to the most frequently used information. The most frequently used information is defined according to single user requests, which also provides the dynamics of the model itself.

Two-way information, data and voice communication with the user, provides the user with the possibility to define their route prior to starting their movement along the traffic network by using navigation applications, and during their movement, the user can independently enter the information that had not been entered before. For safety reasons, the information can

be very important, for instance, if there are works in the direction in which the user is moving or some information at the intersection are incorrect.

Information of users, position precision of the user – by applying other technologies (RfID, Bluetooth, WiFi, RTLS or NFC) the user receives precise information about their position.

Automatic control of signal-controlled system, longer green phase for pedestrians – when identifying the user, the system allows longer duration of green phase for pedestrians. After the user leaves the system, the system returns to the state prior to user identification.

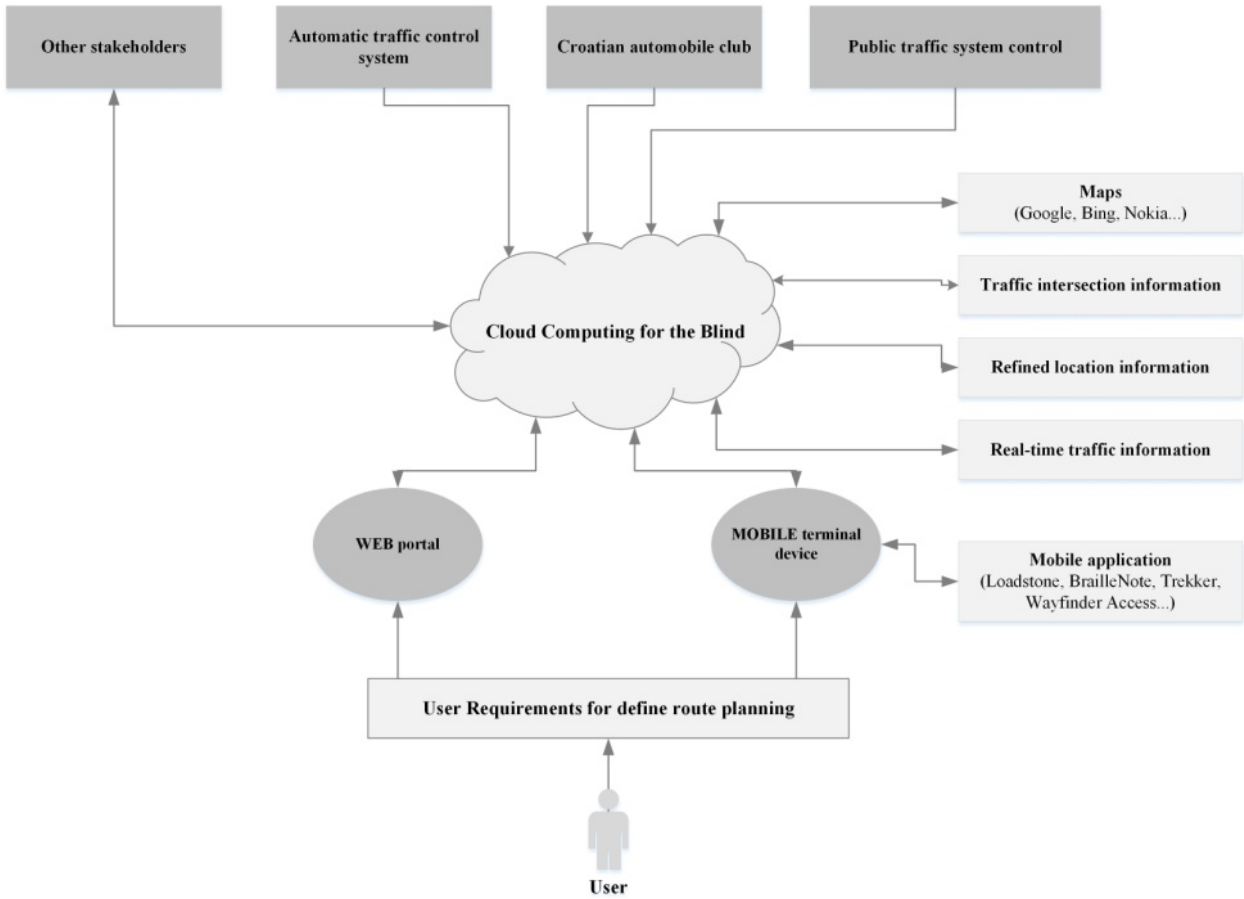
Another category of user requests represents a group that is based on the already described definitions, but supported by new ICT and services. Therefore, it is necessary to satisfy additional requirements:

- precise location of the user  $\sim 0.5$  [m];
- precise information about the movement;
- user-friendliness of the mobile terminal device (keyboard and screen reader);
- possibility of creating priority information;
- economically affordable solution;
- possibility of creating pre-announcement prior to arriving to the destination;
- possibility of facility identification;
- possibility of identifying the traffic intersection, and
- selection of the device operation mode offline–online.

For everything mentioned, it is important that the system elements can operate in any weather conditions for the user safety. If the weather conditions allow some changes in the system operation, the user has to be informed.

## **5. Possibilities of applying advanced technologies in increasing the safety of user movements**

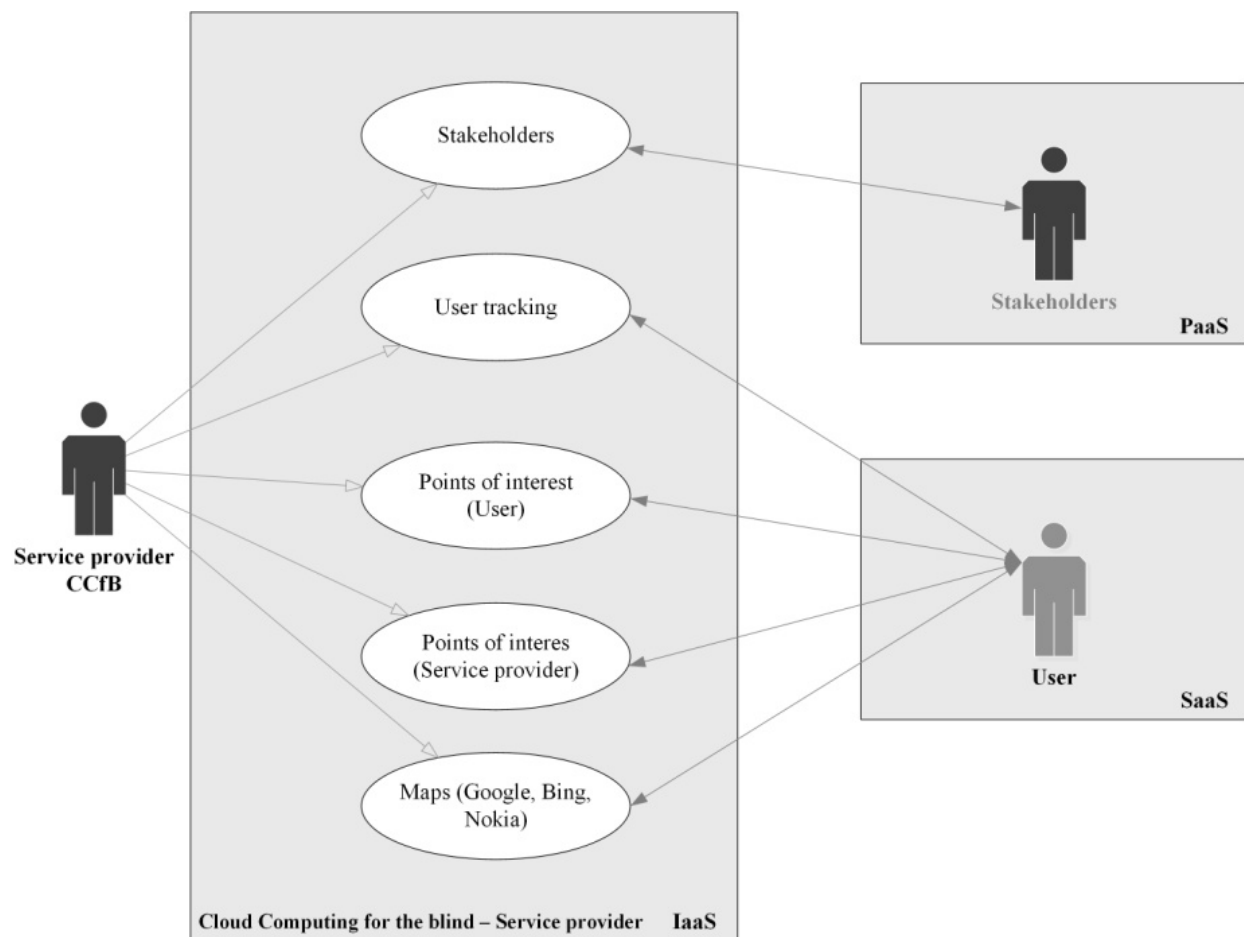
The user requests described according to the possible operating modes can be integrated into one whole by applying the concept of Cloud Computing. For this purpose, the CCfB (Cloud Computing for the Blind) architecture has been defined and it makes it possible to combine all relevant information into one database [7]. An example of such architecture is presented in Figure 5 where the user is in the very centre of the system, and is surrounded by all relevant information necessary for safe and coordinated movement along the traffic network. The user access to relevant information is possible by implementing Web 2.0 technology, which allows adapted Internet and mobile application [26].



**Figure 5.** Simplified architecture of the Cloud Computing for the Blind system

Functionality of the presented model based on CC platform is shown in Figure 6. CCfB architecture is based on IaaS service model described by UML diagram of the Use case. IaaS model provides the possibility of storing data and computation abilities as standardised service via network. The data found in IaaS architecture are created and updated by the users, service provider and the third party (stakeholders). This allows delivery of services in SaaS or PaaS architecture in the public scenario, which has been defined depending on the user requirements.

The implementation model used in the presented solution is the Public Cloud, where the infrastructure in CCfB is accessible not only to the users but also other stakeholders (AuP system, HAK (Croatian automobile club), public urban transport system, traffic light control system). Public Cloud represents a model of open use by public, infrastructure can be managed, used and in the ownership of one or several business, public or state organisations (it exists at the service provider location). The mentioned approach, i.e. by applying CC platform in combining the described data, the dynamic scaling of the system depending on the users' needs and the requirements of the system itself is possible.



**Figure 6.** Functionality of conceptual model based on Cloud Computing platform [7]

The mentioned architecture elements (User tracking, Points of interest) allow creation of the user knowledge base, thus providing the system in future operation with independent decision-making processes.

The access to the contents of information, as already mentioned, is possible by using mobile application or by means of the Internet browser. Therefore, the MTD interface accessible to visually impaired persons is important to satisfy all the accessibility aspects “Design for Usability” [27]. According to the elements of universal design, the mobile application has to be available to all the groups of users, which means that it should not deviate in its design and possibilities from the standard solutions. The design has to be equally adapted for both the left-handed and right-handed persons. The usage flexibility is important when satisfying the user requirements, and for this purpose it is recommended during user installation to define the user profile so that the user would always have the requested information. Because of the possibility of connecting the application with the web interface, it is necessary for the mobile and web application to have satisfied standards in the selection of colours for the partially sighted persons, as well as the possibility of increasing or reducing the font size.



The contents of application must provide clear and understandable information, mostly because of compatibility for the screen readers. When defining the basic information, it is important to provide the users with the possibility of defining their own level of disability in order to be able to modify the information.

By defining the level of disability, the user can have better accessibility of the requested information, and it can be thus modified according to the user requirements. Image information has to be accompanied by description and the information has to be understandable, regardless of the user experience, knowledge, language knowledge or current level of concentration. Information provided by the application also has to have linguistic support for the majority of world languages.

The application design has to be such as to minimise the dangers, and to prevent consequences of incidental or unintentional activity. The information management elements need to be set in such a way as to reduce to minimum the danger and errors due to the application operation: the most frequently used elements; the most accessible ones; elimination of dangerous elements, isolated or covered. Insure the warnings of danger or possible error. Provide protection elements. Disable involuntary procedures in creating information that require full concentration of the user. Operation with the application should not present for the user any physical or mental effort, i.e. such effort should be reduced to a minimum.

The real-time passenger information, a service which informs the user by means of audio or voice information about the changes on their movement route. Example: if there are works on the pedestrian crossing and there is possibility of not being able to cross, the user receives information about this, and receives suggestions about alternative routes for safe movement. Two-way information, data and voice communication, with the user is important before moving along the traffic network. The users can create themselves their routes within the application, the information that is not entered can be entered by the users independently during their movement. The information can be very important for safety reasons; for instance, if there are works along the direction of the user movement or the information at the intersection is incorrect.

The accompanying contents that surround the user can be defined within the application as points of interest. The possibility of such information can be used if the user wants to receive information about the accompanying content such as cafés, restaurants, museums, shopping centres, hospitals, etc.

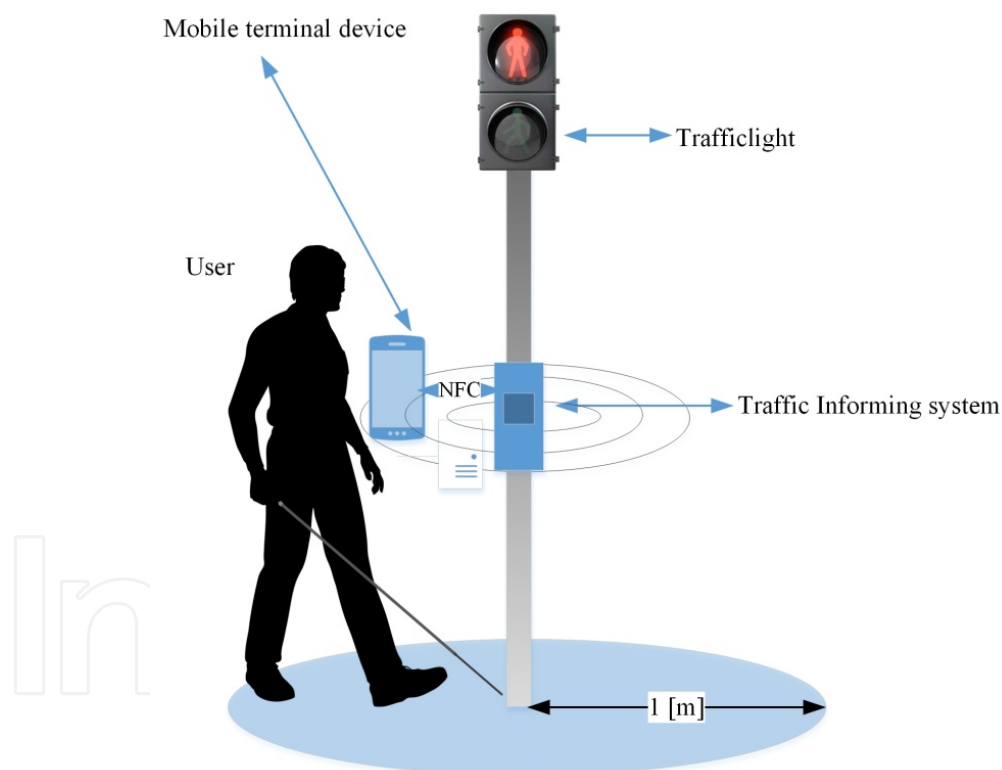
Because of the possibility of connecting with the web application, it is necessary to insure compatibility of the device. Current data about the number of used devices go in the favour of devices that have a keyboard, whereas there is less usage of the devices with touch screen as input units. Because of its input unit, iPhone device provides a keyboard as an additional component which is also a very good characteristic of the producer in approaching design.

Stakeholders presented in Figure 6 can be expanded with users who base their approach on volunteering. For this purpose, the goal is to enable complete functional service of providing assistance in situations when others need help, regardless of the level of degree and type of assistance to the end user [28]. Today's applicative solutions can be expanded for this purpose

by modules that would connect the people who want to help and those who need that help. Today's development of the technology allows this without mediation of various organisations and societies and strengthens the feeling of unity and trust to public welfare.

The integration with geo-location services allows sending pre-defined SMS messages with the possibility of editing, i.e. automatic connection of pre-defined services and professional services and organisations. Using simple examples: crossing an intersection, passing along a rutted pedestrian path or entering a public transport means, it is obvious that such modules really help the people who want to provide assistance. Special focus is on the social component and further spontaneous development of the system towards a maximally wide range of services and forms of assistance.

For the purpose of informing the users, it is possible to use the short-range technologies (NFC and Bluetooth), as presented in Figure 7. Possibility of informing the user who is at a traffic intersection and uses mobile application on their MTD can be performed by using NFC or Bluetooth technology [29].



**Figure 7.** Possibility of implementing NFC technology for user information

Therefore, it is necessary to satisfy the criteria of the information structure in the very tag, as well as the type of tag. The information need to be simple and precise so as not to endanger the safety of user movement. The user requests also play a big role in creating information. The users' requirements create the priority information important for safe and independent movement of the users. Proper architecture of information provides the user with faster and

easier search of relevant information, creation of movement routes, methods of information while moving along the traffic network elements and customised contents.

Information provided by the user information service contains all the elements of universal design, which is the basic principle for independent participation of the users in everyday life. This refers to the unbiased possibility of usage, equal methods of usage for all users, flexibility, conspicuity, low physical or mental effort and toleration of errors.

By using their mobile terminal devices, the users receive information in the following form:

*Direction of movement north–south Šubićeva street, oblique pedestrian crossing, body posture 30° to the right, three lanes east–west, two lanes of tramway tracks, pedestrian island, three lanes west–east.*

The mentioned information consists of the current location which is indicated by the cardinal points of compass (north, south, east, west and derivatives) and the name of the street which is within the user's environment. The information about the traffic intersection describes all the elements of which the traffic intersection consists with the description of the direction of the vehicle movement. The direction of the vehicle is also described by using the cardinal points of compass. If the intersection configuration has a certain trigonometric form or the pedestrian crossing is set at an angle, then these data also have to be included in the information provided to the user. The distance of the kerbstone is defined by the users using the aids (white cane or guide dog), where the mentioned information in NFC tag is of informative significance. According to statistical indicators, an increasing use of NFC technology is predicted and therefore in further development the mentioned solution is expected to find its application in real environment. The implementation of the mentioned technology is possible in several aspects, one of the examples being in the area of e-Health [30].

## 6. Conclusion

The mobility, accessibility, place of residence, transportation and education of the users are the basic conditions for independent and full participation of the disabled persons in everyday activities. The presented results of the performed studies in this paper say how much the new technologies can help in removing the barriers and hindrances in performing everyday activities of the disabled and senior persons and persons of poor mobility. The design and development of mobile applications for informing, guiding and navigating the users who move along the traffic network have to be done according to the recommendations and standards. The mentioned presentation of past research in this area can be used as the basis in defining the future guidelines about the methods and possibilities of providing new technologies. The new technology and its application according to the presented paper will certainly help in removing the barriers which include the target group of users.

As the basis of the decision-making processes, the new services use the user knowledge bases, with the aim of increasing the level of the users' quality of living. For this purpose, it is necessary to educate all the stakeholders such as the peripathologists, etc. about the possibilities provided by the new services.

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