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Model of guidance for visually impaired persons in the traffic network

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ABSTRACT

The movement of the blind and visually impaired persons in the traffic network is today based exclusively on the application of aids (white cane) and methods that the users learn during the training of orientation and movement. In present paper authors investigate accessibility of information and communication technologies and services with the purpose of increasing the mobility level of the blind and visually impaired persons when moving in the traffic network of the City of Zagreb. The traffic intersections were analysed from the viewpoint of difficult-to-master for independent movement by using the basic methods of crossing a traffic intersection which the users acquire at the training of orientation and movement. The method of survey and interviews with a target group of users was used to evaluate all the relevant parameters of guidance and navigation resulting from the mentioned analyses and by performing training of orientation and movement in the duration of six months. Based on the carried out research and the used scientific methods the dynamic model has been defined and it is based on relevant parameters of guidance and navigation, and on the application of the information and communication technologies and services. The information provided to the user, by the system, is defined according to the currently available technologies. The model was efficiency tested on a real system of the traffic network of the City of Zagreb.

1. Introduction

The City of Zagreb covers an area of 641.35 km^2 which makes 1.13% of the area covered by the Republic of Croatia. The location of the City of Zagreb in regional – Central European space denotes the interrelation of three biggest cities connected by the past, the present and the future – the Zagreb – Vienna – Budapest triangle, lower level of the connection is Zagreb – Graz – Trieste with Ljubljana in the centre, and in Croatia it is the triangle of Rijeka – Split – Osijek with Zagreb in the centre. According to statistical data there are currently 792.875 people living in the City of Zagreb, while there are 91,261 disabled persons which is 13.2% out of the total number of citizens. There are 1985 blind and visually impaired persons (users) in the area of the City of Zagreb and the data refer to all forms of visual impairments (Benjak, 2013).

Today's development of information and communication technology and services in this area may contribute to improving the quality of life for users. Apart from the standard audio signal, which is used for navigation through the traffic intersection, there is also the possibility of developing new solutions and services, which is reflected also in many scientific studies in this field (Manduchi & Coughlan, 2012). The mentioned system uses the mobile terminal device, camera installed on it and the

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application enables the transfer of information to the user. Current solutions are also based on the Global Navigation Satellite System (GNSS), Global System for Mobile Communications (GSM) and Radio-frequency Identification (RfID) technology (Baranski, Strumillo, Bujacz, & Materka, 2009; Bujacz, Baranski, Moranski, Strumillo, & Materka, 2008; Marukatat, Manaspaibool, Khaiprapay, & Plienjai, 2010). The basic function of these solutions is correct navigation of the users. Some of the solutions use also sensor technologies (João, Farrajota, Rodrigues, & Hans du Buf, 2011; Quoc, Kim, Lee, & Eom, 2010). Additional technologies are used because GPS technology still features errors in the locating procedure. The sensor technologies are used to enable better precision in locating the users. The project which is exclusively focused on the area of implementing new Information and Communication technologies (ICT) in the function of precise guidance is Crosswatch (Coughlan & Shen, 2013). The starting facts in setting the future solutions in this issue are considered through the mentioned project. The facts are directed to the issues of what kind of information has to be provided to the users, when (through real-time information) and where (by means of sensor technologies or the similar) (Coughlan & Shen, 2012; Periša, Peraković, & Šarić, 2014). The problem in orientation and moving has also been considered through the implementation of RfID technology thus enabling greater precision in moving (Nassih, Cherradi, Maghous, Ouriaghli, & Alj, 2012; Periša, Peraković, & Runjić, 2011; Zhang, Li, & Amin, 2010; Zou & Wang, 2010). In the mentioned studies the errors have been presented during the usage of the currently available technologies (GPS, DGPS, RfID, and combination of GPS and RfID technology).

The absence of the mentioned research is reflected in the identification of relevant traffic and technical parameters of guidance and navigation, and the education and rehabilitation parameters that define through synergy effect the basic requirements of the user moving in the traffic network. Based on the parameters the users' requirements are defined as well as the knowledge base of the users moving in the traffic network which forms the main elements of the dynamic model of guidance and navigation. The dynamic model makes it possible to obtain precise information about the location of movement and way finding thus increasing the safety level of entities moving in the traffic network.

2. Relevant parameters of guidance and navigation for visually impaired persons

The systemic approach and analysis have been used to define the areas of relevant parameters: the area of the traffic and transport technology, and the area of education and rehabilitation science. The parameters were analysed over a period of six months. Within this period the authors passed the training of orientation and moving. The training was performed with an authorized peripathologist at the following locations: *ZUK "Borongaj"* (internal polygon of the Faculty of Education and Rehabilitation Science and the pedestrian zone of the Scientific and Academic campus "Borongaj"), intersection of *Horvaćanska street* and *Petrovaradinska street* and the pedestrian zone of the street of *Hrvatski sokol*. The used aid for orientation and moving was the white cane, and a fold over the eyes served to present as clearly as possible the condition of the users. For the testing of the applications whose purpose is correct navigation and guidance the following was used: Loadstone, MobileGeo, Outdoor Navigation, Nokia maps, Intersection Explorer and WalkyTalky. From the mentioned applications the study considered the values whose function is defining of the precise information about the location, information about the environment and the adaptability and availability of applications to the users.

In this paper the research was carried out with target population (users) where the planned sample was 175 users. There were 144 users who responded to the survey, which is 82% of the planned figure. The research was carried out in the form of on-line survey and interview which was done with the users themselves. The representative sample was defined according to the data of the Croatian Association of the Blind and the Society of the Blind Zagreb about the number of the employed users (substantial visual impairment) in the area of the City of Zagreb, and there are 171 of them. The mentioned figure indicates the number of users who move every day independently along the traffic network of the City of Zagreb. There were 101 employed users participating in the study which makes the sample representative. The survey also included 29 students from the University of Zagreb which represents 100% of that population.

The mentioned research was used to grade the traffic, and education and rehabilitation parameters important for safe and independent movement of the users in the traffic network of the City of Zagreb. The importance of traffic parameters during movement along the traffic network is presented in Fig. 1. The definitions of parameters that are used in the questionnaire:

- speed – concept which defines the speed of the movement of the user along the desired route (depends on the route and time);
- time – concept which describes the duration of the user movement along the desired route;
- movement safety – undisturbed movement, for the user to gain confidence in the proposed solution and to get the feeling of safety;
- precise information – data that enhances the user's feeling of safety, because if the information is not correct the movement of the user may be endangered;
- landmark – information that may provide the user with the information in which direction to continue moving, information on the location;
- perception – recognition of the environment in which the user is positioned resulting in memorizing of the information;
- orientation – orientation in space (not equally expressed in all persons);
- independence – feeling that the model provided to the user allows movement with minimal assistance of another person;
- mobility – free movement of the user, i.e. capability of walking in a safe and coordinated way; and
- education of the users – education of the users about the method of using the system.

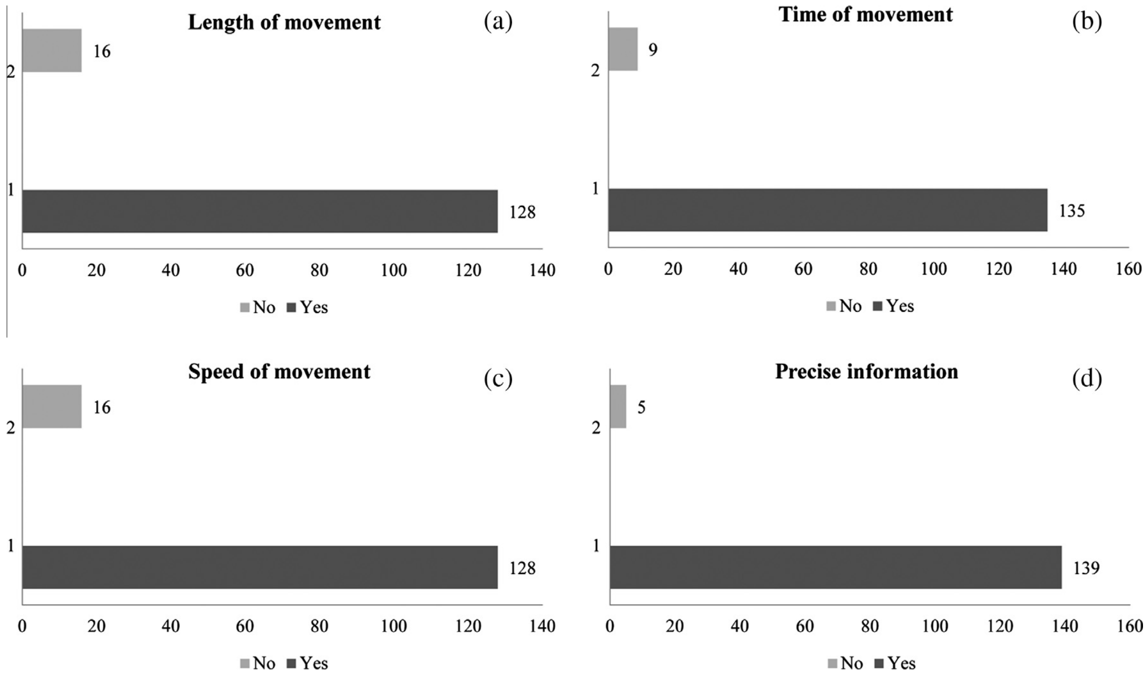

Fig. 1. Importance of traffic parameters. (a) Importance of length of movement. (b) Importance of time of movement. (c) Importance of speed of movement. (d) Importance of precise information.

The parameter of the length of movement refers to the distance the user has to cover in order to safely arrive from points of interest (POI 1) to POI 2 (1a). The length of movement is directly related to the speed and time of movement. Therefore, the users find the length important, because the longer the length for crossing the lane, the more time they need for crossing. If the current (too short) green phase at traffic intersections is taken into consideration, the user has a lower level of safety in their movement (if the length of moving is greater). The importance of this parameter during movement has been emphasized by 128 users, whereas 16 users marked it as unimportant. The parameter of the time of movement refers to the time necessary to travel the path from point A to point B (1b). The time of movement is directly related to the length (path) of movement of the user and the speed, and it should be noted that not all users have an equally expressed sense for safe movement. The importance of this parameter was emphasized by 135 users, whereas 9 users stated that time is not important for them. This is related also to the speed which is not equal for all the users. The traffic intersections which are more demanding additionally reduce the speed, at the same time increasing the time the user spends at the traffic intersection (1c). The movement speed parameter depends on the time and route for which 128 users stated that they find it important in their movement, whereas 16 users stated that this is not important for their movement through the traffic intersection. Precise information as a traffic parameter refers to the information which the user gets by moving along the traffic network (1d). This parameter has been found as important by 139 users, whereas 5 of them consider that precise information is not important for their movement. The information which surrounds the user has to be precise since it refers to the user's location as well as the information about the environment.

The parameter of the feeling of safety while moving along the traffic network was marked by the users with a value of 99% (143 users), whereas the importance of the existence of landmarks that depend on the configuration of the traffic intersection has been presented in Fig. 2.

The importance of the education and rehabilitation parameters is presented in Fig. 3. The environment at the time of arrival to the starting point of crossing is important in the user's perception of the traffic intersection (3a). There are 129 users

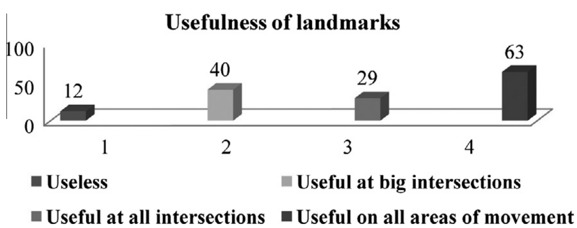

Fig. 2. Importance of the set landmarks on the movement areas.

who consider perception important during movement, whereas 15 users think that it is not important for them. At that moment the user has to determine the configuration of the intersection and all the entities that can be found there. The importance of the parameter of independence is presented in Fig. 3b. The independence parameter is important when the user is moving through a traffic network, 142 users evaluated it as important, whereas 2 users stated that they find this parameter not important. Orientation is in direct correlation with the precise information about the environment and the user's perception while moving along the traffic network. It is also not equally expressed in all the users and therefore additional educational training needs to be done at the orientation and movement trainings with such users (3c). Level of orientation is also important in the movement of the users through a traffic intersection and 137 users consider this important whereas 7 think that it is not important. The study has shown that the users are often not educated about the method of using the new solutions and the importance of the mentioned parameter is presented in Fig. 3d. Often, due to the lack of good education, the users are left to study on their own the application of new solutions which is extremely dangerous from the aspect of safety.

When introducing the new solutions at traffic intersections, 125 users would like to undergo training about the usage methods, whereas 19 users consider this unimportant. The application of the mentioned parameters makes it makes it possible to create a user knowledge base which has been presented in more detail in Fig. 4.

An important segment in this presentation of the generalized model belongs to the peripathologist or instructor of orientation and movement. It's task is to perform the programme with the users so that they can move along the traffic network. Based on the obtained information (based on IC services) the user is provided with the possibility of moving along the traffic network thus regulating their speed which includes also the time of movement (solid colour represents the contribution of IC services).

3. Dynamic model of guidance and navigation visually impaired persons

The dynamic model of guidance and navigation of the users is based on the application of the currently available ICT technologies to the user moving along the traffic network. While moving the user uses the application of guidance and navigation based on the GNSS technology, NFC reader and RfID tag for user identification. The applications for navigation and guidance of the users have been analysed from the aspect of determining the precision of location of the user. The analysis uses the applications which are most frequently used among the users according to the data provided by the Croatian Society for Promotion and Development of Tiphlotechnology (HUPRT): Loadstone, Nokia maps, Outdoor navigation, Intersection, Navigation, WalkyTalky and MobileGeo.

Loadstone GPS is a free of charge the application, i.e. represents Open source variant of GNSS navigation application, which has been specially developed for the users. The application operates n the Symbian series 60 platform and it can be connected to different GNSS modules, external or those that are installed in the mobile device. Loadstone does not use ready-made maps for moving and navigation but the users themselves have to define the maps and routes of movement.

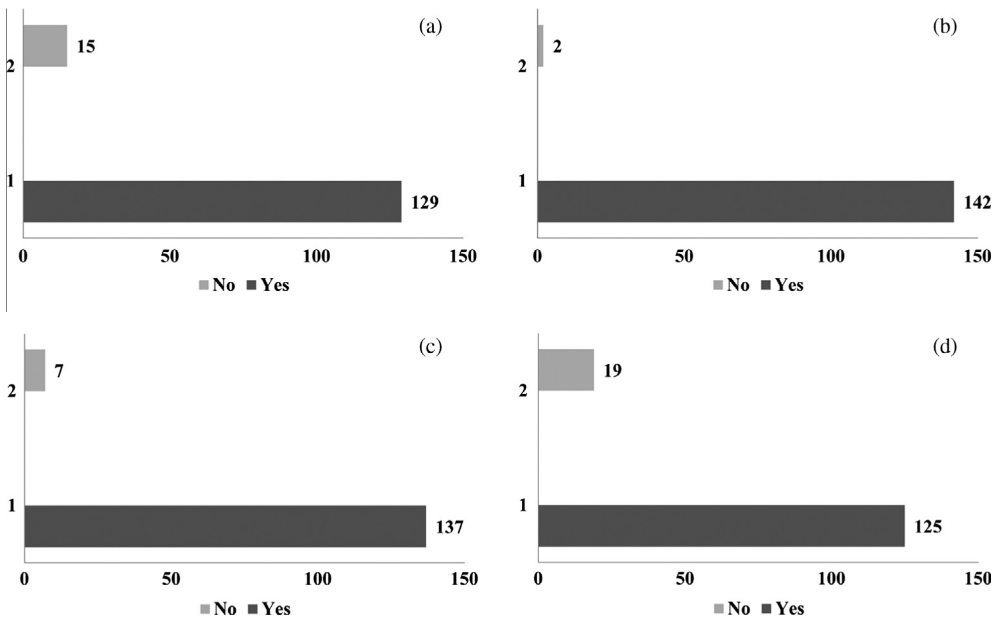

Fig. 3. Marks – importance of education and rehabilitation parameters. (a) Importance of user's perception parameter. (b) Importance of independence parameter. (c) Importance of user's orientation parameter. (d) Importance of user's education parameter.

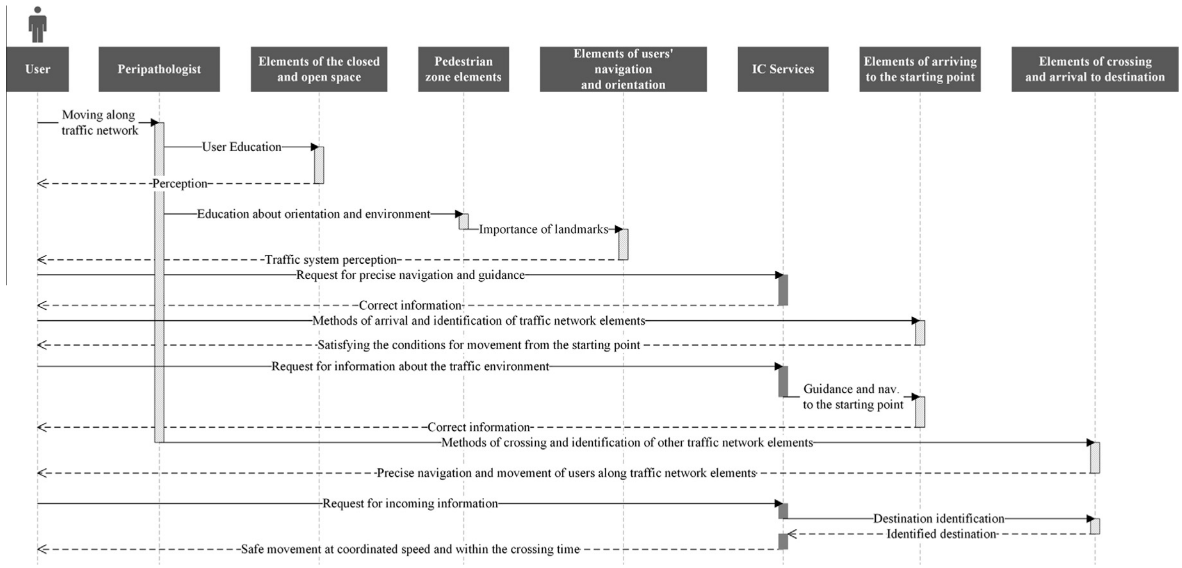

Fig. 4. Generalized model of creating a user's knowledge base.

Afterwards maps and routes can be sent to *Loadstone* central server so that other users may also have the advantage of using the developed maps or routes. The application can operate in offline and online mode (requires connection to the Internet). End user makes the decision on which operating mode to use.

Outdoor Navigation is an Windows phone 7 application which has the possibility of selecting the maps (Google maps, OpenStreetMaps or OpenCycleMaps). The application also supports *offline/online* operating mode, which the users find extremely important (the social aspect). The application is additionally equipped with a travel computer which enables measuring of the average movement speed, distance travelled, measuring of altitude and integrated digital compass. The drawback of the application is the impossibility of using any screen readers and the selling price.

Mobile Geo is an application which can be installed on any mobile device operated *Windows Mobile* platform. *Mobile Geo* cooperates directly with the screen reader *Mobile Speak for Smart phones* and allows the users to use mobile devices with installed GNSS modules or to connect them with other commercial modules. Using GNSS solutions developed in the Sendero group, Mobile Geo user is provided with great portability and flexibility in provision of diverse information, using the installed maps in the memory of the mobile device and at the same time allowing the creation and 100% control of the new routes or extension of the existing ones. The drawback of the application operation in the Republic of Croatia is the non-existence of the maps for this area and support of the Croatian language.

Intersection Explorer is an application which is exclusively intended for the blind and visually impaired users without the navigating function but provides the user with the information about the location of the traffic intersection. It operates on the principle of *Google Street view* that provides the users with virtual search of the location and orientation by means of panoramic images recorded at the street level. A blind or visually impaired person with the mentioned research has the possibility of easier perception of the environment (traffic intersection) in the surrounding.

WalkyTalky is an application which is also intended for the users operating together with the application *Intersection Explorer* (*Android*). The purpose of the application is guidance and navigation of users to the set target by using *Google* maps. The application allows overview of the points of interest but has no possibility of their input. The advantage of the application is the voice support which has been integrated in the application.

Nokia maps is an application mainly used by newer generations of Nokia mobile devices (*Nokia Belle OS* and *Nokia Anna OS*), but its maps can be downloaded also for *iOS* and *Android* operating system. Nokia maps allows storing and sharing of routes the user uses by means of social networks or by sending them via electronic mail. A detailed overview of points of interest and their input are defined according to the user's requirements. The information about public transport within this application is not provided by any of the analysed applications, and it is of great help to users.

All of the mentioned applications were tested in a real environment. During the testing shortcomings were observed in determining of exact location provided by the GNSS enabled mobile devices. Because of the mentioned this paper suggests a model which uses technologies like GNSS, RfID and NFC. The change of the currently available technology which meets the users' requirements during movement of the users through the identification zones is reflected in the dynamic system of technology selection. The users' identification zones have the function of identifying the users and further managing of the communication system. The dynamic system of the selection method of the currently available technologies is presented in Fig. 5. The figure shows that additional technologies provide higher level of precision, whereas the white cane is still being used as the basic aid.

The meeting of the conditions by using the offered technologies, and through education by the authorized peripathologist, enables the user to move safely. The basic aid in moving is the white cane which in this case represents a component of the traffic network and as such raises the level of user's safety while moving. Apart from the basic training of orientation and moving, the peripathologist also has to meet the criteria of implementing the information and communication technologies with the user (blind or visually impaired person). While moving independently along the network, by dynamic selection of technology divided into three identification zones, the user is provided with precise information, presented in Fig. 6.

The first zone is defined in the radius of 1 [m] in relation to the audio indicator which at the same time defines also the initial point of crossing. Audio indicators are input as points of interest (POI) which navigate the user. The points of interest in themselves also use the information about the traffic intersection. The second Zone is defined at the distance of 10 [m] in the direction of the user's arrival, and the third Zone at a distance of 30 [m]. The mentioned zones are defined through the carried out research of the analysis of applications for the guidance and navigation and the conditions of traffic intersections in the City of Zagreb. For the size of the third zone the distance for the orientation of the user in relation to the audio signal which would be activated after having identified the user is considered as sufficient. In order to identify the user when entering the third identification zone the user uses RfID active tag which activates the audio indicators at the traffic intersection thus forwarding the information to the signal-controlled intersection management system which modifies the operating mode. The characteristics of the already mentioned technologies of zone coverage are presented in Fig. 7.

The identification zones allow the obtaining of precise information received by the user about the distance that is required to arrive to the first point of crossing the traffic intersection. The generalized presentation of the dynamic model during the user's moving through the traffic intersection is presented in Fig. 8.

The operation of the system is based on the presented diagram, where the users move along the traffic network using their mobile devices to receive all relevant information about their movement. When the user enters the third identification zone the system controlling the traffic lights receives the information and changes the operation mode. For the identification the user is equipped with an RfID tag which is identified by means of an antenna directed towards the movement. By arriving to the starting point of crossing the intersection (POI 1), the user receives the information about the location and all the necessary information about the intersection. The information that the user obtains are: size of the intersection (how many lanes in which direction), street names (defined according to the geographical directions), existence of landmarks, tactile elements of accessibility, tramway lines, and possible directions of movement. If the pedestrian crossing is at an angle), the user also obtains this information and should align the body to the respective position. For instance: *the direction of movement North–South, Šubićeva street, position of the body 30° to the right*. The user receives the information by means of the mobile device if the interest point is entered using NFC technology which serves to read the information from the indicator. After confirmation of the traffic-light system to cross the street, the user passes the pedestrian lane and arrives to the destination point (POI 2). Upon arrival the user receives the information that they have arrived to the destination, and the information about the possibility of further moving by using the directions of movement according to the geographical directions. The user can move towards the destination point by using the application for guidance or navigation (POI 2) or to the emitted audio signal. The exit of the user from the system is identified by RfID system that forwards the information to the traffic-light system which returns to the initial mode of operation. The time interval is determined according to the size of the traffic intersection and the traffic volume that runs through it. After exiting the system the user receives the information on the mobile device that they have exited the traffic intersection zone. The sequential diagram presented in Fig. 9 shows in detail the current method of crossing the intersection equipped with audio indicators (black tag of duration shows that the user is in the traffic intersection during the red phase). The diagram shows the difference in the duration of the green phase during the movement of the user through the pedestrian crossing.

For orientation at traffic intersections equipped with audio indicators a blind or visually impaired person uses mostly the sound emitted from them. The change of sound while walking (green phase to red phase) additionally endangers the safety

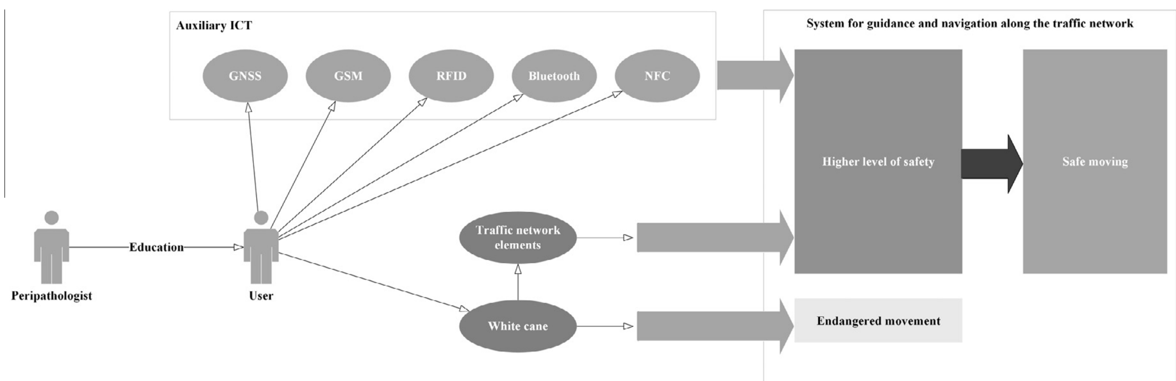

Fig. 5. Dynamic system of technology selection.

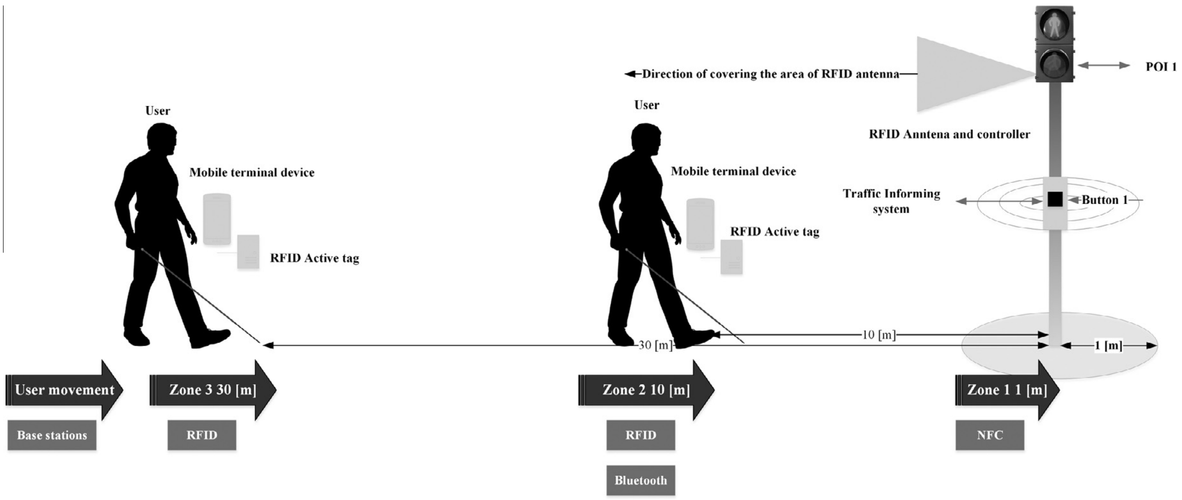

Fig. 6. Zones of identification and navigation of the users.

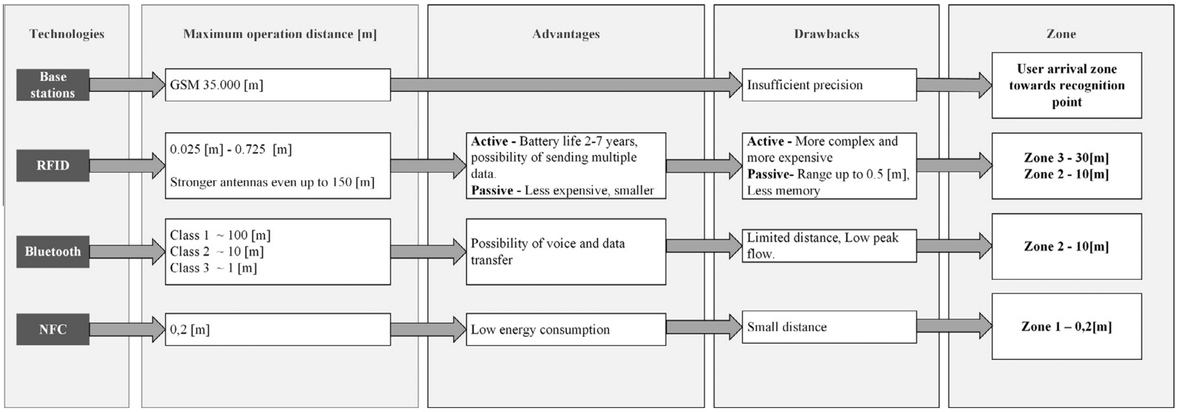

Fig. 7. Characteristics of available technologies according to user coverage zones.

of the user since a blind person cannot see the condition within the traffic network, but rather only feels or hears it. The movement of the users by implementing new technologies is also presented by a sequential diagram which can be seen in Fig. 10.

The most important segment from these two diagrams is the difference in the time of movement of the users through the pedestrian crossing. The grey colour designates the movement of the user during the green phase which leads to the conclusion that the user has successfully crossed the path from the starting to the end point. The information that surrounds the user does not endanger them but rather navigates them to the desired point.

4. Validation of the dynamic guidance and navigation model

The validation of the dynamic guidance and navigation model of the blind and visually impaired persons was carried out at the traffic intersection which was graded as the least safe according to the survey results. The intersection graded by the users according to the survey as the least safe for crossing is the intersection of *Šubićeva street* and *Zvonimirova street*. According to the opinion of the users this intersection is the least safe (there is least feeling of safety in walking) for the following reasons:

– obliquely set pedestrian crossings;
– poor audio signalization;
– poorly set tactile surfaces;
– hard to identify pedestrian islands, and
– incorrect information on the indicators.

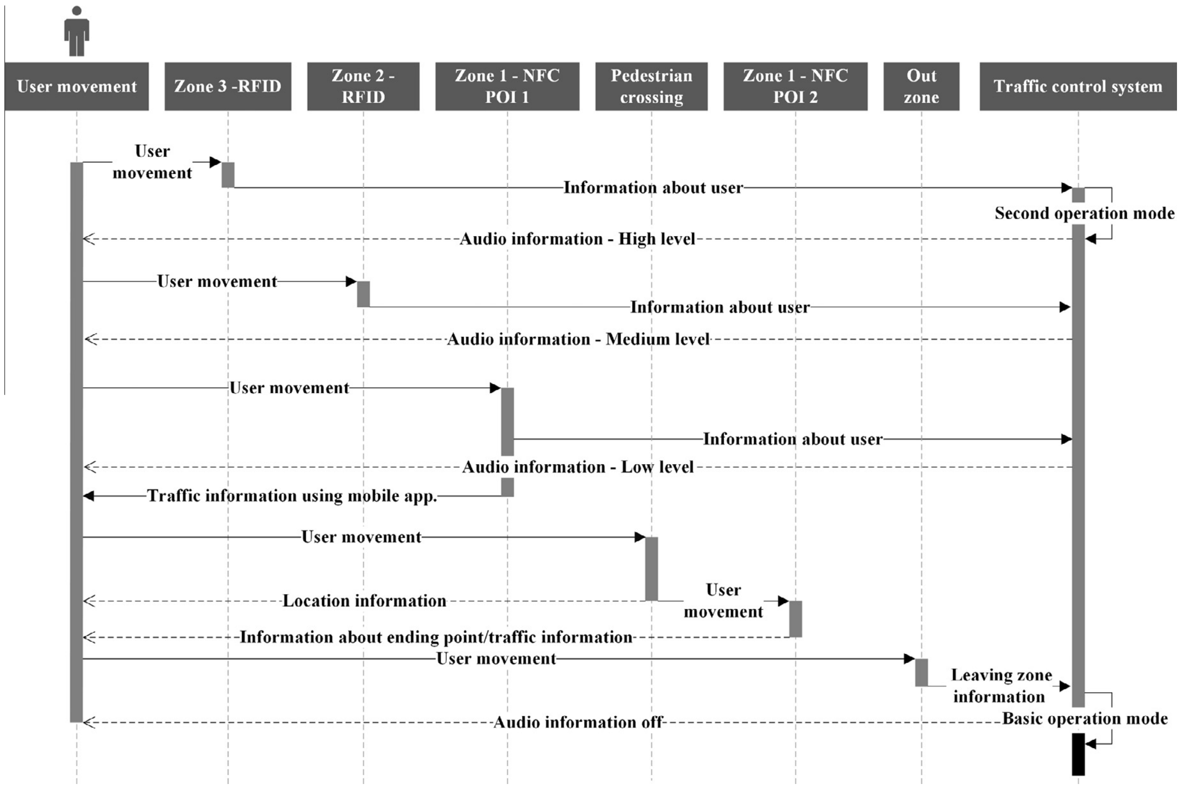

Fig. 8. Generalized presentation of the dynamic model of the user's movement at intersection.

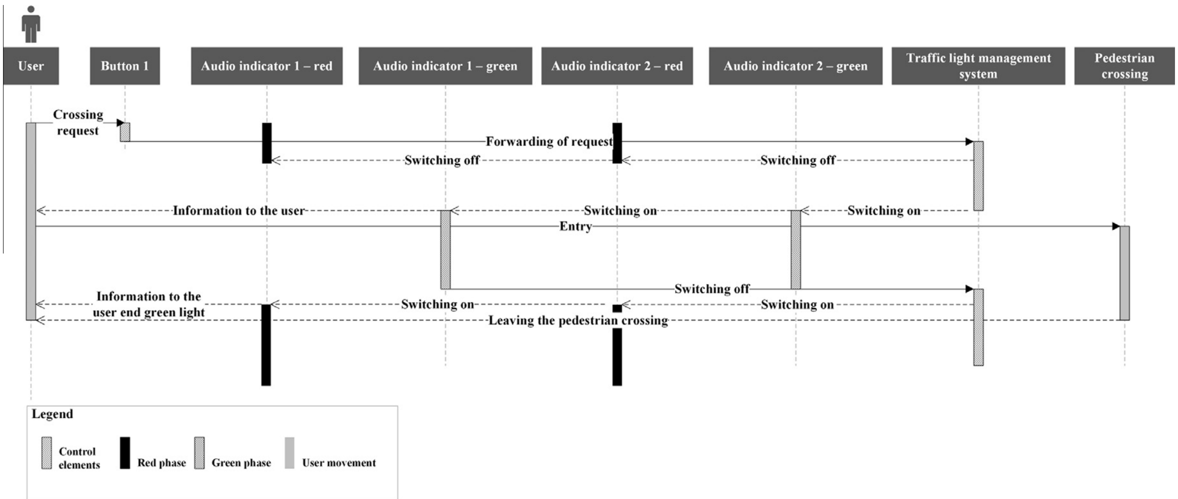

Fig. 9. Movement of users through intersection (without ICT assisted information).

In order to master the crossing audio indicators have been installed on the islands. There are tram stops within the traffic intersection as well. The starting, destination and the point which denotes the pedestrian island are input as interest points in the used application (Loadstone). The Loadstone application was used because it was the commonest among the respondents. The steps in the procedure of validating the model are:

– defining and marking the identification zones;
– input of interest points into the application for the navigation of the users (points POI 1 and POI 2);
– psychological preparation of the users about all the elements of model management;

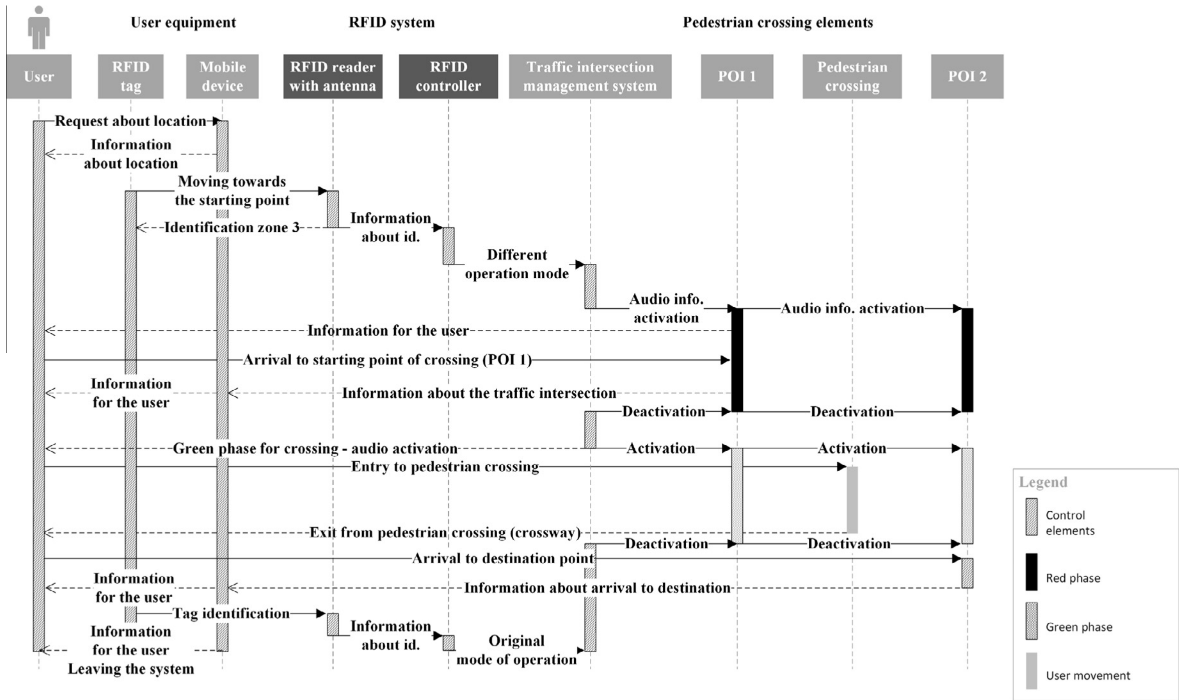

Fig. 10. Movement of users through intersection with the application of new technologies.

– defining of the intensity of the emitted audio information;
– input of information at the starting and the end point;
– defining of the green phase duration; and
– checking the accessibility elements.

During user education about all the elements of model control their speed of walking towards the starting point of crossing amounted to 0.55 [m/s] (1.98 [km/h]). The first identification of the user moving along *Zvonimirova street* in the east–west direction along the northern side, occurred at 30 [m] from the audio signal. After the identification the audio signal was activated (simulated RfID system of identification – Active RfID reader SCIEL, SCIBT36 and RoHS Compliant 433 MHz Active RfID Tag). The user also received the information about the starting point of crossing via the navigation application. The user directed the movement towards the starting point and upon the entry into the second zone received the information that his starting point for the intersection crossing is at 10 [m] in the direction of movement. Upon entering the first zone the user using the white cane felt the pole with the installed indicator, and also received the information via his mobile terminal device about the arrival to the starting point of crossing. The user received via his mobile terminal device the information about the traffic intersection that needs to be crossed in the following form:

Moving direction north–south Šubićeva street, oblique pedestrian crossing, body position 30 to the right, three traffic lanes east–west, two tramway lines, pedestrian island, three traffic lanes west–east.

After approval of the signalized system for the crossing, the user stepped onto the crossway while using the white cane and the navigation application successfully reached the first destination point B. Upon arrival the user received the information via the mobile device about the arrival and further movement instructions. The information received from the information system: two traffic lanes. After crossing approval, the user successfully reached the destination point C. While moving the user had the possibility of using the tactile elements of accessibility, but due to the badly designed tactile lines the user concentrated exclusively on his aid and the guidance system which navigated him to the desired point (Fig. 11).

The model was tested by theoretical test. After having described the method of model operation to the users, the testing began. The first user who tested the operation of the model had several years of experience of moving in the traffic network of the City of Zagreb. After user identification upon entering the third identification zone, the user arrived in a safe and coordinated manner to the starting point of crossing. The audio signal which was activated, after user identification, raised the safety level and he orientated himself according to it. Upon reaching the starting point of crossing the user received the information in the form: moving direction north–south *Šubićeva street*, oblique crossway, body position 30° to the right, three traffic lanes east–west, two tramway lines, pedestrian island, three traffic lanes west–east.

Fig. 11. Defined zones of user identification during model validation.

After having received all the necessary information about the intersection, the user took the position to start crossing by touching the curb. After approval of the green phase and simulated audio signalization, the user started towards the pedestrian island with the first crossing point. Upon reaching the pedestrian island, identified by the user because of the curb, the user received the information via his mobile terminal device about the arrival and the possibilities of further navigation. After green phase activation, the user passed the road lane and reached the destination point. At the destination point the user received the information about his location. When he exited the system the user received the information that he is no more within the zone of the traffic intersection and the traffic-light system returned to its original mode of operation. The user reached his destination in a safe and coordinated manner. After educational passing of the user with a peripathologist, the user passed independently the entire walking route with the walking speed amounting to 2.4 [km/h], which is an increase by 66%.

The results of testing the efficiency of the model allowed safe and independent movement through the intersection. The user had all the relevant information about the environment and the configuration of the traffic intersection thus improving the user's perception. More efficient usage of the currently available technology and its functionality provided the users an improved quality of living. The application of new technologies and services defined new methods in the education of moving and orientation of the users.

5. Conclusion

A blind and visually impaired persons today in their movement tend to become as independent as possible and perform their movement in a coordinated manner. The purpose of this study has been to provide a higher level of safety for the blind or visually impaired person by implementing new technologies and services and by obtaining precise information about the location and the environment while moving along the traffic network of the City of Zagreb. The dynamic model of guidance and navigation of the users has been defined according to the relevant traffic, technological and education and rehabilitation parameters whose role is important for defining the users' requests.

The criteria for the selection of the traffic, technological and education and rehabilitation parameters have resulted from the everyday needs of the users who move along the traffic network of the City of Zagreb. The model was tested experimentally, i.e. using the theoretical method on a traffic intersection denoted by the users as the least safe for their movement. Due to various individual needs of each user reflected in orientation, perception, speed of movement and method of using the mobile terminal device and mobility the experimental method for testing the model was used. The results of model testing are reflected in the higher degree of safety during user's movement along the traffic network by providing precise information about the user's location and the environment.

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