Development of safe routes for children in urban environment

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Abstract. The matter of development of safe travel routes for children between school and home is analyzed. The availability of various applications and devices to identify the location of the child and his/her travel routes is noted. The main factors to be taken into account when planning children travel routes are described. The most popular Russian services for route planning, Google, Yandex, and 2GIS, are discussed. These services are shown to have a number of shortcomings which does not allow them to choose really safe routes. A decision on making the route selection by two criteria (the travel time and the probability of an accident) is obtained. As a numerical example, the Pareto area for possible routes is constructed.

Introduction

The lives of children in urban environment are fraught with many challenges. The necessity of travels between school and home requires solving problems on routes choice and travel control. The GIS and GPS technologies are widely used for solving those problems. Location tracking systems allow the parents to monitor their children’s location [1]. Such systems are helpful within the context of security enhancement, peace of mind settling, and the need for reducing parents' uncertainty. That is why parents are encouraged to use surveillance technologies for keeping their children “safe” [2].

In [3], the following parental control tasks were described:
- to give care;
- to be responsible;
- to be protective;
- to be involved, which task includes control and establishing sets of rules and norms;
- to avoid instilling fear;
- to foster self-reliance;
- to trust;
- to foster communication through dialogue;
- to (co-)regulate their son or daughter in order to help him/her to become a conscientious and self-reliant adult.

Although such parental tasks are important ones, the availability of location-based services (LBS) raises a number of problems that should be borne in mind [3]. Location-based services may create deceiving situations for parents. Also, such services may impede developmental processes towards establishing the children’s autonomy and self-reliance.

Location-based services identify the location of a user based on the indications of some handheld, wearable, or implanted device used for a particular purpose. L. Perusco and K. Michael [4] have identified potential risks related with LBS within the context of security and privacy. The major dilemma here consists in privacy-security dichotomy.

J. Boesen et al. [5] have reported a study in which using LBS by families was analyzed. The possibility of undermining the trust in children, which may become an upbringing problem, was described. Location-tracking technology can generate anxieties and conflicts between parents and children. Tracking technology must be based on a better understanding of the complex interplay between the technology and the inter-human relationships in various social groups [6].

In this connection, the society has to address the following issues [3]:
- the right to privacy;
- the right to know who controls your data;
- the right to know that you are being tracked;
- the right to agency, in order to become a responsible person;
- the right to learn by trial and error and the right to make mistakes;
- the right to autonomous decision-making.

In the field of health care and education, governments can use monitoring systems to identify and “manage” the behavioral deviations from the norm [2]. However, today the devices and applications monitoring the location of children are not so common tools (or they are no commercial success) because [1]:
- some parents have not ever heard of location-tracking technologies;
- many parents are not aware of the fact that such technologies are indeed available;
- only a minority of parents advocate using the location-tracking technologies;
- most of parents need no location-tracking tools;
- the control effected via location tracking was considered to be a threat to the self-direction of children and to the trust in them.

The physical activity of children

Many studies were devoted to the matter of children’s physical activity. Monitoring systems offer a unique possibility to track the physical activities of children and adults. Children’s current physical activity levels are disturbingly low in comparison with the recommended levels [7].

The time spent by children outdoors with other children is an important source of children’s physical activity [8]. Interventions to intensify the physical activity may benefit from fostering friendship groups and from restricting the time during which the children stay alone.

The researchers have identified the following important factors positively influencing the physical activity among children:
- the growth of the walking between home and school [9, 10];
- the presence of green belts near the house;
- the presence of parks located over the travel route [11];
- the presence of green school gardens [10];

On the schoolyard, children’s physical activity levels are higher than on the average [7].

Travel route choice

Since the beginning of the XX century, the modern cities have been designed around the use of motor vehicles despite the unfavorable interactions between vehicles and pedestrians.

There is an increasing interest in community walkability [12]:
- initiatives on the development of safe routes to school are being advanced;
- concerns regarding the epidemic obesity are being delivered;
- political initiatives designed to convince travelers to switch from auto trips to more environmentally sustainable bicycle and walking trips are being put forward.

The study [13] was performed to examine the extent to which the street network configuration is associated with the path selection by pedestrians. Designing better connected street networks with a reduced distance between home and school may serve a factor supporting the navigation choices and walking behavior.

Nowadays, a multitude of new applications have been developed for different types of navigation systems [14]. There exist significant differences between the nature of route choice problems for pedestrians and those for motor cars as the navigation services designed for vehicles proved to be inappropriate for pedestrians.

That is why M. Sahelgozin et al. [14] have proposed a multi-criteria path optimization method that offers a Ubiquitous Pedestrian Way Finding Service. The developed model allows one to construct routes on the basis of a linear convolution of criteria. Thus, the latter procedure yields alternative routes for people. In particular, it was shown that the most important value for children is the prevention of accidents; those for young people, the inadmissibility of teen crimes; and those for retirees, short walking distances.
The travel route choice depends on many factors [15], which involve
- connectivity (Bus/Taxi stops, Commercial area, Business area, Residential area)
- conspicuous signage (indicating names, directions, distances, etc.)
- conviviality (Food and beverages vendors, Public parks, Recreation/Rest centers)
- shelters (Row of Roofs, Row of Trees)
- convenience (Walking time, Walking distance)
- traffic safety (Presence of crossings, Presence of traffic lights)
- perceived security (Proximity to abandon area, Proximity to construction sites, Proximity to public alleys).

The study of road collision risks is important for the improvement of pedestrian safety [16]. The article [16] discusses the formulation of the problem of route choice with different road crossing options (zebra crossing, controlled intersection of roads). The risks assessment problem is a difficult one due to the lack of information about roads intersection (traffic volumes and amounts of accidents).

The route choice during the active transportation of children to school is under study [17]. Children avoid streets with a high rate of accidents. They prefer residential streets yet avoid zebra crossings. The majority of the differences between the real and shortest routes can be attributed to children and their parents’ preferences to avoid walking along busy roads on their way to school.

**Services for making routes in Russia**

The number of cars in cities exhibits a permanent growth. The interaction between people and cars can be expressed in specific figures. For example, according to the State Traffic Safety Inspectorate statistics, a significant number of road accidents with the injured and killed occur as a result of the violations of traffic rules by pedestrians. This fact is illustrated by Fig. 1.

**Figure 1.** The number of accidents and victims due to the violation of traffic rules by pedestrians in Russia

It is seen from the figure that systematic activities aimed at reducing the injury rates are being conducted. There are changes in the legislation - the measure of responsibility for drivers and pedestrians is growing, together with the amount of penalties imposed for the violation of rules. Road marking and visibility of pedestrian crossings are being improved significantly. Clothing and individual elements


with reflective properties are put into use. However, we believe that additional opportunities for reducing the number of accidents and injuries are available.

Wearable electronic devices (phones, smartphones, communicators, and smart watches) greatly simplify the life of modern individuals as those devices enable the voice and video communication, the messaging, the access to information, etc. Also, there exist an opportunity to plan car and foot routes using the public land and underground transport. The most widely used software products are Yandex.Maps, Google.Maps, and 2GIS.

As a rule, most of the existing programs are used by motorists to construct fast or short routes taking into account the busy city roads, repair works and road accidents. Pedestrians are given fewer criteria for choosing their routes. As a rule, here just one, rarely, several options are offered. If we are talking about moving from point A to point B without using public transport, then, as a rule, a shortest route, or a lowest-distance route, will be constructed.

In our opinion, modern software products and tools are presently capable of taking into account more criteria for constructing routes. In addition, among a variety of options for movement, one of the routes can be identified as the safest one. We believe that the so-called "safe route" is a pre-planned route with the lowest risk of injury or illness. We would like to highlight some criteria that can affect the level of route security.

1. Traffic lights, signs, and marking. Separation of transport and pedestrian flows in different planes with the use of overground and underground pedestrian crossings will exclude the contact between cars and pedestrians and, in this way, will reduce the probability of auto-pedestrian accidents and injuries. The probability of injuries occurring as a result of auto-pedestrian accidents on regulated pedestrian crossings is much lower than that on non-regulated pedestrian crossings and, especially, when roads are crossed in the wrong places. The presence of sidewalks on the route is an advantage.

2. Time of day. Movement in the night-time is associated with a load on the visual analyzer, a neuro-emotional strain, an increased probability of stumbling or falling, for example, because of works on the improvement of the yard territory, repair works, etc. In the early morning hours, as a rule, the street is not crowded.

3. City lighting. The central streets are much better illuminated than the secondary and courtyard territories. Good lighting increases the safety on the route.

4. Season. Long-term exposure to low or elevated temperatures can adversely affect the health status of people (hypothermia, frostbites, heat and sunstrokes, sunburns). Under such conditions, when compiling the route, it is necessary to take into account the outdoor temperature, the continuous time to be spent in the open air, the possibility of heating on the route, and the possibility of linking with public transport. For example, the temperature is minus 24°C, the bus stop is 40 minutes away, the traffic schedule is one bus per hour, not all the cars (part of them is frozen or cannot be started, etc.) have come on the route. Here, the pedestrian gets in an extremely difficult situation.

5. Crime and accidents. The safe route must be laid taking into account the criminality and accident foci and, also, the probability of an unfavorable public.

6. Weather. Weather phenomena, - strong wind, rain, fog, snowfall, ice, - this is a warning not only for car enthusiasts, but also for pedestrians. When laying the route, the program should prompt the user of unfavorable weather conditions.

7. Age of the user and his/her personal features. Information about the age of the user is stored in a portable device. Using it, you can make routes that take into account the age (children, adults, elderly or disabled people).

8. Parkland areas. In some cases, it would be necessary to avoid constructing routes through such areas in the spring, during the period of mite activity providing that no adequate anti-maltreatment measures were taken. In all other cases, when moving at daytime, parkland areas located on the route will be an advantage (nature, fresh air, etc.).

9. A route in the group. It is necessary to take into account the number of people (children) on the route. For organized groups of schoolchildren, it is necessary to draw up special routes.
10. Police. Police strongholds and stationary posts are to be indicated in the map as places where you can apply for help if necessary.

11. Medicine. Hospitals, polyclinics, private clinics. Places where you can get medical help.

12. Toilets. Public paid or free toilets for comfortable route planning for long distances or in case of urgent need.

| Table 1. Comparison of software products |
|-----------------------------------------|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|----|----|----|
| Google.Maps | - | - | - | - | - | - | + | - | + | + | - |
| 2GIS | - | - | - | - | - | - | + | - | + | + | + |
| Yandex.Maps | + | - | - | - | - | - | + | - | + | + | + |

It should be noted that Google.Maps offer a schematic representation of urban environment which can be used for identifying the location with high accuracy. However, in compiling the route the user is limited in information; for instance, when viewing the route the user is devoid of information about the presence of traffic lights, pedestrian crossings, paths and courtyard aisles. Everything is fairly approximate and conventional; in fact, here the user deals just with the direction of the movement. On the other hand, Google.Maps can construct an alternative (second) route with time and distance indication.

2GIS offers more detailed information about the terrain and pedestrian paths in parkland areas, but, here, no traffic lights or pedestrian crossings are indicated. Routes are laid without taking into account traffic signs. When following Google.Maps or 2GIS, you should consider with care the choice of highways intersections.

Today, you can get a most complete idea of moving along a route by using the Yandex.Maps service. Here, all kinds of pedestrian crossings, ground, above-ground and underground ones, are indicated. Pedestrian crossings equipped with traffic signaling are shown. An extensive road-and-track network and intra-courtyard passages are represented. Routes constructed by Yandex.Maps use pedestrian crossings when crossing a highway. All maps bear police stations and medical facilities, but only in 2GIS these are shown permanently. In the two other programs, the police stations are displayed on demand. All the above programs lack the function of constructing a safe route.

**Example of development of a movement route**

Investigating a particular situation, the daily trips of a child from home to school, you can be sure that there are many options to overcome this distance. Some of the most commonly used routes are highlighted on the map below.
The school is located at a distance of 950 meters from the house along a straight line. To get to the place of study, you need to cross the road at least once. On the way, there are regulated and non-regulated pedestrian crossings, a parkland area, and yard territories. Schematically, potential routes can be represented as a graph.

On each of the route sections, the distance and the time required for covering the distance were measured.
**Table 2.** The results of the measurements

| Section | Type | Time, min | Route length, m |
|---------|------|-----------|-----------------|
| 0 – 1   | 2    | 4         | 310             |
| 0 – 2   | 2    | 6         | 460             |
| 0 – 3   | 1    | 12        | 1100            |
| 0 – 6   | 1    | 19        | 1700            |
| 1 – 3   | 2    | 8         | 720             |
| 1 – 5   | 1    | 10        | 890             |
| 3 – 4   | 0    | 3         | 280             |
| 3 – 5   | 0    | 3         | 270             |
| 2 – 6   | 0    | 11        | 950             |
| 4 – 6   | 0    | 6         | 450             |
| 5 – 6   | 0    | 5         | 410             |

In addition, for route sections having an intersection with a road through a non-regulated pedestrian crossing, it is a common practice to denote this type of intersection with digit 2, whereas the regulated pedestrian crossings and the places where intersections with motor roads are absent are traditionally denoted respectively with digits 1 and 0. We have performed calculations of the occurrence probability of negative events on each of the routes with the adoption for the probability of a road accident at regulated and non-regulated intersections the values of 0.000001 and 0.00001, respectively.

**Figure 4.** The Pareto area

In Fig. 4, the Pareto area is highlighted in green, so the choice should be made between the two routes, the route 0-6 being less risky yet slower, and the route 0-2-6, more risky yet faster. The final decision on the choice of the final route remains for the person (pedestrian).

**Conclusion**

The article discusses the issue of choosing secure routes for children. It is shown that there exist many technical solutions allowing the design and control of the routes. The proposed measures enable an improvement of the existing services in the development of children's walking routes. The proposed approach allows one to find optimal travel routes for children in urban environment with taking into account safety considerations. In the future, we are going to increase the
number of used criteria that describe the routes. Also, various transportation purposes, environment conditions, and child conditions will be included in consideration. This approach will offer routes meeting the various needs of the child. In the future, the proposed approach will be incorporated in a navigation system intended for monitoring children’s location. Also, the proposed approach will allow solution of the important task of urban planning in transport infrastructure to ensure the safe movement of children.

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