IS ITS THE SOLUTION TO CREATING A SAFE CITY ENVIRONMENT FOR CHILDREN?

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ABSTRACT

Our cities should be designed to accommodate everybody, including children. We will not move towards a more sustainable society unless we accept that children are people with transportation needs, and ‘bussing’ them around, or providing parental limousine services at all times, will not lead to sustainability. Rather, we will need to make our cities walkable for children, at least those above a certain age. Safety has two main aspects, traffic safety and personal safety (risk of assault). Besides being safe, children will also need an urban environment with reasonable mobility, where they themselves can reach destinations with reasonable effort; else they will still need to be driven. This paper presents the results of two expert questionnaires focusing on the potential safety and mobility benefits to child pedestrians of targeted types of Intelligent Transportation Systems (ITS). Five different types of functional requests for children were identified based on previous work. The first expert questionnaire was structured to collect expert opinions on which ITS solutions or devices would be, and why, the most relevant ones to satisfy the five different functional requests of child pedestrians. Based on the first questionnaire, fifteen areas of interest (problem areas) were defined. In the second questionnaire, the experts ranked the fifteen areas, and prioritized related ITS services, according to their potential for developing ITS services beneficial to children. Several ITS systems for improving pedestrian quality are discussed. ITS services can be used when a pedestrian route takes them to a dangerous street, dangerous crossing point or through a dangerous neighbourhood. An improvement of safety and other qualities would lead to increased mobility and a more sustainable way of living. Children would learn how to live to support their own health and a sustainable city environment. But it will be up to national, regional and local governments, through their ministries and agencies and public works departments, to promote, fund, and possibly mandate such systems. It is clear that we need to offer an acceptable level of convenience, efficiency, comfort, safety and security to pedestrians but it is less clear if society will prioritize resources towards this.

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Highlights:
- ITS services adapted to children’s needs can be used to improve safety and mobility for child pedestrians
- Traditional solutions are sometimes better than ITS solutions for protecting children
- ITS services can be used when a pedestrian route takes them to dangerous street, dangerous crossing point or through a dangerous neighborhood
- ITS services can be used to help children when they or a vehicle are violating a red light at a traffic signal.

1 INTRODUCTION
An inadequate traffic planning regarding pedestrian needs can lead to an unfriendly “walking environment” with people feeling unsafe. This can go as far as creating a real fear of walking to an activity or a destination point, excluding some vulnerable road users from important activities in society. The reduction in walking has economic implications for society (e.g., costly vehicle-aimed infrastructure, negative environmental aspects of vehicle traffic) but even more so for specific individuals such as health loss due to less exercise. It is important to improve the walking environment to attract new pedestrians, e.g. children, but it is equally important to aid current pedestrians. This aim should be to improve safety, security and aesthetics while reducing traffic noise, emissions and severance (or barrier) effects to facilitate pedestrian trips. Personal safety and security for pedestrians should be an obvious right in any civilized society; and a person’s, or their parent’s, fear of them having an accident or being assaulted is one of the limiting factors for leaving home and walking, as revealed by the results of the SIZE research (Zakowska and Monterde-i-Bort, 2003; Monterde-i-Bort and Moreno-Ribas, 2003).

Our cities should be designed to accommodate everybody, including children. We will not move towards a more sustainable society unless we accept that children are people with transportation needs, and ‘bussing’ them around, or providing parental limousine services at all times, will not lead to sustainability. Rather, we will need to make our cities walkable for children, at least those above a certain age. Safety has two main aspects, traffic safety and personal safety (risk of assault). Besides being safe, children will also need an urban environment with reasonable mobility, where they themselves can reach destinations with reasonable effort; else they will still need to be driven.

It is quite well known how adults react to changes in street design and we are starting to learn how they react to Intelligent Transportation Systems (ITS) services. The safety effects of more than 20 ITS solutions were assessed in the EU projects eIMPACT (Wilmink et al., 2008), PreVAL (Scholliers et al., 2008), CODIA (Kulmala et al., 2008) and INTERSAFE2 (Wimmershoff et al., 2011). Conclusions from those projects are that potential effects of individual ITS systems may be 1 to 17% reduction of all fatalities in traffic in the EU. The lower effects are for measures aiming at eliminating relatively rare types of crashes whereas the higher effects are for ITS solutions aimed at common accident types and assuming perfect reliability, high effectiveness and high penetration rates. However, we do not know much about how children respond, and to what extent ITS services are feasible for children of different ages. There is a need to further study this area. Most probably such ITS systems have to be improved and essentially adapted to young users. This will lead to a new generation of such devises.
The guiding principle used in this paper is to examine how to design a safe and functional traffic environment for children, where ITS services are used when they are beneficial to the children. Some of the results presented in this paper have already been published, seen from a different perspective, in Leden et al. (2012).

2 AIM AND METHODOLOGY

This paper presents the opinions of a sample of experts on the potential safety and mobility benefits to child pedestrians of different types of ITS, targeted for children. For gathering the experts’ opinions, two questionnaires were developed, in two phases, the first one provided input for the second one. The aim of the first questionnaire was to collect expert opinions which ITS solutions or devices that would be, and why, the most relevant ones for improving children’s safety and mobility in urban traffic. The experts’ suggestions were summarized for a second questionnaire. In the second questionnaire the experts ranked these areas with respect to potential for developing effective ITS services.

The population was defined as senior and early career researchers in the areas of ITS and vulnerable road users’ safety, and the sampling frame was constituted by the current 2012 year members of the ICTCT society (International Co-operation on Theories and Concepts in Traffic Safety), and members of the Pedestrian Committee of the US Transportation Research Board, plus the partner teams of the following international research projects: Pedestrian Quality Need project (PQN), 2-BE-SAFE project (2-wheeler BEhaviour and SAFEty), and the VRUITS consortium (Improving the safety and mobility of Vulnerable Road Users through ITS applications). A total of 88 experts were contacted by e-mail. Questionnaire I was responded to by 14 European experts and six North American experts; Questionnaire II by 15 European experts, six North American experts and two Israeli experts.

The theory behind using experts to estimate the effect of new technologies is based on Kulmala (2010) which builds on work by Draskóczy et al. (1998) and Wilmink et al. (2008). Earlier studies have shown that when empirical evidence of the effect of a technology is not available, using experts’ estimates may be the best way of assessing potential safety benefits. This is especially true when low-cost field tests or driving simulator experiments cannot be developed to reflect a real driving environment realistically. Expert may not be able to predict exactly what would happen if a technology were to be implemented in a large scale, but expensive simulations and field tests often do not come up with precise estimates either, and if all we want is to give decision makers an indication of what direction to proceed in, using expert surveys may be the optimal choice.

The experts were instructed to cover the following five functional requests, or needs, of child pedestrians when assessing suitable ITS solutions or devices to improve children’s safety and mobility in urban traffic:

1. Environmental adaptation (using ITS to change driver behavior to child pedestrian limitations)
2. Guidance (leading or navigating the pedestrians)
3. Danger alerts or information (about risks)
4. Confidence and security enhancements (to feel safe enough to leave home and walk)
5. Contact systems (to get in touch with others and/or being localized).

The selection was based on work done within the Pedestrian Quality Need project, PQN, network of COST (358) (Methorst et al., 2010; Monterde-i-Bort et al., 2010), where a set of
functional needs were defined and described within the working group “Functional needs.” From this list the five needs listed above were chosen as the most relevant ones in the context of improving children’s safety and mobility in urban areas.

The experts’ responses with respect to the effects on safety and mobility of ITS systems for child pedestrians are summarized below together with results from the state-of-the-art literature review for the five functional needs listed above. Based on the experts’ responses to the first questionnaire, fifteen areas of interest (problem areas) were defined. In the second questionnaire the experts ranked these fifteen areas for their potential of having ITS services developed. Before those areas are discussed, there will be some elaboration of the general aspects of the five needs listed above.

3 QUALITATIVE ASSESSMENT OF ITS SOLUTIONS TO IMPROVE CHILDREN’S SAFETY AND MOBILITY

3.1 Environmental Adaptation
The concept Environmental Adaptation in this context includes usage of ITS to change driver behavior to child pedestrian limitations and the use of ITS to inform drivers and pedestrians. ITS services can be directed towards the driver, to ensure appropriate driver behavior, the child pedestrian, and towards the infrastructure, to adapt it to the particular characteristics of each pedestrian.

3.2 Guidance (Leading or Navigating)
There were two main potential applications mentioned by the experts: Safe Route Guidance and Safe Crossing Guidance through warnings. Half of the experts that expressed an opinion (five out of 10) stated that route guidance systems, advising people about their safest choice, would improve safety at least for adult pedestrians.

3.3 Pedestrians or Drivers Being Alerted or Informed of a Danger
Half of the experts stated that services that alert or inform pedestrians of a danger would improve their safety. The experts emphasized that such devices need to take the ability of children into account when designed and developed, introducing characteristics which are attractive and user-friendly for children. On the other hand, more than half of the experts expressed a concern about the functionality of such systems and pointed out that the systems could affect pedestrian behavior in a negative way. For example, the provision of such systems may lower the pedestrians natural scanning for dangerous situations and thus lead to lower ‘alert’ levels.

There are systems to warn drivers or pedestrians when there is an imminent risk of collision. Dedicated Short Range Communications (DSRC) can be used to synchronize portable devices such as a GPS in a car and a mobile phone for a pedestrian. Other developments of this type have been based on the localization and intensity of activity in the cellular (mobile) phone network, measuring the intensity and place of the phone activity to estimate, by computer algorithms, the level of road-user activity in streets, as the Italian LocHNEs project does (Calabrese et al., 2011).

Also, systems that warn drivers about the presence of school children are available on the market in the form of Variable Message Signs (VMS) or in-car systems. An example of an in-car system is one that warns drivers of a ‘dangerous’ crosswalk (or other crossing type) ahead,
enabling the driver to adapt his speed in advance. The warning can be made dynamic, i.e. only given when a person is actually near the crosswalk, or at a time based warning sent to the car. (Christ et al., 2010).

3.4 Feeling confident and secure (to leave home and walk)
According to six out of 10 experts addressing this area, services providing confidence and security would likely affect the feeling of security and safety rather than safety itself. Security is very important nowadays in the walking environment. To make people feel confident and secure can best be achieved by assuring people that help is available should they need it. However, half of the experts were distrustful; doubting that the services would be reliable enough to detect emergencies, or that the response time from alerts generated by these systems would be sufficiently short to allow for an effective intervention. Devices such as cameras and emergency-call push-buttons/phones along streets, in parks, at train stations, in metro/train carriages, in elevators/lifts, etc., where the presence of pedestrians is expected, can be used to enhance confidence and security.

A special case of ITS in this field would be those resources developed to automatically recognize the behavior of pedestrians to determine if a situation needs attention in order to prevent an incident, such as an accident, a crime, or a suspicious activity of other kind.

3.5 Getting Contact with and/or Being Localized
GPS systems permitting a person to establish contact are useful from a safety perspective especially for demented elderly people, who suddenly do not know where they are. Such systems can enable relatives to localize them. There are systems that send out SMS messages to all designated contacts with the user's exact current position. But for children and older people in general, a regular mobile phone is by most experts regarded to be more than enough.

4 QUANTITATIVE RANKING OF PROBLEM AREAS AND ASSESSMENT OF ITS TECHNOLOGIES

4.1 Ranking

Based on the experts’ responses to the first questionnaire, fifteen areas of interest (problem areas) were defined. In the second questionnaire the experts ranked these areas with respect to potential for developing effective ITS services. The results of this are shown in Table 1. For each problem area, examples of related ITS services were given. The experts highlighted the most important ones according to their views or suggested new ones. The answers were analyzed, and are summarized below. They are presented in order of importance in Table 1.

Table 1: Areas of interest in order of their proposed priority

<table>
<thead>
<tr>
<th>Rank</th>
<th>Area</th>
<th>Sum of points*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Driver traveling too fast where children are crossing</td>
<td>155</td>
</tr>
<tr>
<td>2</td>
<td>Driver not yielding to child or other pedestrian in uncontrolled crosswalk</td>
<td>123</td>
</tr>
<tr>
<td>3</td>
<td>Driver not seeing child pedestrian because of sight obstructions, such as stopped or parked vehicle</td>
<td>110</td>
</tr>
<tr>
<td>4</td>
<td>Driver distracted by advanced ITS-equipment or mobile phone</td>
<td>95</td>
</tr>
</tbody>
</table>
### Table: Risks Contributing to Accidents Involving Children

<table>
<thead>
<tr>
<th>No.</th>
<th>Risk Description</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Driver operating under the influence of alcohol or drugs</td>
<td>93</td>
</tr>
<tr>
<td>6</td>
<td>Driver not seeing child or other pedestrian at night</td>
<td>91</td>
</tr>
<tr>
<td>7</td>
<td>Child pedestrian not supervised and running into street without looking for cars</td>
<td>84</td>
</tr>
<tr>
<td>8</td>
<td>Driver not seeing child pedestrian when reversing their car or truck</td>
<td>72</td>
</tr>
<tr>
<td>9</td>
<td>Child pedestrian or other slow moving pedestrian not given enough time to cross a street at a signalized intersection</td>
<td>64</td>
</tr>
<tr>
<td>10</td>
<td>Child pedestrian not knowing that a fast-moving car is approaching an intersection</td>
<td>54</td>
</tr>
<tr>
<td>11</td>
<td>Child pedestrian route taking them to dangerous street (high crash potential) or dangerous crossing point</td>
<td>50</td>
</tr>
<tr>
<td>12</td>
<td>Child or other pedestrian violating red light (walking during don’t walk phase)</td>
<td>48</td>
</tr>
<tr>
<td>13</td>
<td>Child or other pedestrian NOT knowing that a red-light-running car is approaching</td>
<td>36</td>
</tr>
<tr>
<td>14</td>
<td>Child pedestrian route taking them through dangerous neighborhood</td>
<td>21</td>
</tr>
<tr>
<td>15</td>
<td>Emergency vehicle traveling at high speed</td>
<td>14</td>
</tr>
</tbody>
</table>

*Sum of points calculated as: An expert giving an area Rank 1 gives 10 points, Rank 2 gives 9, etc. down to Rank 10 giving 1 point. Ranks 11-15 give 0 points.

#### 4.2 Driver travelling too fast where children are crossing

The speed of the vehicle involved in a collision is a determining factor for both the chance of an accident, and the severity of an accident involving a pedestrian. Measures that lower the speed of vehicles at crossing facilities and locations where the road is shared with pedestrians are very effective for improving safety. For explicit estimates, see e.g. Elvik et al. (2004).

Examples of devices that have as a goal to reduce speeds include speed-measuring systems with feedback to the driver on roadside displays, in-car systems that remind the driver of local (legal or advised) speed limits, and in-car systems that intervene to reduce the speed when someone tries to exceed the legal speed limit.

Setting the legal speed limit to be safe is equally important. And that speed limit should maybe vary from minute to minute if circumstances change. In other words, it has to be defined what “too fast” means when children are adjacent to or in traffic. Johansson and Leden (2010) concluded that pre-school children should not encounter cars in their play areas or where they walk. Children 7 to 12 should not cross streets at locations where vehicle speeds exceed 15-20 km/h. This speed is often called human-powered speed, and is used in the context of “shared space” and area marked by road sign “Residential area.” Older children should not cross at locations where motor vehicle speeds exceed 30 km/h. This applies to routes to school, to leisure activities, and when visiting friends. For adults, the general accepted maximum safe speed is also 30 km/h, but the elderly may require lower speeds to be safe.

#### 4.3 Driver not yielding to child or other pedestrian in uncontrolled crosswalk

In Sweden, a large portion of accidents, 11% of fatally injured and 30% of seriously injured, take place in marked crosswalks according to STRADA. In the United States about the same...
share, 15%, of fatally injured pedestrians in 2010 were killed in marked crosswalks, according to FARS\textsuperscript{2}. The layout of the pedestrian crosswalk, the presence of traffic signals and the applicable priority rules have a significant influence on its safety. Generally speaking, empirical evidence shows that, in most jurisdictions, crossings without any markings are safer than marked crosswalks. This is likely due to the fact that the markings provide the pedestrian with a false sense of security (Ekman, 1997).

Leden, Gårder and Johansson (2006) concluded that 90-percentile speeds at crosswalks should not exceed 30 km/h on any approach or safety will deteriorate. However, as a “first aid” various types of in-pavement marker (IPM) systems are emerging. Such systems, using flashing lights, offer a range of designs and functional features intended to warn, guide, regulate, or provide visibility of the crossing facility, and thereby a higher likelihood that drivers will see pedestrians. IPM systems have been installed, e.g., in Oklahoma already in 2000, to provide supplemental warning in school zones. In Oklahoma, the IPM system is activated when classes begin in the morning and end in the afternoon. In other towns, the system is on only when activated by the presence of a pedestrian, either through automatic detection using radar technology, or through push buttons (TRB, 2008).

A more futuristic example of ITS aid is presented in Figures 1 and 2. They show different aspects of the Virtual Wall idea designed by Lee Han Young to ‘protect’ pedestrians in crosswalks (HanYoung, 2008; Murph, 2008). The Virtual Wall provides a barrier made up of plasma laser beams depicting pedestrians (Espinoza, 2008).

\begin{figure}[h]
\centering
\includegraphics[width=0.4\textwidth]{figure1.png}
\includegraphics[width=0.4\textwidth]{figure2.png}
\caption{Crosswalk protected by a virtual wall \hspace{1cm} The virtual wall from the pedestrian perspective}
\end{figure}

4.4 Driver not seeing child pedestrian because of sight obstructions such as a stopped vehicle

Advanced Driver (Rider) Assistance Systems, ADAS (ARAS) include pedestrian detection systems. The development of tools like ADAS and collision warning systems for on board support is a critical development, and manufacturers of modern vehicles are already commercializing such collision avoidance and warning systems.

Today’s passive detection technologies (using LIDAR, RADAR or optical imaging technology) could in the future be complemented with a transponder in order to enable

\textsuperscript{2} FARS analysis by the authors. Fatality Analysis Reporting System (FARS) is provided by the US National Highway Traffic Safety Administration (NHTSA), see www-fars.nhtsa.dot.gov.
detection when the line of sight is obstructed during part of the approach. This requires that pedestrians are equipped with a ‘tag’ (Eisses, 2011).

There are systems that help a driver to perceive pedestrians and possibly intervene in the driving task to avoid collisions. Such systems may warn the driver if the vehicle is on collision course with a pedestrian, increase the braking power for an emergency brake (Brake Assist) or even autonomously activate the brakes in case of imminent risk. Volvo (2010) has developed such a system referred to as “Pedestrian Detection with Full Auto Brake.”

Systems may or may not involve devices carried by the pedestrian that facilitate his/her automatic detection. A specific area of interest is eliminating blind spots for truck drivers by automatic detection of pedestrians.

4.5 Driver distracted by advanced ITS-equipment or mobile phone
A review of several hundred publications reveals that this topic is very complex. Even though a large number of controlled studies show that using a mobile telephone while driving has a negative impact on driving performance, this is not reflected in an increase in crash rates in real traffic when phones become more common (Kircher et al., 2011).

Our survey shows that experts consider “Driver distracted by advanced ITS-equipment or mobile phone” to be among the most serious areas that needs attention. Fifteen of the experts suggested that the solution to this problem (driver distracted by advanced ITS-equipment or mobile phone) should be that drivers’ mobile phones do not work in moving vehicles (hands-free phones included). Currently, the legislated regulation in a number of countries around the world is to ban drivers’ handheld phones in moving vehicles or, in some jurisdictions, to ban them when the engine is running. However, very few, if any, jurisdictions limit the use of hands-free phones while driving.

Six experts suggested that in urban areas, navigation instruments become “audible only” when the vehicle is moving, i.e., display is switched off. The reason that this should happen in urban areas only may be that there is a relationship between driver workload and safety. Not only does too high a workload result in more crashes, but too low a workload does too, since a driver not getting enough stimuli may get sleepy or less alert than a driver offered more stimuli. So driving on a motorway, having single-occupancy vehicle drivers engage in a phone conversation may give a net benefit to safety.

4.6 Driver operating under the influence of alcohol or drugs
Twenty-two experts suggested an alco-lock to be installed in the cars of habitual offenders or in every new car, with almost half going with the latter suggestion. This could be a very cost-effective solution, especially in jurisdictions where drivers do not pass roadblocks with a regular frequency.

4.7 Driver not seeing child or other pedestrian at night
A large portion of accidents with pedestrians happen in darkness: around 46% for the EU18 in 2005, with much higher figures for Poland, Hungary and Estonia (Eisses, 2011). In the United States, 70% of all pedestrian fatalities in 2010 occurred in darkness (on lighted or unlighted streets), 4% occurred in dawn/dusk conditions and ‘only’ 25% during daylight conditions. Only one in 24 pedestrians killed in darkness on rural trunk roads in Finland in 1993-1997 was wearing a reflector (Leden, 2000; Seppelin, 2000). Observations show that 60-70% of pedestrians walking along rural roads at night were wearing reflectors, reflective clothing or a
flashlight (Sipinen and Parkkari, 1999). So the use of reflectors was much greater among ‘surviving’ pedestrians than for fatally injured ones, which indicates that using a reflector is an important safety measure at night. There is a great possibility that safety would improve significantly if we could get more people to use reflectors. An important part in getting to that would be to have factory-installed, pre-mounted reflectors on jackets, coats, shoes and backpacks. Another efficient countermeasure could obviously be to develop ITS nighttime systems.

4.8 Child pedestrian not supervised and running into street without looking for cars

Children are involved in crashes when they are playing in streets and crossing streets, for example to reach a school bus or an ice cream truck. They may be the most vulnerable when they suddenly run out into a street without looking for cars, so called dart-out or dash-out crashes. In 2010 in the United States, 11% of the pedestrians were killed in accidents classified as dash or dart-out. However, dash and dart-out made up 36% of fatalities for pedestrians 0-6 years old (43/120), 34% for children 7-12 (30/89), and 16% for those 13-17 (27/165), whereas adults, ages 18-120, had only 9% of pedestrian fatalities (457/4280) categorized as dart or dash-out.

There is another category of pedestrian crashes, “pedestrian failed to yield,” which is related to these crashes, but the pedestrian does not suddenly run out into the street in these. A total of 1,256 pedestrian fatalities (29%) were categorized in this category. For 0-6 year olds, there were 24 such fatalities (20%), for 7-12 year olds there were 13 (15%), and for 13-17 year olds 33 (20%). In other words, American children are not overrepresented in this latter category but very clearly overrepresented in the dash and dart-out categories.

There were nine experts who suggested that streets be equipped with video cameras that process images of objects and people in a street, and if a child is detected, an in-vehicle alarm is triggered. Four experts suggested that children carry emitting devices which broadcast a signal that is picked up by a detector in the vehicle and an alarm is triggered whenever a child is within X meters from the vehicle, where X would vary with vehicle speed. Finally, three experts suggested that children carry emitting devices and when a device is within the roadway as determined by GPS, an in-vehicle alarm is triggered.

4.9 Driver not seeing child pedestrian when reversing their car or truck

A backup camera combined with sound alarm was the most commonly suggested solution. Detecting pedestrians is crucial when reversing. In the US, there is pending legislation to mandate detectors or cameras by 2014 on all new cars and trucks, but NHTSA has requested more time in order to finish the new rules that are meant to save the lives of those involved in back-up crashes. There are around 300 fatalities a year associated with back-up accidents in the US. Approximately a third of the 300 fatal back-up crashes involve children ages five and under, and one third of the deaths involve senior citizens who are 70 or older. Blind spots behind vehicles can make it hard to see pedestrians or cars approaching while backing up, and while automakers have already added video cameras and other detection sensors to some vehicles, these devices are optional accessories on many vehicles, and only about 20 percent of new models have such equipment.

A major challenge is to detect children who might not respond to auditory warning systems on trucks for example. Reversing collision warning systems may employ a range of
proximity detection sensors (ultrasound, radar or laser-based) or video cameras (rear-view displays) to detect objects behind vehicle when reversing. These systems provide auditory warnings to the driver, as well as visual when cameras are used. Reversing collision warning systems are relevant to reversing or parking crashes, where the vehicle is travelling in reverse at low speed. Could there be a risk that such systems, especially the ones lacking a camera with a video monitor, have negative behavioral adaptation effects?

4.10 Child pedestrian or other slow moving pedestrian not given enough time to cross a street at a signalized intersection

A traffic signal control system that uses sensors to detect the presence of pedestrians and adjusts the traffic signals accordingly is an ‘intelligent’ ITS solution. Apart from radar and infrared detection systems, detection by mobile phone/DSRC and other over-the-air interface systems have been developed in recent years. These systems detect the presence and speed of pedestrians at crosswalks, triggering the green walk signal in place of traditional push-button systems. Using Intelligent Pedestrian Traffic Signal control increases safety and comfort for pedestrians who require more than average time to cross a road, by extending the green time. Such systems may also skip cycles when there is no pedestrian crossing the road and thus increase acceptance and compliance among motorists.

The duration of the walk signal may be adjusted to accommodate slow-moving pedestrians. Pedestrian detection systems have been shown to significantly decrease the number of pedestrians who violate “don’t walk” signals in the US (MacCubbin et al., 2005).

An ITS solution, VRU-TOO (Vulnerable Road User Traffic Observation and Optimization) (Carsten, 1998), replaces the normal push-buttons. It provides early activation of the pedestrian phase, an extension of the pedestrian phase for late arrivals, and privilege time. Privilege time is the time when the walk phase can be initiated starting with parallel vehicles getting their green phase. The system also gives longer pedestrian intervals when there are a large number of detections or the pedestrian velocity is lower than normal, such as for older adults or impaired people.

4.11 Child or other pedestrian not knowing that a fast-moving car is approaching

There are two strategies that can be applied to this problem. Either we accept that some drivers are going too fast and warn pedestrians that a fast moving car is approaching, or we slow down all vehicles so that no cars will be speeding, i.e. going faster than a desired speed. A clear majority of experts consider the latter solution to be preferable. Fourteen experts state that the applicable ITS solution would be Intelligent Speed Adaptation, ISA, to reduce approach speeds. Another six experts state that one should go one step further and stop the vehicle when necessary by using Full Auto Brake when a pedestrian is detected in or near the path of the vehicle.

A total of ten suggestions support warning the pedestrian: Six experts suggest we use an audible warning telling them that a car is approaching at high speed; four experts suggest that we warn pedestrians using a street display. It is not surprising that audible warnings are recommended more frequently than visual ones. Unpublished research by one of the authors has shown that people react the quickest to touch (tactile message), second quickest to what they hear (audible message) and the slowest to what they see (visual message). This is fairly obvious. Think about being at a busy location such as in an airport terminal, and someone
touches your shoulder, someone calls out your name, or someone holds up a sign with your name. What would you be most likely to react to quickly? That audible messages are more effective than visual ones is probably true especially for children. No expert suggested that pedestrians be warned on a device they carry with them. This may be because such systems are still very uncommon. However, such devices could be vibrating and give a tactile signal as well as an audible one.

Besides slowing down vehicles or warning pedestrians of fast-moving cars, we can try to voluntarily have drivers slow down to safer speeds, or at least to be more alert of potential pedestrians crossing. Two experts suggest that we use IPM systems (also known as embedded pavement lighting) to achieve this.

4.12 Child or other pedestrian route taking them to a dangerous crossing point
Seven experts suggest that pedestrians are given route directions, on a GPS or cell phone, to have them walk around crossing points that are dangerous with respect to vehicle traffic. But there are alternatives to avoiding dangerous locations. The crossing points can also be made less dangerous with the use of technology, such as that covered in the previous section. Six experts suggest that streets have video cameras that process images of objects and people in a street, and, if a child is detected, in-vehicle alarms are triggered in nearby vehicles. Five experts suggest that children carry emitting devices with signals picked up by a detector in the vehicle and that an alarm is triggered. This can either be done whenever a child is within $X$ meters from the vehicle, where $X$ can vary with vehicle speed (3 experts) or dangerous proximity can be determined by a GPS device when a child is already in the roadway (2 experts).

A different strategy than avoiding dangerous crossing points, or mitigating their danger, is to change the child’s destination. This can obviously not always be done, but rather than trying to find the safest way to the closest convenience store or bus stop, maybe there is another one slightly further away that can be reached in a safer way, and quicker than the nearby one when following safe routes.

There are many ITS solutions that can be used for guidance (leading or navigating) away from dangerous points. For navigation, we can distinguish between two groups of devices: those based on GPS and others, the latter are normally used to complement the first in order to improve their accuracy getting a seamless positioning.

“Tele-Atlas” is of special interest among the GPS-based systems as it has developed versions of maps specific for pedestrians, combining its traditional Multinet cartographic database with a series of special attributes such as detailed information about tunnels, footbridges and pedestrian paths to provide security and comfort to people walking.

4.13 Child or other pedestrian violating a red light
Eight experts suggest that vehicles be equipped with ISA, which slows vehicles down when they encounter jaywalking pedestrians. ISA can set a car speed to the characteristics of the specific pedestrian present. Seven experts want to have the vehicle come to a full stop through emergency braking, i.e., Full Auto Brake, when a pedestrian is detected in or near the predicted path of the vehicle. In other words, a total of fifteen experts state that the vehicle, i.e. a computer co-driver of the vehicle, should take automatic evasive action and another five recommend that the technology to be developed should “give an alert message to all approaching vehicles” when there is a jaywalking pedestrian in their path. This can be
compared to seven experts suggesting that the pedestrian be alerted (audible feedback) so that the pedestrian can take evasive action when a vehicle is approaching while they cross during the red phase. Hopefully such systems would not increase jaywalking. Other solutions aiming at affecting driver behavior is the Collision Avoidance System (CAS) which aims at foreseeing and avoiding a collision, including those with jaywalking pedestrians. A special case of ITS solutions would be those which act on autonomous vehicles, those ‘driven’ without a driver.

4.14 Child or other pedestrian NOT knowing a red-light-running car is approaching

Fourteen experts suggest that we reduce the frequency of red-light running vehicles by using camera enforcement. Ten experts suggest that we use Full Auto Brake and stop vehicles when drivers do not stop themselves for a red light, similar to Automatic Train Control Systems on mainline railroads. Eight experts suggest that we use red-light running detectors setting of an alarm (audible signal) on the street. Finally, one single expert suggests that we use red-light running detectors setting of a warning on a device carried by the [child] pedestrian.

There has been research and development of systems that can provide various types of information to pedestrians. Among the features of such systems are voice interfaces with input data by a voice recognition method and information output by a voice synthesis method. One of these systems can handle several languages such as Japanese, English and Spanish (Ozaki et al., 2011). Such a system can be used to warn pedestrians about red-light-running or speeding cars if it is linked to red-light cameras or a detector measuring vehicle speeds.

4.15 Child or other pedestrian route taking them through a dangerous neighborhood

In most communities, there is a higher risk of being injured in a traffic accident than from an assault. However, in some cities, the risk of becoming a victim of crime is greater than the risk of dying in a traffic accident. One example is New Orleans, Louisiana, USA (McLaughlin, 2012). In other words, avoiding dangerous neighborhoods may be a high priority to pedestrians of all ages in New Orleans and in many other cities around the world.

Microsoft was granted a patent in January 2012 for its “avoid ghetto” feature for GPS devices. This system has a focus on pedestrians avoiding an “unsafe neighborhood or being in an open area that is subject to harsh temperatures.” Eight experts think such a system is a good idea, stating that they support pedestrian route production (walking direction) systems so pedestrians can avoid areas that are undesirable. Seven experts suggest that child pedestrians carry GPS, such as a mobile phone with GPS, and that a parent is monitoring their location online, whereas three experts support the idea that child pedestrians be physically accompanied by a parent or other adult with a mobile phone who can call for help. Three experts suggest that streets have video cameras that are monitored by police and three experts suggest that streets have video cameras that automatically process images of people and events. A special case of ITS in this field would be those resources developed to automatically recognize the behavior of pedestrians to determine which situations are likely to lead to more serious incidents, such as accidents, assaults and other suspicious activities (Candamo et al., 2010).
4.16 Emergency vehicle traveling at high speed
If the strategy is to slow down all vehicles to a safe speed, can that be done to ambulances, fire trucks and police cars during emergencies as well, or can one rely on their audible and visible warning systems to keep pedestrians from getting in conflicts with them?

5 CONCLUSIONS AND DISCUSSION
Several ITS systems for improving pedestrian quality have been discussed. But it will be up to national, regional and local governments, through their ministries and agencies and public works departments, to promote, fund, and possibly mandate such systems. It is clear that we need to offer an acceptable level of convenience, efficiency, comfort, safety and security to pedestrians but it is less clear if society will prioritize resources towards this.

Besides what is presented above, experts also gave some other thoughts or ideas on how ITS can be used. They also commented on negative aspects of further introduction of ITS to children as pedestrians. Many of these comments dealt with ethical or cognitive aspects of children as road users. Proponents of alternatives to ITS often stated that it is not a question of using technology but instead better safety will be achieved through urban planning measures and education of drivers as well as children. These experts stated that children’s safety should not rely on technological devices, but that drivers should be fully responsible for their actions, to drive more slowly and attentively, to be on the watch constantly for more vulnerable road users, and to be ready to stop immediately if there is a chance that a person may cross their path. Technology removes the driver one step further from this vision of road safety, giving drivers the sense that technology allows them to drive even more distractedly than they do now. The more interesting question is therefore how do we create Intelligent Drivers (ID), not ITS.

The ethical question is also: Should we endow children with devices or should we, like good parents, accompany them and communicate with them directly? Can devices substitute parental or other caretakers’ communication and responsibility? When answering the two questions above you should also consider that children need practical knowledge instead of descriptive knowledge in order to stay safe (Johansson and Leden, 2009).

Children are not as experienced as adults and cannot anticipate potential risks as well. Therefore, the adaptation of ITS services to the needs of children has a high potential for improving children’s safety. Many experts have some difficulty imagining what devices can be used by young children and how much freedom of movement children can be allowed in practice. The dangers are manifold and children's mental capacity is not yet fully developed to function independently, in complex and potentially dangerous situations.

As can be seen from the experts’ responses summarized above there is not a straightforward reaction to the question asked in the heading of this paper, but there is a clear warning that maybe we should not rely too much on ITS-based services. However, we should not be afraid of embracing the ones that clearly have positive safety effects. ITS solutions developed for children might be needed to reach the target for EU set by the European Transport Safety Council, ETSC (2009), that the EU should see a 60% reduction in children fatalities in traffic between 2010 and 2020. For other age groups, the goal is a 40% overall reduction in fatalities. Such an improvement of the safety for children, should lead to increased mobility and a more sustainable way of living. Children would learn to act in such a way and live such lives that are necessary for obtaining a sustainable city environment. The
next challenge is to examine the needs and ITS services for child cyclists. For elderly cyclists this is already done (Leden, 2008).

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