APPLICATION OF INTELLIGENT TRANSPORTATION SYSTEMS TO ENHANCE VEHICLE SAFETY FOR ELDERLY AND LESS ABLE TRAVELLERS

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ABSTRACT

Elderly drivers have a high accident rate per kilometer driven, though not per person per year, and elderly pedestrians and transit users also have above average accident rates. The potential of Intelligent Transportation Systems (ITS) to enhance vehicle safety for elderly and less able travellers is examined. For car drivers, Advanced Vehicle Control and Safety Systems (AVCSS) and Advanced Transportation Information Systems (ATIS) should make driving easier, less stressful and safer. Transit users should be helped by better information before and during travel and by smart cards. Pedestrians with visual impairments can be helped by hand-held guidance equipment and by talking signposts; road-crossing facilities can be improved to benefit everybody.

INTRODUCTION

Intelligent Transportation Systems (ITS) is the term used to describe the application to road transportation of advanced technologies including computing, sensors, communications, and controls. These technologies have been in use for some time, but the rate of application has increased dramatically in the past few years. Real-time display of information in public transportation systems is becoming common, multimodal information terminals are starting to appear, major rental car companies have been offering in-vehicle navigation systems since mid-1996 and automobile manufacturers now offer these systems as options. These systems are intended to improve the safety, efficiency and capacity of the highway system.

Almost all developed countries have growing elderly populations and a large increase in the number of elderly and less able drivers. In Canada, the population of people aged 65 and over is expected to increase from 3.2 million in 1995 to 7.8 million in 2025; already, about 10 percent of the adult population of Canada have specific transport disabilities (Mitchell, 1997). In the U.S., the population aged 65+ is forecast to more than double between 1990 and 2030 (NHTSA, 1996).

The number of licensed elderly drivers has increased rapidly, and is likely to continue to do so. In the U.S. in 1994, 90 percent of men and 58 percent of women aged 70 years and over held driving licences. Even for people over 85 years of age, 75 percent of men and 26 percent of women held licences. As early as the year 2020, elderly and less able drivers and travellers will probably contribute more than 20 percent of the total market for ITS equipment. Their requirements should not be neglected in ITS developments, on commercial as well as safety grounds.

As people age, they become more fragile and therefore more vulnerable to accidents. Elderly people have higher than average accident rates as pedestrians, as transit users and, per kilometer, as drivers (NHTSA, 1996; TRB, 1988; Department of Transport, 1991). A given accident causes more damage to an elderly individual, and older people take longer to recover from injury (Evans, 1991). Injuries are more likely to be fatal for people over the age of 65. Many elderly people are more concerned about safety and security than are younger people.

The purpose of this paper is to examine the potential of two classes of ITS system, Advanced Vehicle Control and Safety Systems (AVCSS) and Advanced Traveller Information Systems (ATIS) to help elderly and less able drivers and travellers. The paper lists the safety and security concerns of elderly and less able people and reviews the potential of ITS to improve the safety of elderly and less able drivers, transit passengers and pedestrians.

The important role of ITS in trip planning for all modes is not covered in this paper.

WAYS IN WHICH ITS CAN IMPROVE SAFETY

The ways in which ITS can improve transport safety vary between the different modes. Their main contributions are towards primary safety - that is, preventing accidents from happening. In the case of car travellers, it may also be possible to improve secondary safety - that is, reducing injuries to people when an accident does happen.

Furthermore, widespread implementation of these systems, taking care to maximize their potential for improving accessibility of public transit, will encourage elderly drivers to use other means of transport when age-related sensory, cognitive or motor deficits preclude them from driving safely, even with ITS enhancements. Using ITS to reduce the mobility cost of the decision to stop driving will increase road safety for all.

Travel by Car

ATIS can provide information on traffic conditions, provide specialized weather forecasts and guide the driver to a selected destination. This information can warn drivers of congestion and severe weather, both conditions which elderly drivers try to avoid and that increase the risk of accidents. Navigation systems, which provide route guidance information, give drivers advance warning of junctions and lane changes. This reduces the pressure to initiate manoeuvres late, with consequent risk of conflict with other vehicles or sudden manoeuvres with the possibility of loss of control. This is discussed further in the section on ITS and car drivers.

AVCSS can provide information specifically to avoid collisions, improve visibility at night, assist with the longitudinal and lateral control of the vehicle and assist with speed control. Furthermore, occupant restraint systems will likely be able to adapt themselves to the occupant's size, weight, age and sitting position, to minimize injury in any particular collision.

Public Transport Users

Although the main value of ITS to public transport users will be through better information before and during a journey, and the use of smart cards to pay fares, all of which will reduce stress and increase security for travellers, these systems will also directly improve safety.

Many injuries to bus passengers result from falls when boarding or alighting from the vehicle, or in the vehicle during a journey. They mainly happen when elderly passengers must stand while the bus is in motion, or hurry to board, pay the fare and find a seat. On-board displays that name the next stop, and stop request buttons that can be reached by seated passengers, will allow passengers to remain seated until the bus has stopped. Elderly passengers are often concerned about the time it takes them to board and pay their fare. Using a smart card for fare payment reduces the things a passenger has to do while boarding. Non-contact smart cards do not need to be taken out before use - if a wallet or purse is placed on the card reader, the payment is made. Both of these technologies should reduce the numbers of falls while boarding and alighting from the vehicle. This is discussed in the section on ITS and public transport users.

Pedestrians

Apart from improvements to light-controlled crossings, discussed in the section on ITS and pedestrians, the main safety benefit of ITS to less able pedestrians is the help it can give to prevent from people walking into traffic areas and falling off railway platforms. For people whose vision is seriously impaired, who have a high accident rate as pedestrians, these areas pose very real dangers (Gallon et al., 1995).

ITS AND CAR DRIVERS

In most countries the risk of accident involvement per driver per year decreases steadily with increasing age. In British Columbia in 1994, only 2.2 percent of drivers over 65 were involved in collisions, compared with 4.4 percent of all drivers. However, because elderly drivers drive less as they age, their accident rate per kilometer increases after the age of about 60, and sharply after the age of about 70-75.

Older drivers have more accidents than average at junctions, particularly at unsignalized junctions on two-lane roads, and are more likely to be involved in right of way violations. They have fewer single-vehicle accidents, accidents at night, accidents involving speeding and drink/drive violations. Older drivers are more likely to be "at fault" for accidents than middle-aged drivers, but only after the age of 75 are they more likely to be at fault than teenage drivers. Older drivers recognize that they have problems with night vision, turns across traffic and merging into lanes of traffic, along with failing to respond to road signs and signals (Malfetti et al., 1987).

The effects of aging are well known, though the abilities of older drivers vary greatly between individuals (TRB, 1988). Older people's vision usually deteriorates, particularly at night. This reduces the ability of older people to read signs and to see objects such as pedestrians in poor light. Their sensitivity to visual motion decreases, increasing detection failures and making traffic gap judgements less accurate. Their reaction time increases, particularly in complex situations (Stamatiadis et al., 1990) or when information location is uncertain (Ranney et al., 1992). They become less able to divide attention between two or more tasks. This age-related decrease is characteristic of a switch from automatic, parallel processing to effortful, serial processing (McDowd et al., 1991). If ITS equipment is to help older drivers to continue driving safely, it must compensate for these effects.

Barkow et al. (1993) found that the primary concern of elderly and less able drivers was for greater safety. Of the ITS features wanted, the most favoured were driver's aids - cruise control, steering assistance, snooze alarm and a Mayday system to obtain medical or mechanical assistance. Second was information on roads, traffic and weather. Third were features that enhanced the ease and comfort of driving - an electronic memory to reset seats, steering and mirrors, and monitoring of vehicle condition (to minimize the risk of a breakdown or flat tire).

Drivers over 55 years of age report more problems than do those aged 35-44 with reading traffic signs, seeing clearly at night, turning their heads while reversing and when merging into high-speed traffic (Rothe, 1990). Drivers in Illinois over 65 years of age found that driving at night, in heavy traffic and at high speed on freeways had become more difficult (Benekohal et al., 1994a). Older drivers avoid bad weather and ice, night driving, rush-hour traffic and limited access highways (Rothe, 1990; Benekohal et al., 1994b; Laux et al., 1990). Older people drive less frequently, and a smaller percentage of their trips include unfamiliar neighborhoods or major thoroughfares. Table 1 shows how ITS equipment has the potential to compensate for the effects of age-related impairment in drivers.

Some ITS equipment has the potential to increase the mobility of elderly and less able drivers by making driving easier. Other systems have the potential to improve safety by increasing the distance from which obstructions can be seen in darkness, by warning of obstacles in blind spots, by warning of conflicting traffic, by monitoring the condition of the driver and generally by helping with the aspects of driving that elderly drivers find difficult. Systems such as emergency alert (Mayday) can increase the security of drivers by enabling them to summon help if it is required. These systems were designed for all drivers, but they have the potential to provide particular benefits for elderly and less able drivers. The European DRIVE II Project EDDIT evaluated ITS equipment being used by elderly drivers (Oxley et al., 1995). The reactions of users were very positive and only one system caused distraction from the task of driving.

TABLE 1.
Car Driver Impairments, Safety Problems and ITS Equipment

Impairment	Problems	ITS equipment
Increased reaction time. Difficulty dividing attention between tasks	Difficulty driving in unfamiliar or congested areas	Navigation/ route guidance Traffic information, VMS
Deteriorating vision, particularly at night	Difficulty seeing pedestrians and other objects at night, reading signs	Night vision enhancement In-vehicle signs
Difficulty judging speed and distance	Failure to perceive conflicting vehicles. Accidents at junctions	Collision warning. Automated lane changing
Difficulty perceiving and analyzing situations	Failure to comply with yield signs, traffic signals and rail crossings. Slow to appreciate hazards	In-vehicle signs and warnings. Intelligent cruise control
Difficulty turning head, reduced peripheral vision	Failure to notice obstacles while manoeuvring. Merging and lane changes	Blind spot/obstacle detection. Automated lane changing and merging
More prone to fatigue	Get tired on long journeys	Intelligent cruise control Automated lane following
Some impairments vary in severity from day to day. Tiredness	Concern over fitness to drive	Driver condition monitoring

(Source: Mitchell and Suen, 1997)

Specific ITS Systems for Car Drivers

Congestion and Weather Warnings Traffic and weather information can be broadcast to vehicles for display as text messages or information on maps. These systems are already in service and enable drivers to take informed decisions not to drive in conditions they would find difficult or dangerous.

Route Guidance Navigation systems are in service that guide a driver to a selected destination, giving advance warning of junctions and necessary manoeuvres such as lane changes. During the EDDIT Project (Oxley et al., 1995), one driver described a navigation system as "a co-driver who knows the way". Vocal instructions along with turn-by-turn visual guidance reduce memory load and visual interference with the primary driving task, and offer the most dramatic improvement and error reduction of older drivers' performance. These systems certainly reduce driving stress and, by avoiding the need to make lane changes or turns shortly before a junction, should reduce conflicts and accidents.

Obstacle Detection Systems already exist to detect obstacles behind and beside a vehicle during low-speed manoeuvres such as parking. Prototypes of similar systems can warn of vehicles in blind spots or converging during merges and lane changes. These can warn the driver and prevent conflicts and collisions.

Night Vision Enhancement Several systems are being developed to improve vision for drivers at night. Some illuminate the roadway to the front of the vehicle with radiation outside the visible spectrum (i.e., ultra-violet or infra-red radiation) and use fluorescence to enhance visibility directly, or process the radiation reflected back to a sensor array to generate images of objects that would not be visible to the driver's naked eye. Other systems generate images from thermal energy emitters (particularly living beings) in the environment. The detection range for pedestrians, obstructions and curves in the road can be increased considerably. Some of these systems are based on night-vision technology already in military service. Some allow the driver to see objects directly through the windshield, and others project a processed image onto a head-up display (HUD) inside the windshield, through which the outside world can still be seen (conformal imaging). However, older drivers may be particularly vulnerable to cognitive capture, a phenomenon whereby a HUD preempts visual attention and prevents detection of critical outside objects (Tufano, 1997).

Intelligent Cruise Control and Lane Keeping Assistance Intelligent cruise control (ICC) is a system for controlling a vehicle's speed and distance behind a preceding vehicle. Versions that will soon be commercially available control the vehicle's speed to a pre-set value while maintaining a safe headway between vehicles. Future variants will tell the driver if the pre-set speed exceeds the local limit, and ask if the driver wishes to comply. They may take control of accelerator and brake to prevent rear-end collisions, if a dangerous situation is detected. Further into the future, ICC systems may automatically limit the vehicle speed to the local limit and reduce speed when approaching a bend, a yield sign or red traffic signal. Local speed limits could be varied by time of day or weather condition.

Prototype systems exist to provide assistance with lane keeping. These apply small forces to the steering to 'nudge' the vehicle into the centre of the lane it is following. They only work when the driver is holding the steering wheel, and the forces can be over-ridden by the driver if necessary.

ICC and lane-keeping assistance are particularly likely to benefit older drivers, who may neglect the low-level sub-tasks involved in course maintenance while performing higher-level subtasks such as visual search or route planning. ICC and steering assistance will preserve course maintenance when necessary to compensate for difficulties in dividing attention during high cognitive task loads.

Collision Warning and Avoidance Intelligent cruise control can provide protection against rear-end collisions. Obstacle detection systems to warn of conflicts while merging or changing lanes, which elderly drivers find difficult, are likely to be available within a few years. Elderly drivers are more likely than average to be involved in collisions when turning across traffic or at uncontrolled junctions. Trials with a gap-measuring system to help drivers turn across traffic have given promising results (Oxley et al., 1995), but any such system is many years from commercial implementation. Systems to warn of dangerous situations in the more complex case of general manoeuvres at uncontrolled junctions are likely to be many years in the future.

Furthermore, the effectiveness of a collision warning depends critically on whether the driver is processing available information in serial or in parallel (Najm et al., 1995). The implication here is that if the technical difficulties can eventually be solved, older drivers may be better served by an automatic control intervention in the event of an imminent collision, because a collision warning may interfere with the driver's primary task of vehicle control. However, such a system may not be well accepted by drivers, although older drivers have indicated a wish for steering assistance.

Driver Condition Monitoring Development is well advanced for systems that monitor the condition of the driver and warn of impairment by fatigue, alcohol or a variable disability. These are likely to appear first on commercial vehicles, but could well be applied to cars in due course.

In-vehicle Signing Systems will be developed eventually that display road signs inside the vehicle and warn drivers of hazards or unusual conditions ahead. These will need extensive monitoring of road conditions and many transmitters to relay information from the road to the car. The investment in this infrastructure is likely to delay the implementation of these systems. Alternatively, details of road signs could be stored with the digital map for the navigation system, for display at the appropriate time. In this case the problem is keeping the data base updated. An autonomous system could not display temporary signs such as "Diversion", "Road works" or "Flood".

Smart Occupant Protection Systems Occupant protection systems such as seat belts and air bags are designed to protect a large male occupant in the most severe survivable accident. Because of this, they may apply greater forces than are necessary to people who are small, light and sit near to the steering wheel. In particular, they may cause injuries to a fragile older person in a relatively minor accident that could have produced no injuries if the restraint systems had been tailored to the attributes of the specific occupant. It is possible to imagine an occupant protection system that uses sensors to measure occupant weight and sitting position, and a smart card to define occupant age, gender and other characteristics (as well as automatically positioning seat, mirrors and steering wheel to suit the individual). In a given crash, the system would then adjust the loads applied to the occupant to be the lowest necessary to restrain them. Restraint systems are already in service that pre-tension and lock seat belts to minimize the movement of an occupant during a crash. Smart restraint systems would extend development further.

ITS AND PUBLIC TRANSPORT USERS

For older people no longer able to drive safely even with the benefits of ITS, the increase in safety, convenience and ease of use that ITS affords elderly and less able users of public transit will encourage the decision to stop driving. Furthermore, travel by public transport vehicles is much safer than travel by car or on foot (Department of Transport, 1991). Problems with using buses currently include walking to the stop, waiting at the stop, climbing the steps at the entrance to the bus, pressure of time when boarding, paying the fare and finding a seat. There are also information problems: not recognizing the bus service required, difficulty recognizing the destination stop and not knowing the fare required. Overall, the need to move quickly while using public transport vehicles reduces in-vehicle safety, causing stress for elderly and less able passengers, and increasing the danger of accidental falls. In Britain, in 1976, 14 percent of casualties to bus passengers occurred in collisions, 29 percent during emergency action and 57 percent as a result of falls and other incidents during normal operations. Of the casualties not involving collisions, 43 percent were aged over 60 years. More recent statistics show that 50 percent of those passengers killed or seriously injured on buses are people aged over 60, despite only 27 percent of all passengers being of this age (Department of Transport, 1991).

ITS technologies are being used to improve the efficiency, productivity, reliability and in-vehicle safety of bus services. These include Advanced Traffic Management Systems (ATMS), Automatic Vehicle Location (AVL), Automatic Vehicle Identification (AVI) and communication between buses and a control centre (Schweiger et al., 1994). ITS technologies can help all passengers, by providing information or in other ways, and in many cases will be particularly helpful for elderly and less able passengers (see Table 2).

TABLE 2.
Bus Passenger Impairments, Problems and ITS Equipment

Impairment	Problems	ITS equipment
Cannot stand for long, sensitive to cold	Unable to stand while waiting at bus stops	Display of waiting time at home, at bus stop on hand-held unit
Poor vision	Cannot read service number	Service display at bus stop Audio announcement by bus
Poor vision	Cannot see community bus in time to hail it	Hand-held device for communic-ation between bus and passenger

Lack of manual dexterity, cannot do things quickly	Paying cash fare while boarding. Risk of falling while hurrying	Smart payment card
Poor vision, unfamiliar with area	Cannot identify destination stop	Display name of next stop in bus
Impaired hearing	Hearing announcements	Induction loop in bus
No vision	Finding bus stop, knowing which stop for which bus route	Talking signs, stops that announce route name or number

Smart payment cards can reduce the number of actions a passenger has to complete in a limited time while boarding a bus. Displaying the name of the next stop inside the bus gives passengers confidence and provides extra time to alight. In the medium future it should be possible to receive and display real-time transit information on a hand-held unit. This should reduce waiting times at bus stops and increase the perceived safety and security of passengers by providing information on the operation of the service.

ITS equipment can be used to improve security. With AVL and a communication system the driver can summon assistance quickly in response to any incident. Safety can be improved by systems to detect passengers close to the bus where the driver cannot see them, as is being tested on school buses in the U.S. There may be scope for people detectors to warn the driver if a passenger is trapped in the doors.

ITS AND PEDESTRIANS

Older persons have the highest per capita pedestrian fatality rate of any age group (NHTSA, 1996). In Britain in 1989, nearly half of all pedestrians killed on the roads were over 60, although people over 60 formed only 20 percent of the total population (Department of Transport, 1991); in Canada in 1992, 32 percent of all pedestrians killed in traffic accidents were aged 65 or more, while 12 percent of the population were over 65. Various surveys show that about 30-35 percent of elderly and less able pedestrians found traffic or crossing roads a significant difficulty (Hitchcock et al., 1984). In the U.S., two-thirds of older people in two U.S. metropolitan areas feared for safety while walking (Knoblauch et al., 1995). They were afraid of being attacked, being hit by a car or falling.

In Britain, a survey found that virtually all visually impaired independent travellers reported at least one accident, and over half had sustained injuries (Gallon et al., 1995). Visually impaired people have a higher frequency of walking accidents than sighted people and are more likely to be injured. Visually impaired people also have more accidents than sighted people when crossing roads, and over a third of respondents had experienced accidents involving steps. Of the respondents who travelled by rail, 35 percent had experienced at least one accident. Twenty-three percent had had an accident during boarding or alighting and 5 percent had fallen off a station platform.

Many ambulant less able people as well as people in wheelchairs are seriously limited in the distance they can walk or travel in a wheelchair. Access can be prevented by distance, slopes and road crossings as well as by the normally recognized curbs, steps and poor surfaces. Pedestrians in general are afraid of being attacked, being hit by a car or falling. ITS has considerable potential to help less able pedestrians, particularly with road crossings and with orientation for visually impaired people, thus minimizing pedestrian-vehicle conflicts (see Table 3).

TABLE 3.
Pedestrian Safety Problems and ITS Equipment

Impairment	Problems	ITS equipment
Everybody	Crossing roads	Crossing signals that extend crossing time for slow pedestrians and/or warn drivers of pedestrians on crosswalks
Visual	Crossing roads	Audible signals at crosswalks Hand-held navigation system
Everybody	Falling on uneven pavements	Pavement condition monitoring Hand-held fall detector/Mayday system
Visual	Walking into traffic	Hand-held navigation system
Visual	Accidents: walking into plate glass, falling off platforms, steps	Hand-held navigation system

In Canada, 32 percent of fatal accidents to pedestrians involve people aged 65 or more; in Britain, nearly half of all pedestrians killed on the roads are over 60. The timing of road crossings is usually based on a pedestrian walking faster than many elderly or ambulant less able people can walk. Fear of being caught by traffic while crossing roads limits mobility and represents a clear lack of safety. In Britain, people detectors are being used to extend the length of the pedestrian phase when a slow-moving pedestrian is on the crossing. The same equipment omits the pedestrian phase if there is no pedestrian waiting to cross, even if the pedestrian button has been pushed. This avoids delaying traffic unnecessarily and increases respect for light controlled crossings. Pedestrian crossings can also be regulated by video cameras capable of distinguishing pedestrians from animals and cyclists and providing sufficient crossing time for individual pedestrians. Similar equipment can flash lights in the road surface to highlight the crossing when it is in use (Urban Transportation Monitor, 1996).

The greatest problem for visually impaired pedestrians is location and wayfinding. ITS should soon offer hand-held navigation systems using differential GPS. These could provide warnings of hazards plus instructions for the route to a selected destination (Gowda et al., 1995). Walking into traffick areas is another problem which could be helped by warnings from local beacons. An increasing number of elderly people suffer from dementias, such as Alzheimer's disease, causing them to become lost. If they are equipped with a portable transmitter they can be tracked and found, using equipment similar to that used to track stolen cars or trucks.

CONCLUSIONS

Elderly drivers have a high accident rate per kilometer driven, though not per person per year, and elderly pedestrians and users of public transport also have above-average accident rates. ITS has the potential to improve the safety and security of elderly and less able travellers and drivers, as well as to increase their mobility. For car drivers, various ATIS and AVCSS systems provide services or perform tasks that should make driving easier, less stressful and safer. Smart restraint systems could improve occupant protection.

Public transport users will be helped by smart cards and better information while travelling. These will reduce the need for passengers to hurry or to stand while the bus is moving, which reduces the risk of accidental falls. Their security can be improved by using real-time transit information to reduce waiting time at bus stops, particularly in bad weather, and by automatic vehicle location and communications to call for assistance when incidents occur.

Pedestrians can be helped by better road-crossing facilities, making use of existing people detectors. Pedestrians with visual impairments can be helped by hand-held location and guidance equipment, by talking signposts and by information displays that can talk when triggered.

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