Elderly and Disabled Travelers: Intelligent Transport Systems Designed for the 3rd Millennium

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The TELeomatic Standards and Coordination of Advanced Transport Telematics systems in relation to elderly and disabled travelers (TELSAN) project in the Transport Sector of the Telematics Applications Programme of the European Union has developed a _Handbook of Design Guidelines_ (Nicolle & Burnett, 1999) to support designers of Intelligent Transport Systems (ITS) to include the needs of people who are elderly or disabled. This article describes the methods of the _Handbook_’s development, including an overview of the methodology for capturing the requirements of elderly and disabled travelers, a survey of existing guidelines, and empirical results and lessons learned from simulator testing. The authors conclude that although general guidelines are necessary, the most specific and useful guidelines emerge only when carefully chosen research questions can be investigated. The development of such guidelines should help us come closer to achieving usability of ITS not only for elderly and disabled people, but for everybody as we enter the 3rd millennium.

The main objective of Intelligent Transport Systems (ITS), also known as Advanced Transport Telematics (ATT), is to increase safety and efficiency in transport, whether it be on the road, rail, sea, or in the air. However, some persons may experience difficulties in both their performance of the traveling task and the use of new technology. This may be due to a decline in motor performance, reaction times, vision, hearing, or information processing ability, caused by the normal process of aging, disease, or an accident. Some ITS may provide information to the traveler, some may provide warnings in hazardous conditions, and some may assist a driver in controlling the vehicle. Emergency call systems and route guidance and navigation systems may increase safety and restore confidence for elderly or disabled drivers, provided that the controls and displays are designed with their special requirements in mind. If this is the case, elderly and disabled people need not be “handicapped” by their impairments. This can best be illustrated by referring to definitions from the World Health Organisation (1980/1993):

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• **Impairment**: Any loss or abnormality of psychological, physiological or anatomical structure or function, that is, parts or systems of the body that do not work (p. 47).
• **Disability**: Any restriction or lack (resulting from an impairment) of ability to perform an activity in the manner or within the range considered normal for a human being, for example, unable to see clearly, to walk unaided, or to hear (p. 143).
• **Handicap**: A disadvantage for a given individual, resulting from an impairment or a disability, which limits or prevents the fulfilment of a role that is normal (depending on age, sex, and social cultural factors) for that person (p. 183).

It could therefore follow that a handicap is the result of a mismatch between the user's needs and abilities and the ITS environment. It would then be possible to have an impairment and a disability but no handicap: A person who uses a wheelchair may not be handicapped if the environment has been designed to take account of wheelchair users, for example, through the use of “curb-cuts” to allow easy access from sidewalk to street.

With regard to new technology, elderly and disabled travelers may be the most likely to benefit, but in reality may have difficulties in taking advantage of the system due to the very same limitations. Thus, as vehicles get faster, our roads busier, and the able-bodied traveler seemingly more efficient, elderly or disabled travelers may find themselves lagging further behind and with potentially increased safety risks—unless ITS are designed with their functional impairments and requirements in mind. So, just as everybody loves a “curb-cut,” like the mother with a stroller or the child on a skateboard, it is not just the disabled or elderly traveler who will benefit from better guidelines for ITS.

**BACKGROUND RESEARCH ON ELDERLY AND DISABLED TRAVELERS**

The Telematic Applications for the Integration of Drivers with Special Needs (TELAID) project was part of the European DRIVE II Programme and ran from 1992 to 1995. TELAID systematically investigated the requirements of people with disabilities who need the use of car adaptations while driving (Naniopoulos & Bekiaris, 1995). The DRIVE II Elderly and Disabled Drivers Information Telematics (EDDIT) project concentrated on the elderly driver, using conventional controls but with a normal, gradual deterioration in perceptual and performance abilities. This article is based on the research from TELAID, which joined with EDDIT to form the current Telematic Standards and Coordination of ATT systems in relation to elderly and disabled travelers (TELSCAN) project in 1996. Part of the Transport Sector of the 4th Framework Telematics Applications Programme of the European Union, TELSCAN broadened the research to include the needs of elderly and disabled drivers and travelers in the development and application of ITS, whether it be as drivers using their own cars or as travelers in various modes of public transport (Naniopoulos & Bekiaris, 1997). Thus the earlier research for this article centered on the driver and then was extended to the needs of travelers using all forms of transport.

Although the use of public transport is promoted as more environmentally friendly, a private car is still the most common form of travel, providing a level of freedom and independent mobility for people with impairments that public transportation does not offer. Access to private cars can bring a new dimension to the lives of disabled and elderly people who may otherwise have lost, or are starting to lose, their mobility.
In Europe, figures for the number of elderly and disabled drivers vary widely depending on the country’s definition of disability. Over the next 20 to 30 years, it is fair to say that elderly people over 65 years will represent more than 20% of the total European population, and many of these people will have some form of disability. However, elderly people do not form a homogeneous group, and many elderly people have active and healthy lives, even though the natural process of aging has reduced certain abilities. Chronological age is not a true indicator of deterred performance and increased disabilities, and variability also increases with age (see e.g., Hakamies-Blomqvist, 1996; Waller, 1991). Therefore, where this article uses the terms elderly and disabled, we do not imply that elderly people are disabled. It is also important to stress that any available figures cannot necessarily indicate the number of people who would benefit from better design of ITS. To illustrate, if elderly drivers do not want a collision avoidance system to take control of their driving, then a well-designed interface will not convince them to buy it. It is, therefore, very important to investigate the likelihood of people actually using or wanting to use a system. This kind of information is not easily available and requires further study, including intensive cost–benefit analyses.

People with disabilities do not want vehicles designed specifically for them, which would emphasize their disabilities. Instead most would prefer existing systems that can be adapted to their requirements—a “design for all” or universal design that does not exclude them from using the system. Everyone has the right to enjoy using a system that suits his or her needs and aspirations. Designing for the least able also usually ensures that the device is easier and more convenient for everyone to use (e.g., Waller, 1991).

Although in principle many product designers and developers wish to consider the needs of elderly and disabled people, they may find it difficult to know where to begin, which groups to include, how to include them, and how to ensure that all the users’ main problems and concerns are covered. TELSCAN has developed a Handbook of Design Guidelines (Nicolle & Burnett, 1999), promoting the “design-for-all” concept, which can assist in this process.

**THE TELSCAN GUIDELINES HANDBOOK—A WORKING DRAFT**

TELSCAN’s *Handbook* (Nicolle & Burnett, 1999) proposes guidelines for designing systems so that they are easier and safer to use by elderly and disabled drivers and travelers. It is a living, working document on the World Wide Web, and more specific guidelines are being added as TELSCAN conducts collaborative testing with other projects as well as literature and project searches for further guidelines.

The *Handbook* (Nicolle & Burnett, 1999) emphasizes that driving is just one aspect of the total traveling chain, and in order for an elderly person or a person with a disability to travel, each link in that chain must meet the user’s requirements. For example, a multimodal trip planning system ought to contain relevant information for the traveler with a disability to park his or her car at the train station, know ahead of time if there are any delays, and if the destination station has any stairs or long distances to cover. Currently the *Handbook* consists of the following sections, each level becoming more relevant to specific systems:

- Usability principles applicable to all ITS.
- General guidelines for all ITS and their facilitating technologies (e.g., controls, displays, smart cards, the Internet, etc.).
- Guidelines for varying contexts of use (e.g., kiosks for the traveler or systems for drivers, whether inside or outside the car).
- Guidelines for specific systems and system functions.

METHODOLOGY TOWARD DEVELOPMENT OF DESIGN GUIDELINES FOR ITS

The guidelines have evolved through a number of activities, starting during TELAID and continuing in the TELSCAN project:

- Survey of existing guidelines that may be relevant to vehicles and ITS, including those developed for computer accessibility by people with disabilities.
- Identification of requirements of elderly travelers and travelers with disabilities.
- Identification of design issues that then need to be considered in the design of ITS.
- Simulator tests and field trials, either as the project’s own empirical testing or in cooperation with other transport telematics projects.

Survey of Guidelines

Many existing guidelines were developed with a view to be used for traditional computer applications in offices and may not readily apply to the complexity of the driving task or to a changing environment while driving (e.g., Nordic Cooperation on Disability, 1993/1998). Furthermore, various guidelines may either be conflicting or may be too general to provide the advice needed by designers. To illustrate, recommended minimum text sizes for visual displays may range from 0.3° to 0.6° visual angle, corresponding to a character size of 3 to 6 mm viewed from 60 cm (Suen, Mitchell, & Henderson, 1998). A more general guideline for in-vehicle displays suggests that the size of the characters must be large enough and the contrast high enough so that the driver does not need to bend toward the display to read the information (Graham & Mitchell, 1997; Nicolle & Burnett, 1999). This guideline, even though emerging from in-vehicle testing, leaves interpretation to the designers themselves. Many other available guidelines, drawn from sectors such as telecommunications or from good human factors in general, have simply been based on expert opinion and intuition, and not on experimental evidence. Therefore, reliable data is often missing that could provide more specific design advice.

Some guidelines for the design of ITS exist already (Campbell, Carney, & Kantowitz, 1998; Green, Levison, Paelke, & Serafin, 1995; Ross et al., 1996) and others are under development, for example, within transport telematics research projects like TELSCAN. Although these guidelines may consider the general needs of older drivers, they do not always address the needs of people with disabilities, often due to the difficulty of making specific recommendations for such diverse user requirements.

The DRIVE II Harmonization of ATT Roadside and Driver Information in Europe (HARDIE) project developed guidelines for the presentation of information in navigation and route guidance systems, travel and traffic information systems, collision avoidance, Autonomous Intelligent Cruise Control, and Variable Message Signs (Ross et al., 1996). Although the needs of elderly people and people with disabilities were considered in a general sense, these user groups were not specifically included in the testing. In contrast, Green et al. (1995) conducted a road-based study that aimed to establish the optimum timing of voice-based route guidance messages and
included driver age as an independent variable. It was found that older drivers required guidance messages to be presented significantly further back from a decision point, as compared with younger drivers. These studies are being used as a basis for some of TELSCAN’s recommendations, but more similar work is needed in this area.

Identification of User Requirements

The TELAID project identified the requirements of drivers with different types of impairments. The study involved interviews with 56 experts and some 50 interviews and observations of drivers with special needs across seven European countries (covering visual impairments, reading, hearing, speech, lower limb, upper limb, upper and lower limb, upper body, sudden loss of control, and cognitive impairments).

A definition of the driving task was used as a series of prompts during the interview process. This driving task definition covered not just safely controlling the vehicle, but also actions like ingress and egress, which could determine whether the person was able to drive or not. This data collection was then extended during the TELSCAN project to include the requirements of elderly and disabled travelers using different modes of transport, including private cars (integrating the results of TELAID and EDDIT), buses or trams, metros or trains, ships, and airplanes.

The specification of users’ requirements (Nicolle, Ross, & Richardson, 1993; Nicolle, Veenbaas, & Ross, 1997) suggested many design issues that need to be investigated further, either through empirical testing, discussions with experts, or comparative studies of existing guidelines.

Identification of Design Issues

The users’ requirements stressed that a driver must be able to choose the most appropriate input or output mode to meet any special needs. The visual channel, for example, must not become overloaded for people with hearing impairments. The tendency to use synthetic voice and other acoustic output might lead to some people becoming drivers with special needs if they are not able to hear a message or warning from the system.

Design guidelines for in-vehicle information systems state that route information should be given sufficiently in advance of the maneuver for it to be accomplished safely (e.g., Southall & Robertson, 1994). However, some users, particularly a disabled or elderly person, may require earlier messages to compensate for slower reaction times (Green et al., 1995).

Response times need to be investigated for various systems and with all possible users. For example, a value of 4 sec for time-to-collision is recommended for collision avoidance systems (Nilsson, Alm, & Janssen, 1992). An older or disabled driver might require earlier warning or information presentation. Older drivers, whose speed of perceptual and cognitive processing slows down, would also benefit if the display time of messages on the screen could be increased or if alert messages could remain on the screen until they are dismissed by the user.

An area that needs to be investigated is the glance time necessary to obtain information from an in-vehicle display. Guidelines exist for the number and duration of glances that an able-bodied driver needs to obtain a specific chunk of information. Zwalen, Adams, and Debald (1988) indicated that visual information on displays should be designed so that not more than three consecutive glances of average duration 1 sec are needed to obtain the information and that glances in excess of 2 sec are unacceptable. Older people are likely to take a longer time to deal with visual information and to perform a task (Hakamies-Blomqvist, 1996). Furthermore,
the more complex the information presented on the screen, the greater the number of errors made, especially by older drivers (Graham & Mitchell, 1997). To help alleviate the problems of excessive glance duration and complex visual displays, Graham and Mitchell (1997) suggested a break between screens in a message pair to enable drivers to reorient themselves to the road ahead. This is good human factors but even more crucial for the older or disabled driver.

Above all, the users' requirements identified that the control aspects of the driving task can be crucial for people with disabilities, sometimes stopping them from even setting out on a journey. Drivers with severe lower limb disorders have to rely on their upper limbs to drive a car. Both steering and speed-keeping require continuous control of the steering wheel and the accelerator, causing static and sometimes uncomfortable postures that have to be maintained over long periods. A driver who must use hand controls for the primary (steering, braking) and secondary (lights, directional signals) driving tasks may find that additional control tasks either prove difficult or could have serious safety implications.

The user requirements surveys (Nicolle, Ross, & Richardson, 1993; Nicolle, Veenbaas, & Ross, 1997) identified long-distance driving as a particular problem for many drivers with disabilities. It was decided to investigate this issue further: first, how the driving performance of people with lower limb impairments compared with that of able-bodied drivers, and second, what effect telematics might have on workload and performance for the driver with disabilities.

Investigating Workload and Performance Without Telematics

Hand control systems for drivers with lower limb impairments can be implemented in different ways. Figure 1 illustrates three types of controls: a ring accelerator, a segment accelerator, and a manually operated brake (Veenbaas & Hekstra, 1993). Only one of these hand-controlled accelerators would be present at any one time. With a ring accelerator, the acceleration pedal is replaced by an acceleration ring of smaller radius, mounted on top of the steering wheel and operated by the thumbs or palms of the hands. This enables the driver to steer with both hands and operate switches on either side of the steering column. With a segment accelerator, the acceleration pedal is mechanically connected to a curved lever to the right of the steering wheel. The brake pedal is connected to an additional lever to the right of the segment accelerator.

Alternatively, Figure 2a shows a single combined lever for accelerator and brake mounted on the floor between the front seats. This single lever could instead be placed to the side of the steering wheel. Figure 2b shows another system consisting of two separate levers for accelerator and brake placed on the right side of the steering wheel column (Peters, 1996).

Two important aspects of hand control systems are positions of the control(s) and if there are combined or separate controls for brake and accelerator. Physical discomfort and fatigue are common problems (Peters & Nilsson, 1993; Verwey, 1995). Because of a lower limb impairment, drivers using particular car adaptations (e.g., a hand-controlled segment accelerator) find it difficult to accelerate or brake at the same time as using another control, and ring accelerators are preferred over segment accelerators. This applies to drivers with disabilities driving with or without telematic systems because of the discomfort associated with the segment accelerator (Verwey, 1995).

Peters and Nilsson (1993) conducted a driving simulator study in order to investigate the driving performance of people with lower limb impairments compared with that of able-bodied drivers. The study was conducted with drivers with quadriplegia (paralyzed lower limbs and trunk and impaired mobility and strength in upper limbs), using the two types of hand controls
shown in Figure 2. The moving base driving simulator at the Swedish Road and Transport Research Institute (VTI) was used for the testing (see Figure 3).

Twenty-six drivers with quadriplegia were compared with a group of able-bodied drivers, matched in age, gender, and experience. All participants drove an 80-km-long route on a rural road with a signed speed limit of 90 km per hr. The drivers with quadriplegia drove with the same kind of hand controls as they had in their own cars. There were no significant (5%) differences in speed control between the driver groups. However, using NASA Raw Task Index
(NASA-RTLX) to measure their subjective workload (Byers, Bittner, & Hill, 1989), the drivers with quadriplegia experienced a heavier time pressure compared to the able-bodied control group. Drivers with quadriplegia, and even more so those using the single lever hand control, also thought it was physically more tiring to brake and accelerate compared to the able-bodied participants. As a measure of the drivers’ lateral control, the mean variation in lateral position was calculated over all straight sections of the route for each participant. There was no significant difference between the drivers with quadriplegia and the control group. However, drivers using the dual lever system mounted on the steering wheel column had greater variation in lateral position. This could have been caused by interference between steering and speed control. It was also found that drivers with quadriplegia driving with hand controls had a 10% longer brake reaction time (group average 0.90 sec) compared to able-bodied drivers using a foot brake.

In summary, it was found that drivers with quadriplegia using hand controls largely compensate for their disability, but they do it at a cost of physical tiredness and high workload. The longer reaction time also indicates that the design of the hand controls was not optimal and did not fully compensate for their disabilities.

Could in-car ITS help to alleviate these driving control fatigue problems?

Adaptive cruise controller (ACC)—a step in the right direction? Cruise controls (CCs), which keep a constant speed set by the driver, have been available as options in many cars for 15 to 20 years. The CC is often considered to contribute to comfort for the average driver, but it is also a crucial support system for many drivers with lower limb impairments, allowing them
to decrease load on the upper limbs. However, CC is only useful on highways with no or low traffic density.

The ACC is an improved CC that can adapt speed to preceding slower vehicles without driver intervention. This is achieved by linking the cruise controller with a sensor in the front of the vehicle that can detect forward moving obstacles. Speed is then adapted to keep safe distance to a leading vehicle. This extended functionality of the ACC could be of great help even on short journeys for drivers with lower limb disabilities.

Driving with ACC can influence driving behavior in many ways both positive and negative. In a driving simulator study, Nilsson and Nåbo (1996) found that ACCs improved driving performance during car-following situations. Speed and headway variabilities were reduced and the shortest headways were decreased. However, another driving simulator study (Nilsson, 1996) revealed some negative effects in critical traffic situations. ACC drivers had more collisions than unsupported drivers when approaching a stationary queue. This result was explained by too high expectations on the ACC system. There is a risk that the driver might expect the ACC to function also as a Collision Avoidance System. Thus, it is very important to make this distinction clear to the user and this should be reflected in the interface design of the ACC. Feedback must be designed so that the driver is able to hear, see, or feel the information, whatever disabilities he or she may have.

The issues just mentioned formed important considerations in the design of the testing conducted in the TELAID project. It was anticipated that this testing could then be used to formulate some specific design guidelines to help bring the system closer toward a "design for all."

Driving Simulator Test—Introducing ITS

A driving simulator study was performed to evaluate an ACC system with drivers with lower limb disabilities, or paraplegia (Peters, 1996). The purpose of this experiment was to investigate how ACC driving contributes to improving the driving conditions for drivers with lower limb disabilities. Another consideration was to investigate whether ACC had a different influence depending on the type of hand control system the driver used for accelerating and braking.

Twenty experienced drivers with lower limb disabilities participated in this experiment. All participants had full strength and mobility in their upper limbs. The participants were divided into two groups depending on the type of hand control they used: single or dual lever system. All participants drove with the same type of hand controls they had in their own cars. The types of hand controls used were the same as in Peters and Nilsson (1993) (Figure 2).

The driving simulator at VTI was equipped with an ACC. The ACC controlled both throttle and brakes and could adapt speed in order to keep a safe distance from the vehicle in front. The driver selected a target speed that was maintained if there were no slower leading vehicles. Selected speed was indicated by light emitting diodes (LEDs) around the speedometer. When a lead vehicle was detected by the ACC, an amber car symbol would illuminate on the dashboard. The ACC control switches were placed on the direction indicator stalk on the left side of the steering wheel. All 20 participants drove both with and without ACC.

The driving task, which included both free-flow driving and car following, was performed on a 2-lane road, along a 100 km test route with random oncoming traffic. Speed, lateral position, and time headway were recorded and analyzed for all test rides. Subjective workload was assessed with the NASA-RTLX rating scale (Byers, Bittner, & Hill, 1989). Finally, question-
naires were used to collect the participant's opinion concerning speed and distance control and ACC usability.

**Key results.** A number of interesting results were found from this simulator test:

- ACC reduced workload and decreased physical discomfort.
- ACC improved speed and distance control as experienced by the drivers.
- ACC speed feedback was considered to be well designed.
- ACC control switches were not optimal with respect to the use of hand controls.
- ACC driving produced a shorter mean time headway compared to manual driving.

In this article we describe and discuss the time headway, feedback, and control findings that were used in the development of specific TELSCAN design guidelines for the design of ACC to support elderly and disabled drivers.

**Mean time headways.** The car-following situations were analyzed with respect to mean headway, variation in headway, and shortest headway. Headway was calculated as the time it would take to drive the current distance to a leading vehicle with the current speed. Fourteen car-following situations were included in the analysis.

The mean time headway was longer for the unsupported condition—driving without ACC—compared to driving with ACC (Table 1). The longest mean headway was found when the dual lever users drove without ACC. A two-way analysis of variance revealed a main effect of ACC, $F(1, 36) = 8.82, p = .0053$, but no effect of type of hand controls, and there were no significant interactions.

The ACC system tested was using a shorter mean time headway than preferred by people with lower limb disabilities. This was a first step toward a more specific guideline for ACC systems that are designed for all.

### DESIGN GUIDELINES FOR ACC SYSTEMS

As ACC systems are not yet available on the market and only limited testing has been performed so far, there has been little guidance on how the ACC should be designed (e.g., International Standards Organization Technical Committee 204 Transport Information and Control Systems, Working Group 14 Vehicle/Roadway Warning and Control; Ross et al., 1996) and virtually nothing with respect to drivers with disabilities. The TELSCAN project took the results on time headway from the simulator test as input to the development of guidelines for ACC systems.

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<tr>
<td>Without ACC</td>
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<td>Both</td>
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*Note.* ACC = Adaptive cruise controller.
that would better include the needs of elderly and disabled people. It is recommended, however, that the guidelines proposed here be further tested in real traffic and during long-term usage. These guidelines are considered just a beginning in the difficult search for guidelines specific enough, but not too prescriptive to restrict innovative design.

As a result of the study of users’ requirements and the simulator testing, the following guidelines for ACC form part of the TELSCAN Handbook of Design Guidelines for Usability of Systems by Elderly and Disabled Travellers (Nicolle & Burnett, 1999).

ACC Guideline: Adjustable Headway

It is important that headway is individually adjustable, by a qualified specialist, according to the driver’s characteristics and preferences. People with different types of impairments should be included when the adjustable range of the headway is determined. This need for adjustable headway becomes even more pronounced in poor weather conditions, nighttime driving, or when the severity of a driver’s impairment increases. Headway should not be altered by the driver, especially while driving. As a starting point it is recommended that the ACC system uses a headway that is 0.7 sec longer compared to that used for able-bodied drivers.

**Example.** An often-used headway value is 1.4 sec in ACC systems. This value should be prolonged to 2.1 sec (Peters, 1996). It is recommended, however, that testing in real traffic is undertaken to validate this guideline.

**Rationale.** An evaluation of one ACC system with drivers with lower limb impairments (Peters, 1996) revealed that this group of drivers preferred a longer average headway, or distance to a leading vehicle, than that of the system being used. The study found that mean headway was approximately 0.7 sec shorter for the ACC condition. This means that on average the participants drove 17 m closer at a speed of 90 km per hr to the leading vehicles. This shorter distance was accepted, but it does not conform to the distances found under the unsupported condition. Some participants explicitly stated that the ACC used headway that was too short.

ACC Guideline: Relevant Feedback

The input and output of the ACC should be designed with respect to the function provided as viewed by the driver. Do not allow the driver to believe that it is a Collision Avoidance System (CAS) instead of an ACC by displaying irrelevant information (Peters, 1996).

**Example.** Explicitly displaying that a vehicle is in front might make the driver think the system has the functionality of a CAS, even if this is not the case.

**Rationale.** The purpose of an ACC system is to assist the driver in controlling the speed of the vehicle. Yet the extended functionality of ACCs, compared to conventional CCSs, might confuse the driver, who might expect to be able to use it as a CAS. It is very important, therefore, to make this distinction clear to all drivers, especially when the feedback or information presentation subsystem of the ACC is designed (Ross et al., 1996; Peters, 1996). With respect to the ACC system tested (Peters, 1996), information about detection of the lead vehicle could be confusing to the driver.
ACC Guideline: Adaptable Controls

It should be possible to adapt the ACC controls easily so that they can be operated simultaneously with the primary driving task, but without interfering with it.

Example. If the ACC controls are placed on an acceleration lever for drivers requiring hand controls, then the driver could activate the ACC at the same time as controlling the speed (Peters, 1996).

Rationale. In the evaluation of an ACC system with drivers with lower limb impairments, the controls were placed on the direction indicator stalk at the left-hand side. However, one switch had three different effects depending on the status of the ACC. The switches were obscured by the steering wheel, which made it difficult visually to identify the controls. In order to operate the switches, it was necessary for the driver to release his or her hand from the steering wheel. The study found that it was important that the ACC controls were adaptable to cater for such requirements, regardless of the type of hand controls used for accelerator and brakes.

ACC Guideline: Integrated Feedback

The ACC feedback to the driver should be integrated into existing instruments as far as possible, as long as relevant information can be accurately and quickly deduced (Peters, 1996). Feedback from the ACC should also be adaptable so that the needs of individual drivers with disabilities can be considered.

Example. In the tested ACC system, feedback was considered well designed and integrated into existing instruments, using the original speedometer to display selected speed. When the ACC was switched on, the word CRUISE would appear in amber at the lower right on the dashboard. The speedometer had a circle of amber LEDs that were lit to display the currently selected speed, as long as the driver did not brake or turn the ACC off. From this testing, however, it is not possible to provide a specific guideline on appropriate feedback for an ACC system. In order to do this, it would be necessary to compare one system with another, and this needs testing in the future.

Rationale. Integrating the ACC feedback into existing instruments will enable parallel processing by the driver, meaning that the driver will more easily be able to process two pieces of information simultaneously (Stokes, Wickens, & Kite, 1990). Thus, the time and effort required to obtain information from multiple sources should be reduced, leading to reduced workload and higher efficiency. This is important for all drivers but especially for people who are experiencing higher workload due to their disability.

CONCLUSION

The TELSCAN Handbook of Design Guidelines for Usability of Systems by Elderly and Disabled Travellers (Nicolle & Burnett, 1999) is beginning to fill some of the gaps present in current guidelines. The Handbook will be further developed through TELSCAN’s continued surveys and empirical evaluation of other guidelines and system prototypes. It forms an important part
of TELSCAN’s database on the World Wide Web and a working draft can be downloaded from
the following address: http://hermes.civil.auth.gr/telscan/telsc.html

Many of these guidelines are still too general and more specificity would better assist
the designer to include the needs of people who are older or disabled. Although general
guidelines are necessary, the most specific and useful guidelines emerge only when carefully chosen
research questions—such as those posed during the simulator testing described in this article—
can be investigated.

However, even when designers have guidelines in an accessible format, there is still much
work to be done. Further increased awareness is needed so that designers know not only which
guidelines are available but also when to use them. To facilitate this process, developers of
guidelines for ITS should work together in coordinating their efforts and integrating their
guidelines, thus providing a “one-stop shop” for designers wherever possible.

Always including people with physical, perceptual, and cognitive impairments in the design,
development, and evaluation of ITS will make such systems more usable and safer for everyone.
Indeed, the “temporarily able-bodied” traveler may also benefit from such research in the 3rd
millennium.

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COMMENTARY

Commentary on “Elderly and Disabled Travelers: Intelligent Transport Systems Designed for the 3rd Millennium”

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Within both industry and government, there have been a number of recent efforts to develop human factors design guidelines to aid transportation system development. These efforts reflect the growing information gap between the advanced and diverse status of transportation systems and the availability of human factors data that can be used during their design process. The increasing complexity of in-vehicle transportation devices has underscored the importance of providing system developers with user-centered, human factors guidance early in the design process.

Frequently, the speed with which transportation systems must be brought into the competitive marketplace far exceeds the research community’s ability to empirically address every human factors design issue. Thus, design guidelines provide a means to integrate existing research findings that are relevant to a particular system or device into a clear, focused handbook of design recommendations that can be used immediately by system developers. The process of developing human factors design guidelines can also serve to identify research gaps for high-priority design topics, thus providing a road map for future research efforts.

The Nicolle and Peters (1999) article is therefore timely and provides an interesting discussion of design guideline development as well as a presentation of draft Intelligent Transport Systems (ITS) design guidelines. Although the development of design guidelines is crucial to the health and success of human factors as a discipline (see Meister, 1997), we have largely ignored the many conceptual and methodological issues associated with their development. Hopefully, this article, as well as others published recently (e.g., Burns & Vicente, 1994; Campbell, 1996; Zwaga, 1998) will help maintain our profession’s interest in this important topic. In addition to the discussion of design guidelines, the article also addresses an important technical area within an equally important general topic—designing ITS devices, such as Adaptive Cruise Control (ACC), for elderly and disabled drivers. Design requirements for disabled drivers in
particular have not been sufficiently addressed in the transportation human factors literature, and this article provides a valuable synopsis of key issues.

Overall, the article addresses a number of important issues in a clear and cogent fashion. Some especially useful insight includes the importance of identifying user acceptance of ITS devices early in the design process; specifically, “If elderly drivers do not want a collision avoidance system to take control of their driving, then a well-designed interface will not convince them to buy it” (p. 123). Another is provided later in the article in which the authors note the difficulty in making guidelines specific “but not too prescriptive to restrict innovative design” (p. 131). Both are excellent points that demonstrate the authors’ understanding of critical issues in both ITS and design guideline development. Many interesting topics are presented in this article, including an overview of the Telematic Standards and Coordination of Advanced Transport Telematics systems in relation to elderly and disabled travelers (TELSCAN) project, a discussion of fundamental issues associated with designing for the elderly and the disabled, methods of design guideline development, a summary of key experiments conducted in the project, and four sample design guidelines from the TELSCAN guidelines handbook.

Despite the clear contributions that this article makes to the transportation human factors literature, there are some instances in which the guideline development effort described in the article lacks definition and breadth. These include the need to identify guideline user requirements, the lack of graphics and figures within the draft TELSCAN guidelines, and the apparent exclusion of many relevant research studies in the guidelines. Each of these concerns is described and discussed in the following sections.

THE NEED TO IDENTIFY USER REQUIREMENTS IN GUIDELINE DEVELOPMENT

An enduring problem with human factors design guidelines has been their underutilization by the system design community. A number of studies conducted over the past 30 years (e.g., Campbell, Carney, & Kantowitz, 1997; Meister & Farr, 1967; Rouse & Cody, 1988) have reported that human factors guidelines following traditional formats for presenting information are not useful and are generally ignored by designers. Although there are many reasons for this situation, a primary reason has been the lack of communication between human factors guideline developers and the intended users of the guidelines. Developing effective human factors design guidelines requires an understanding of who will use them and how they will be used.

Although the Nicolle and Peters (1999) article does describe an effort to identify “user requirements,” this effort is best understood as an attempt to identify the requirements of drivers with disabilities. The actual users of the final guidelines and their particular needs and requirements for human factors design guidelines are not described in the article. This raises a number of questions about the eventual user population of the guidelines. Are they all human factors specialists, or do they also include non-human-factors designers such as mechanical engineers, hardware designers, software engineers, and graphic artists? What is their general level of knowledge regarding human factors methods, issues, and terminology? What are the relative priorities among candidate design topics to be addressed in the handbook? Also, how will the handbook be used during the ITS design process; what design constraints (if any) have already been established? Answers to these questions will help identify ITS designers’ unique needs for the content (design topics addressed by the guidelines), organization (handbook structure and search-and-find features), and format (content and layout of individual guidelines) of the design guidelines.
LACK OF GRAPHICS AND FIGURES IN THE GUIDELINES

One of the most frequent and consistent complaints that system designers have made about human factors reference information is the lack of graphics in most design guidelines and handbooks. Indeed, criticisms about human factors guidelines being "too wordy" and having "too much text" are seen throughout the literature (Campbell, 1995). The chief reason behind this complaint is that system design is an inherently visual process. Few product design efforts could be accomplished without visual aids and tools such as sketches, schematics, blueprints, and mock-ups. Most participants in the system development process, particularly artists, concept engineers, and industrial designers, see the product under development not as a series of numerical or verbal relations, but in spatial terms, with form, shape, color, and depth. Even in a more commonplace sense (i.e., nondesign environments), graphics convey purpose, meaning, and subtleties in a way that words alone cannot. Accordingly, human factors design guidelines must, to the extent possible, present design recommendations in graphic form.

Unfortunately, the draft TELSCAN guidelines presented in this article and on the TELSCAN Website (http://hermes.civil.auth.gr/telscan/telsc.html) include few graphics. Specifically, the four guidelines presented in the article include no graphics and, although my downloaded version of the Internet-based handbook was somewhat scrambled, I can find only four figures in the entire handbook. The problems associated with this cannot be overstated. All other things being equal, a set of guidelines that has been consistently enhanced with graphics will be viewed as being more interesting, relevant, and useful than guidelines with no or few graphics.

Whereas the preferred graphic is usually a figure, chart, photograph, or graph, a range of options for graphics can be used in design guidelines. Generally, representational figures are the most useful, that is, figures that exemplify or illustrate all or part of the actual design guideline. Flow charts are somewhat less often preferred, although they may be used in certain cases, for example, when the design guideline consists of some sequence of suggested development activities. Decision trees can be valuable because they are both spatial in nature and allow the designer to select design information based on their own unique design situation. To the extent possible, quantitative specifications and explanatory text should be incorporated directly into the graphics. In short, graphics are an essential component of effective design guidelines; the lack of graphics in the TELSCAN handbook will undoubtedly reduce its value to the ITS design community.

RESTRICTED RANGE OF DATA SOURCES CITED IN THE GUIDELINES

The TELSCAN guidelines do not seem to include a host of primary research studies that have been conducted in the area of ITS and comparable domains. Studies that are cited as support for the guidelines (in both the article and the on-line version of the guidelines) are limited in both number and type. There is generally an overreliance on data sources that were performed within the same or related project(s) as the guidelines development effort, earlier ITS projects in Europe, and other ITS guidelines. Many of the available research studies conducted in support of Collision Avoidance Systems, Advanced Traveler Information Systems, and Automated Highway Systems in the United States and Japan, as well as a host of studies relevant to important perceptual, cognitive, and psychomotor issues, do not seem to have been included as part of the guideline development process.
To illustrate, the design guideline for ACC headway presented in the article contains only one reference—to a study conducted by the article’s second author. In all, the four sample guidelines presented in the article contain a total of only three references, with only one of the three references representing original research. This is especially puzzling given that the TELSCAN guidelines are intended to cover a range of ITS devices, including route guidance and navigation, collision avoidance, head-up displays, ACC, parking aids, and toll collection. Although research compilations, earlier handbooks, and existing literature reviews are valuable to the guideline development process, they are insufficient when used as the primary source of guideline support. In particular, (a) they frequently do not present detailed discussions of empirical methods and results (key to determining how specific findings should be applied to new guidelines), (b) their goals and objectives may be quite different from those associated with the new guidelines, and (c) due to time lags in publication cycles, they do not include the most recent empirical studies.

As correctly noted by the authors, “As ACC systems are not yet available on the market and only limited testing has been performed so far, there has been little guidance on how the ACC should be designed” (p. 130). However, this does not mean that original research in comparable technical domains cannot be used to develop or support ACC guidelines. For example, there are a number of potentially relevant studies with implications for design guidelines that have examined the issue of vehicle headway in ITS devices (see, e.g., Levitan & Bloomfield, 1998, as well as McGeehee, Dingus, & Horowitz, 1994). Moreover, there is a great deal of research from comparable areas such as supervisory control and automation that can be legitimately applied to the design of ACC systems.

The need to extrapolate findings from comparable systems and related studies to current design problems lies at the heart of design guideline development. In general, the exclusion of potentially relevant research and data sources during guideline development is problematic for two reasons. First, users of human factors design guidelines frequently demand to know the empirical basis underlying a guideline. This is especially so when the design guideline conflicts with their own ideas or inclinations for a design approach. In such cases, unsupported or weakly supported design guidelines, no matter how correct from a human factors perspective, are more likely to be ignored by system designers. Second, the real value of human factors design guidelines—in terms of cost-effectiveness, timeliness, and utility—is in their ability to incorporate research findings from a wide range of related studies. Guidelines capitalize on our ability to review and integrate existing research data and to apply these data to a current system design effort, that is, to “bridge the gap” between the extensive body of human factors thought and research findings contained in the literature and the immediate information needs of system designers. Although time and available resources usually preclude an exhaustive (i.e., 100% complete) search and review of potentially relevant literature, this phase of the guideline development process should generally err on the side on being overly inclusive and not overly exclusive with respect to obtaining data sources (Campbell, 1996).

**SUMMARY**

This article provides interesting and useful information on a number of important topics, including ACC design, the needs of elderly and disabled drivers, and design guideline development. The issues associated with the draft TELSCAN guidelines that I have raised here represent
opportunities for future improvement of the guidelines. If these issues were addressed, the value of the handbook to ITS designers would be greatly increased. The human factors community possesses the ability and the tools to develop effective and valuable design guidelines. These tools include methods associated with conducting analyses of user requirements, presenting design guidelines in a manner that is consistent with system designers’ needs and desires for human factors information, and identifying, reviewing, and integrating relevant data sources for guideline development. Future TELSCAN guideline development activities can use these tools to further improve the usability of ITS devices for elderly and disabled drivers.

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RESPONSE

Reply to Comments on “Elderly and Disabled Travelers: Intelligent Transport Systems Designed for the 3rd Millennium”

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Swedish National Road and Transport Research Institute (VTI)
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The Campbell (1999) Commentary provides us with important and considered suggestions for improvements to the Telematic Standards and Coordination of Advanced Transport Telematics systems in relation to elderly and disabled travelers (TELSCAN) Guidelines Handbook (Nicolle & Burnett, 1999). We therefore appreciate the opportunity to be able to comment directly and indicate more clearly the project’s background, plans, and future hopes. Given the speed with which transportation systems must be brought into the marketplace, the TELSCAN consortium felt that it was better to get draft guidelines into the hands of designers as quickly as possible, even before some of the shortcomings had been corrected.

It is important to emphasize that the TELSCAN project is what is called a support, or horizontal action, within the European Commission’s (E.C.) Transport Telematics Programme. This means that the main focus is to ensure that all transportation systems, but especially those developed within the current E.C. research and development program, take account of the needs of people who are elderly or disabled. This includes supporting other research projects through a number of different activities:

- Identifying the needs of travelers with disabilities.
- Assisting projects through collaborative testing.
- Developing an evaluation methodology that will give advice on which user groups to include in the evaluation; what to remember in certain testing environments and contexts; and methods, tools and protocols to follow when testing with different user groups.

Requests for reprints should be sent to Colette Nicolle, HUSAT Research Institute, Loughborough University, The Elms, Elms Grove, Loughborough, Leicestershire LE11 1RG, United Kingdom.
Developing a traveler information checklist to suggest the type of specific information needed by people who are elderly or disabled (e.g., which bus line has a low floor, how long it will take to walk from one platform to another, and if there are any stairs to climb).

Finally, developing a handbook and database of design guidelines for Intelligent Transport Systems (ITS).

With these various activities and resource constraints clearly in mind, we shall now comment on the issues raised.

THE NEED TO IDENTIFY USER REQUIREMENTS IN GUIDELINE DEVELOPMENT

The project first identified the requirements of people who are elderly or disabled. Second, the requirements of the E.C. transport telematics projects, the main targets of TELSCAN, were identified through a questionnaire survey and related interviews. These data mainly focused on the projects’ needs for support when considering people who are elderly or disabled in the design or evaluation process. In addition to the other E.C. research projects, however, the actual users of the final guidelines are expected to be as follows:

- System manufacturers, who can use the Handbook (Nicolle & Burnett, 1999) as a checklist during the design and evaluation process in order to accommodate elderly and disabled travelers.
- Car adaptation manufacturers, who can use the Handbook to help ensure that a particular ITS device is installed so that it is usable by a particular traveler with special needs and compatible with other car adaptations for that particular driver.
- Human-factors experts, who will find the Handbook useful for evaluating systems for travelers against criteria for human–computer interaction.
- Researchers and standards bodies, who can use the Handbook to identify areas where knowledge exists and those areas where further research is required.

Valuable input has regularly been gained from the car adaptation manufacturers represented within the Telematic Applications for the Integration of Drivers with Special Needs (TELAID) and TELSCAN consortia. Limited interviews were also held with engineers and human factors practitioners with a systems supplier and vehicle manufacturer (Burnett & Nicolle, 1998). These interviews identified some of the requirements for the provision of design advice by the TELSCAN project, including the need for the following:

- Using the World Wide Web (WWW) as a means of communicating TELSCAN advice.
- Both an electronic source of guidelines and a paper-based document.
- More specific guidelines.
- A greater number of examples.
- Graphics to illustrate key guidelines, though this must be balanced against the need for quick and easy access to the WWW.
- Text labels for any graphics that are used on the WWW in case a designer has a visual impairment and is using a text reader.
Although these limited interviews were useful, we appreciate the need for more and better communication with the whole system design community to ensure that the guidelines will not only be used but also used effectively.

Certainly there is a general need to further improve communication between human factors researchers and a broad range of ITS designers. We must seek to try out alternative ways of conveying design considerations that include the requirements of elderly and disabled users. In many cases, there is still a need to enhance the designers’ view of the end users of their products so that they also include elderly and less abled users. This might be done through well-chosen good and bad examples of design. Once designers recognize these users’ specific needs and limitations, they can request specific guidelines, and we can achieve a more effective communication. Such efforts are planned within the future work of TELSCAN.

**LACK OF GRAPHICS AND FIGURES IN THE GUIDELINES**

Graphics are clearly more effective than text to illustrate human factors principles and guidelines. In fact, further graphics and figures will be found in the final draft of the Handbook in June 1999 (e.g., Figure 1, which illustrates the Adaptive Cruise Control (ACC) design guideline for adjustable headway).

Representational figures and line drawings, with limited photographs, have been chosen as the most useful way to illustrate particular guidelines of a prescriptive nature. These graphics emerge not only from TELAID, TELSCAN, and other relevant research studies but also from other existing guidelines in nontransport areas (e.g., Gill, 1997, on guidelines for public access terminals). On the other hand, process guidelines (e.g., to represent TELSCAN’s system evaluation methodology) will be represented by way of flow charts and possibly decision trees.

**RESTRICTED RANGE OF DATA SOURCES CITED IN THE GUIDELINES**

Given TELSCAN’s emphasis on collaborative testing with other projects in the Transport Telematics Programme, the development of guidelines emerging from these studies must be the priority.
There are, of course, a multitude of other guidelines that constitute good design practice and are equally relevant for all travelers, regardless of age or any disability. This *Handbook* (Nicolle & Burnett, 1999) does not attempt to repeat all those guidelines on usability from other sources. However, it does try to highlight those design issues that are particularly important to elderly and disabled people and points designers toward sources of general guidelines where appropriate.

We agree that there is still a great deal of original research, covering a range of ITS devices and comparable domains, that should be applied to and used to support the TELSCAN guidelines. It is evident that there is a fine line between, on the one hand, overinclusive data gathering and extrapolation and, on the other hand, burdening the user with too many facts, figures, and references. Structuring the *Handbook* (Nicolle & Burnett, 1999) in such a way as to keep all rationale and references separate and easily accessible seems like a good solution (as found in Campbell, Carney, & Kantowitz, 1998). With the availability of key-word searches, this could be even more acceptable in the electronic version of the *Handbook*. TELSCAN must still spend time on further developing the interface that will accomplish this most effectively.

Concerning the specific comments on ACC guidelines and referenced related research, it should be noted that the guidelines proposed should, first of all, be viewed as preliminary ones. Second, they should be considered as complementary or even in contrast to other work aimed at guiding a standardized ACC design. There are numerous in-car ITS (e.g., forward collision warning, collision avoidance systems, and automatic highway systems) that address similar aspects to the ACC application. These include, for example, headway, vigilance, taking the driver in and out of the control loop, and the driver’s understanding and response to system messages and warnings (see Farber, 1996; Scott, 1997). The ACC application will be marketed as a system contributing to comfort, but it is likely to also contribute to safety (Farber, 1996), traffic flow (Hogema, Arem, Smulders, & Coëmet, 1997), and environmental impact (Fancher, Koziol, & Baker, 1997). All these concerns will influence the choice of a standardized headway parameter for ACC. Concerns for traffic flow would advocate short headways (1 sec) for the ACC (Hogema et al., 1997). In addition, Scott (1997) stated that user acceptance demands a headway that is not too long and proposed 1.2 sec. However, Fancher et al. (1997) found that elderly drivers, when able to select, preferred a headway of 2.0 sec, which is more in line with what we propose. The ACC headway guidelines proposed in our article should be viewed in this context. The specific numbers mentioned should not be taken for granted but still need further testing. However, we have not yet been able to concentrate on this type of contextual research work within the current TELSCAN project. The outlined procedure and considerations for ACC standardization efforts proposed by Scott (1997) cover the most relevant human factors requirements for ACC, but it would benefit from an expanded user view that includes elderly and disabled drivers.

**SUMMARY AND CONCLUSION**

The final draft version of the *TELSCAN Handbook of Design Guidelines* (Nicolle & Burnett, 1999), at least for this current project, will be produced at the end of June 1999. Even then it is anticipated that, if further funding can be achieved, the issues that have been raised here will lead to future improvements. The TELSCAN consortium possesses the expertise and the tools to continue making a valuable contribution toward the inclusion of people who are elderly and disabled in the design of ITS devices.
In conclusion, we call on developers of guidelines for ITS, including other projects and standards bodies, to work together in coordinating their efforts and integrating their guidelines. No matter what efforts are made to improve TELSCAN and other guidelines, there still remains a need for something like a “one-stop shop” for designers. Perhaps this would be a good way to make the guidelines accessible and therefore more usable and more used.

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Statens väg- och transportforskningsinstitut (VTI) har kompetens och laboratorier för kvalificerade forskningsuppdrag inom transporter och samhällsekonomi, trafiksäkerhet, fordon, miljö samt för byggnade, drift och underhåll av vägar och järnvägar.

The Swedish National Road and Transport Research Institute (VTI) has laboratories and know-how for advanced research commissions in transport and welfare economics, road safety, vehicles and the environment. It also has research capabilities for the construction, operation and maintenance of roads and railways.

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