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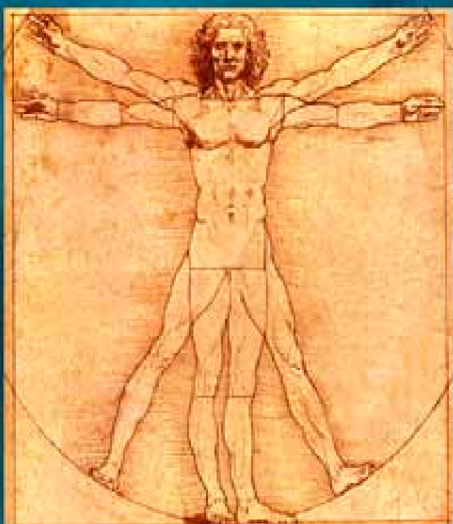

Roadway Human Factors and Behavioral Safety in Europe

MAY 2005

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Federal Highway Administration

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16. Abstract
Human factors issues associated with roadway design and operations are critical components of improving highway safety. The Federal Highway Administration, American Association of State Highway and Transportation Officials, and National Cooperative Highway Research Program sponsored a scanning study of European countries to identify how they incorporate human factors issues in the research, design, and operation of highways.

The U.S. delegation observed seven concepts in Denmark, Finland, France, the Netherlands, Norway, and Sweden that it recommends for possible implementation in the United States. They include self-organizing roads, use of driving simulators in roadway design, multidisciplinary teams to investigate crashes, speed management techniques such as speed cameras, human-centered roadway analysis and design, cognitive models of drivers, and top-down leadership on safety goals.

The team's recommendations for U.S. action include evaluating the 2+1 roadway design, promoting the use of driving simulators among the road-design community, assessing opportunities for coordinating long-term research on human factors and cognitive models, and encouraging top leadership commitment to road safety improvement.

17. Key Words
2+1 roadway, cognitive model, driving simulator, human factors, multidisciplinary crash investigation team, safety, self-organizing road, speed management

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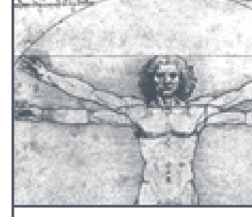

Roadway Human Factors and Behavioral Safety in Europe

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Federal Highway Administration, U.S. Department of Transportation
American Association of State Highway and Transportation Officials
National Cooperative Highway Research Program (Panel 20-36) of the Transportation Research Board

May 2005

FHWA International Technology Exchange Program

The Federal Highway Administration's (FHWA) Technology Exchange Program assesses and evaluates innovative foreign technologies and practices that could significantly benefit U.S. highway transportation systems. This approach allows for advanced technology to be adapted and put into practice much more efficiently without spending scarce research funds to recreate advances already developed by other countries.

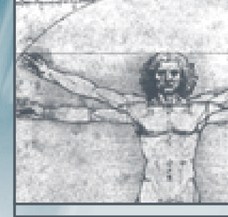
The main channel for accessing foreign innovations is the International Technology Scanning Program. The program is undertaken jointly with the American Association of State Highway and Transportation Officials (AASHTO) and its Special Committee on International Activity Coordination in cooperation with the Transportation Research Board's National Cooperative Highway Research Program Project 20-36 on "Highway Research and Technology—International Information Sharing," the private sector, and academia.

FHWA and AASHTO jointly determine priority topics for teams of U.S. experts to study. Teams in the specific areas being investigated are formed and sent to countries where significant advances and innovations have been made in technology, management practices, organizational structure, program delivery, and financing. Scanning teams usually include representatives from FHWA, State departments of transportation, local governments, transportation trade and research groups, the private sector, and academia.

After a scan is completed, team members evaluate findings and develop comprehensive reports, including recommendations for further research and pilot projects to verify the value of adapting innovations for U.S. use. Scan reports, as well as the results of pilot programs and research, are circulated throughout the country to State and local transportation officials and the private sector. Since 1990, FHWA has organized more than 60 international scans and disseminated findings nationwide on topics such as pavements, bridge construction and maintenance, contracting, intermodal transport, organizational management, winter road maintenance, safety, intelligent transportation systems, planning, and policy.

The International Technology Scanning Program has resulted in significant improvements and savings in road program technologies and practices throughout the United States. In some cases, scan studies have facilitated joint research and technology-sharing projects with international counterparts, further conserving resources and advancing the state of the art. Scan studies have also exposed transportation professionals to remarkable advancements and inspired implementation of hundreds of innovations. The result: large savings of research dollars and time, as well as significant improvements in the Nation's transportation system.

For a complete list of International Technology Scanning Program topics and to order free copies of the reports, please see the list contained in this publication and at *www. international.fhwa.dot.gov,* or e-mail *international@fhwa.dot.gov.* ■



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Abbreviations and Acronyms

AASHTO	American Association of State Highway and Transportation Officials
COSMODRIVE	Cognitive Simulation Model of the Driver
DOT	Department of Transportation
DTF	Danish Transport Research Institute
EC	European Community
EU	European Union
FHWA	Federal Highway Administration
GPS	Global positioning system
HF	Human factors
HUMANIST	HUMAN-centered design for Information Society Technologies
IHSDM	Interactive Highway Safety Design Model
ITS	Intelligent transportation system
NCHRP	National Cooperative Highway Research Program
INRETS	French National Institute for Transport and Safety
SINTEF	Foundation of Scientific and Industrial Research at the Norwegian Institute of Technology
SWOV	Netherlands Institute of Road Safety Research
TNO	Netherlands Organization for Applied Scientific Research
VALT	Finnish Motor Insurers' Centre
VTI	Swedish National Road and Transport Research Institute
VTT	Technical Research Centre of Finland

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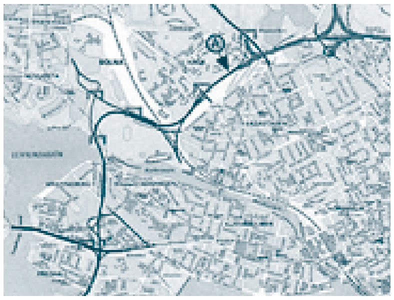

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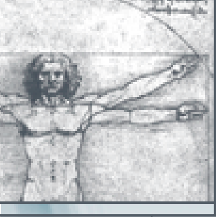

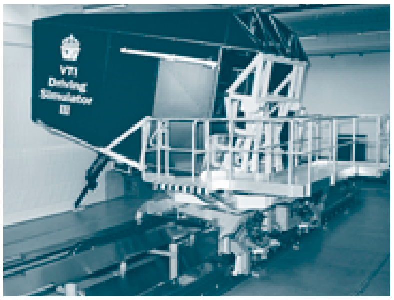

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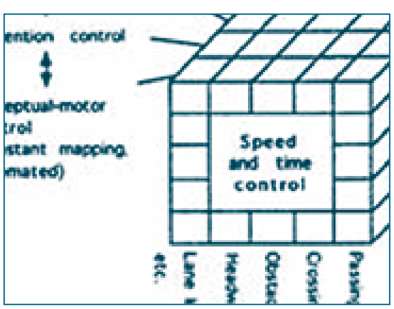

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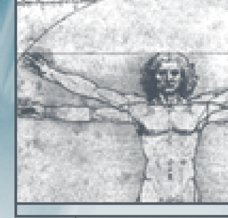


Executive Summary

The U.S. transportation community has placed high emphasis on the need to improve highway safety. The American Association of State Highway and Transportation Officials (AASHTO) and the Federal Highway Administration (FHWA) have adopted a goal to reduce highway fatalities from 1.5 per 100 million vehicle-miles traveled to 1.0 by 2008. AASHTO has established a Strategic Highway Safety Plan to determine the most promising countermeasures that improve safety in a cost-effective manner and are acceptable to the majority of the public. FHWA has focused its Safety Vital Few initiative on reducing intersection, run-off-the-road, and pedestrian fatalities. Human factors issues associated with roadway design and operations are a critical component of these highway safety improvement areas. It is also one of the five critical research needs contained in the highway infrastructure and operations component of the National Highway Research and Technology Partnership's report on highway safety. This study provides methodological and technical insights into how best to incorporate human factors issues in the research, design, and operation of highways.

Panel Composition

The nine scan team members were a cross section of experts from Federal and State government and academia. A great benefit of the study for participants was the opportunity to view information through the eyes of colleagues with different training and experience. For example, human factors experts visiting a construction site gained from the explanations of highway engineers, who, in turn, gained from the human factors experts when the team visited a driving simulator. Team members included co-chair Kevin Keith of the Missouri Department of Transportation (DOT), co-chair Michael Trentacoste of FHWA, Dr. Leanna Depue of Central Missouri State University, Dr. Thomas Granda of FHWA, Ernest Huckaby of FHWA, Bruce Ibarguen of the Maine DOT, report facilitator Dr. Barry Kantowitz of the University of Michigan, Wesley Lum of the California DOT, and Terecia Wilson of the South Carolina DOT.

Sites Visited

The team visited public and private institutions in six European countries (Denmark, Finland, France, the Netherlands, Norway, and Sweden) during a two-week period. When the team spent two days in one location, the first day was devoted to lectures and facilities tours, and the second day was spent on a bus touring road sites that illustrated points explained the previous day. The eight institutions visited included the Technical Research Centre of Finland (VTT), the University of Helsinki, the Foundation of Scientific and Industrial Research at the Norwegian Institute of Technology (SINTEF), the Danish Transport Research Institute (DTF), the Netherlands Organization for Applied Scientific Research (TNO), the Netherlands Institute of Road Safety Research (SWOV), the Swedish National Road and Transport Research Institute (VTI), and the French National Institute for Transport and Safety (INRETS). In addition to representatives of those agencies, representatives from the various Ministries of Transport and others involved in human factors safety research for the countries participated in the meetings. All were exceptionally helpful in addressing the concerns of the panel.

Key Findings

The goal of this report is to make researchers, designers, and operators of U.S. highway systems aware of good ideas that are either unknown or unused here. The best practices identified in this report, if used in the United States, could greatly increase the safety and mobility of highway operations. The scanning team was so impressed by these new concepts that it has pledged to do its utmost to facilitate the early adoption of some of these key ideas. While many excellent ideas and practices were observed, the team agreed to focus on seven vital concepts:

- Self-organizing roads
- Driving simulators for roadway design and visualization
- Multidisciplinary teams
- Speed management
- Human-centered roadway analysis and design
- Cognitive models
- Top-down leadership

These concepts are briefly described and illustrated by successful examples that demonstrate the utility and benefit of each idea. It is important to note that these topics are not mutually exclusive, e.g., self-organizing roads impact speed management.

Self-Organizing Roads

A self-organizing road increases the probability that a driver will automatically select appropriate speed and steering behavior for the roadway without depending on road signs. The geometric features of the road encourage the desired driver behavior, and do not rely on the driver's ability or willingness to read and obey road signs. A perfect self-organizing road would not require speed limit signs and curve advisory warnings.

While the United States has some examples of self-organizing roads, such as using curved road segments in national parks to limit driver speed, this concept is far more common in Europe. It is easy to understand that geographic topography can create a self-organizing road that limits driver speed selection. It is harder to appreciate intentionally designing a road to be self-organizing in an urban area.

A roundabout is a self-organizing road. The road geometry forces the driver to select a lower speed than used on a tangent. Pavement markings help the driver perceive this lower speed requirement.

In a similar manner, intentionally narrowing the roadway and shoulders also creates self-organizing features that instruct the driver to slow down. When there is a conflict between road features and road signs, drivers may often follow the speed implied by the roadway design rather than the speed instructed by the road sign. For example, building a connecting roadway to interstate design standards and then putting a 30-mile-per-hour (mi/h) (50 kilometer-per-hour (km/h)) sign on the side of the road would encourage drivers to ignore the speed limit displayed on the sign.

Another important example of a self-organizing road is the 2+1 roadway design the team observed in Finland and Sweden. This road design also offers significant safety advantages, especially with the cable barrier in a flush divider used in Sweden. The 2+1 roadway is a three-lane road with the passing lane alternating on each side of the road in a regular manner. This organizes the driver's expectations about being able to pass.

One of the teams' most impressive observations involved watching Swedish drivers approaching the end of a passing lane. During a 20-minute observation interval, no driver speeded up to pass a slower vehicle before the passing lane ended. Such driver behavior is quite common in the United States. The expectations induced by the 2+1 design reassured drivers that another passing opportunity would occur shortly. Hence, drivers did not feel a need to pass immediately and so did not incur risk by trying to pass just before the passing lane ended.

Even in more congested conditions, traffic flow remained stable, as passing was reduced and drivers maintained more uniform speeds. Early skeptics, such as emergency responders who expected additional delays in going around median cable guardrails to get to crashes, became highly supportive of the 2+1 design because of the vast reduction in crashes they needed to respond to and the ease of removing the cable barrier when necessary.

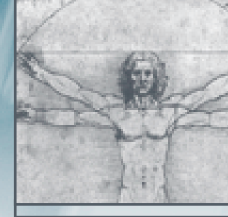
Swedish experience with this design has been better than expected. Level of service has been equal or better at directional flows of up to 1,400 vehicles per hour, with a capacity of 1,500 to 1,600 vehicles per hour in one direction, some 300 vehicles per hour fewer than for an ordinary 13-meter (14.2-yard) road. Traffic safety effects also have been better than expected. By June 2004, there had been nine fatalities, compared to the normal 60, and an estimated 50 percent reduction in severe injuries.

Median cable barrier crashes are very frequent, but normally without personal injuries. Crashes are often caused by skidding, flat tires, or loss of control of the vehicle. Maintenance problems are fewer than expected, but barrier repairs are major concerns. Maintenance costs have increased almost 100 percent per year, although 70 percent of barrier and car repair costs are paid by insurance companies.

Driving Simulators: Roadway Design and Visualization

The fidelity level of the driving simulators (e.g., degrees of motion, picture size and quality, etc.) at the European agencies visited was comparable to the range of simulators in use in the United States at universities and FHWA's Turner-Fairbank Highway Research Center. Driving simulators are often used in Europe, however, to help design roadways, an application that is far less common in the United States. It is much simpler and cheaper to reject a design element in a driving simulator than to rebuild a road or tunnel to fix design errors.

Simulators have been used both formally, with controlled experiments to conduct tests of driver behavior and approval of project features, and informally, with highway designers using the simulator to experience alternate roadway plans. At VTI, for example, an informal simulator project was described in which highway designers had planned to visit for one day to view their new designs in the simulator, but stayed for



three days and made several design changes based on their simulator experience.

An example of a formal evaluation of alternate designs by drivers was explained to the team at SINTEF in Norway. SINTEF was asked to help design the world's longest tunnel in western Norway. Results showed that lighting strategies using blue, yellow, and green lights increased driver safety and comfort in the tunnel. Changes in lighting every 2 km (1.2 mi) reduced driver anxiety. These design strategies have been successful, with high ratings of driver comfort in the tunnel and no crashes. In addition, the Laerdal project has won two European lighting awards.

Multidisciplinary Teams

At the University of Helsinki in Finland, the team learned that all fatal crashes in the country are investigated by a multidisciplinary team that includes a police officer, vehicle engineer, traffic engineer, physician, and sometimes a psychologist. The investigation results are documented in an original folder and a database with more than 300 variables using a methodology from the Finnish Motor Insurers' Centre. Results can vary, depending on the composition of the team. From the examples given, it appeared that the presence or absence of a psychologist on the team could critically alter conclusions and interpretation of data.

No data were presented on the statistical reliability of this method. Since multidisciplinary crash investigation has been criticized in the United States for lacking such reliability, this caveat must be kept in mind when evaluating European results.

Speed Management

The 2+1 roadway design discussed earlier also has worked well for speed management. It has improved throughput and raised speeds on two-lane roadways. In Finland, travel speeds at low flow rates improved 1 to 2 km/h (0.6 to 1.2 mi/h), with gains of 4 to 5 km/h (2.5 to 3.1 mi/h) for higher flow rates. In Sweden, average passenger car spot speeds on two-lane sections are 4 km/h (2.5 mi/h) faster on a 2+1 roadway with a median cable barrier than on a 13-m (14.2-yd) roadway with wide lanes.

In Sweden, France, Norway, and the Netherlands, speed cameras were effective in controlling driver speed. Multiple camera boxes were installed in Sweden with the driver unable to determine which box, if any, contained a speed camera, as is done in the United States with red-light-running cameras. Speeding tickets are sent to the driver of the vehicle.

In Finland, variable speed limits were successful in managing driver speed. Speed limits varied according to the season, with lower limits in winter than in summer.

Human-Centered Roadway Analysis and Design

Human-centered design starts with the limitations and preferences of the driver, and then derives appropriate technology from these human principles. This approach has been extremely successful for aviation and is slowly being incorporated into highway design in both the United States and Europe.

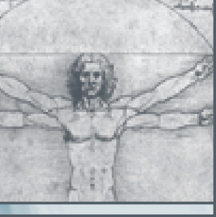
Of course, the general principles of human-centered design apply to many of the topics discussed previously. Self-organizing roads depend on human-centered design. The roundabout is a good example. Instead of blaming the human driver for failing to stop at a signalized intersection, the roundabout removes the need for stopping. People inevitably make errors. Good design anticipates these errors and minimizes their consequences. An error at a signalized intersection can result in a 90-degree crash with drastic consequences to drivers and vehicles. A crash at a roundabout results in an angle much less than 90 degrees with smaller risk and damage to vehicles and occupants.

The cable barrier in a 2+1 roadway also demonstrates human-centered design. Instead of blaming drivers for incorrectly crossing the median, the barrier prevents such a driver error. The Laerdal Tunnel lighting design is human centered because it anticipates and minimizes driver anxiety and boredom inside the tunnel. At TNO in the Netherlands, the team learned about efforts to reduce the number of words on traffic signs because drivers have a limited ability to assimilate language while driving down the highway.

Two excellent examples of human-centered design and analysis were presented at SINTEF in Norway: design for pedestrians and human-based standards for geometric roadway design. The program of active-children pedestrian design derives from the Norwegian preference of having children walk to school instead of being driven by their parents. Observational studies of pedestrian crossings revealed that raised zebra crossings and signalized zebra crossings are best for young children. Studies of human reaction time helped formulate standards for geometric roadway design.

Cognitive Models

The need for cognitive models of the driver was emphasized at the University of Helsinki in Finland, TNO in the Netherlands, and INRETS in France. Such models are useful



in several ways. They are part of microscopic traffic models that can be validated by observing traffic flow. Indeed, the driver models used for this purpose at INRETS are so detailed that they are referred to as "nanoscopic" driver models. Cognitive models are also useful when implementing human-centered design and analysis. Instead of having to perform a new experiment to answer each new question, the model itself can generate answers.

This model is written in Smalltalk, a computer language well suited for artificial intelligence applications. INRETS has a considerable financial investment in this model, which was developed over 10 years with a three-year break because of other internal priorities. Only now are validation studies being conducted for the model. This delay in validation illustrates how important continuous funding is for high-risk, high-reward basic research. The team congratulates INRETS for seeking and funding such a long-term goal.

Top-Down Leadership

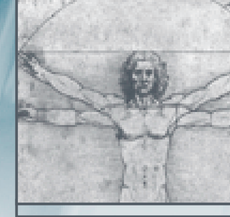
The team was impressed with the coordination between research goals and the highest levels of government in Europe. The best example of this is Sweden's Vision Zero. The Swedish Parliament passed an act specifying that the country's long-term traffic safety goal is zero fatalities. This provides extremely clear direction to researchers and agencies responsible for highway design and operations. Unlike the road safety guiding philosophy in the United State that tolerates a certain number of fatalities and injuries on highways and mandates only a desired percentage decrease in death and destruction, Sweden has stated that no one should die on a Swedish road. SWOV in the Netherlands expressed similar goals. In France, road safety was a campaign issue in the national elections, and President Jacques Chirac has put major emphasis on road safety as a national priority. In general, Europe appears to be ahead of the United States in directing drastic improvements in roadway safety.

Implementation

While the team obtained many useful ideas, six specific topics were selected as potential high-reward areas of opportunity:

- Self-organizing roads
- Driving simulators
- Multidisciplinary crash investigation
- Human-centered roadway analysis and design
- Top-down leadership commitment
- Speed management

More details can be found in the scan tour implementation plan.



CHAPTER 1

Introduction

The U.S. transportation community has placed high emphasis on the need to improve highway safety. The American Association of State Highway and Transportation Officials (AASHTO) and the Federal Highway Administration (FHWA) have adopted a goal to reduce highway fatalities from 1.5 per 100 million vehicle-miles traveled to 1.0 by 2008. AASHTO has established a Strategic Highway Safety Plan to determine the most promising countermeasures that improve safety in a cost-effective manner and are acceptable to the majority of the public. FHWA has focused its Safety Focus Areas initiative on reducing intersection, run-off-the-road, and pedestrian fatalities. Human factors issues associated with roadway design and operations are a critical component of these highway safety improvement areas. It is also one of the five critical research needs contained in the highway infrastructure and operations component of the Nation Highway Research and Technology Partnership's report on highway safety. This study will provide methodological and technical insights into how best to incorporate human factors issues in the planning, research, design, and operation of highways.

Panel Composition

The nine scan team members were a cross section of experts from Federal and State government and academia. A great benefit of the study for participants was the opportunity to view information through the eyes of colleagues with different training and experience. Human factors experts visiting a construction site, for example, gained from the explanations of highway engineers, who, in turn, gained from the human factors experts when the team visited a driving simulator. Table 1 identifies the team members.

Sites Visited

The team visited public and private institutions in six European countries—Denmark, Finland, France, the Netherlands, Norway, and Sweden—during a two-week

Table 1. Team members.

Panel Members
Kevin Keith, *Missouri DOT, Co-chair*
Michael Trentacoste, *FHWA, Co-chair*
Bruce Ibarguen, *Maine DOT*
Wesley Lum, *California DOT*
Terecia Wilson, *South Carolina DOT*
Dr. Thomas Granda, *FHWA*
Ernest Huckaby, *FHWA*
Dr. Leanna Depue, *Central Missouri State University*
Professor Barry Kantowitz, *University of Michigan*

Figure 1. Scan team in Helsinki preparing for its first site visit.

Figure 2. Map of sites visited.

Figure 3. Team co-chairs presenting an overview of the scan study goals in Helsinki.

period (see figure 2). When the team spent two days at one location, the first day was devoted to lectures and facilities tours, and the second day was spent on a bus touring road sites that illustrated points explained the previous day. Table 2 lists the eight institutions visited. In addition to representatives from those agencies, representatives from the various Ministries of Transport and others involved in human factors safety research for the countries participated in the meetings. All were exceptionally helpful in addressing the concerns of the panel.

Key Findings

The goal of this report is to make researchers, designers, planners, and operators of U.S. highway systems aware of good ideas that are either unknown or unused here. The best practices identified in this report, if used in the United States, could greatly increase the safety and mobility of highway operations. The scanning team was so impressed by these new concepts that it has pledged to do its utmost to facilitate the early adoption of some of these key ideas. While many excellent ideas and practices were observed, the team agreed to focus on seven vital concepts:

- Self-organizing roads
- Driving simulators for roadway design and visualization
- Multidisciplinary crash investigation teams
- Speed management
- Human-centered roadway analysis and design
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- Top-down leadership

In the following chapters, these concepts are described and illustrated by successful examples that demonstrate the utility and benefit of each idea. It is important to note that these topics are not mutually exclusive, e.g., self-organizing roads impact speed management.

Table 2. Sites visited.

Institute	Country
VTT Technical Research Centre of Finland (VTT)	Finland
University of Helsinki	Finland
The Foundation of Scientific and Industrial Research at The Norwegian Institute of Technology (SINTEF)	Norway
The Danish Transport Research Institute (DTF)	Denmark
Netherlands Organization for Applied Scientific Research (TNO)	The Netherlands
Institute of Road Safety Research (SWOV)	The Netherlands
The Swedish National Road and Transport Research Institute (VTI)	Sweden
French National Institute for Transport and Safety (INRETS)—Paris	France
French National Institute for Transport and Safety (INRETS)—Lyon	France

CHAPTER 2

Self-Organizing Roads

A self-organizing road increases the probability that a driver will automatically select appropriate speed or steering behavior for the roadway without depending on road signs. The geometric features of the road encourage the desired driver behavior, and do not rely on the driver's ability or willingness to read and obey road signs. A perfect self-organizing road would not require speed limit signs and curve advisory warnings.

While the United States has some examples of self-organizing roads, such as using curved road segments in national parks to limit driver speed, this concept is far more common in Europe. It is easy to understand that geographic topography can create a self-organizing road that limits driver speed selection (figure 4). It is harder to appreciate intentionally designing a road to be self-organizing in an urban area.

A roundabout is a self-organizing road (see figure 5 on next page). The road geometry forces the driver to select a lower speed than used on a tangent. This reduced speed design through the intersection improves safety by reducing vehicle energy when crashes occur, but also by the types of crashes that do occur (sideswipes versus head-on and crossing). The design also often improves mobility and reduces congestion because of the reduced waiting times at a signal. Pavement markings reinforce and help the driver perceive this lower speed requirement.

In a similar manner, intentionally narrowing the roadway and shoulders also creates self-organizing features that instruct the driver to slow down. When a conflict exists between road features and signs, drivers often follow the speed implied by the roadway design rather than the speed instructed by the road sign. For example, building a connecting roadway to interstate design standards and putting a 30 mi/h (50 km/h) sign on the side of the road would encourage drivers to ignore the speed limit displayed on the sign.

Figure 4. Topography can create self-organizing roads. (SINTEF)

Figure 5. A roundabout is a self-organizing road. (SINTEF)

Figure 6. Scan team members examining 2+1 road in Sweden.

Figure 7. 2+1 roadway. Note the cable barrier and sign indicating the length of the passing lane. (Sweden)

2+1 Roadway Design

Another important example of a self-organizing road is the 2+1 roadway design the team observed in Finland and Sweden. This road design also offers significant safety advantages, especially with the cable barrier in a flush divider used in Sweden. The road is designed to eliminate the risk of head-on collisions. As shown in figures 7 and 8 (see next page), the 2+1 roadway is a three-lane road with the passing lane alternating on each side of the road in a regular manner. This organizes the driver's expectations about being able to pass.

One of the team's most impressive observations involved watching Swedish drivers approaching the end of a passing lane. During a 20-minute observation interval, no driver speeded up to pass a slower vehicle before the passing lane ended. Passing slower vehicles in advance of lane drops is common driver behavior in the United States. The expectations induced by the 2+1 design reassured drivers through the use of effective signing that another passing opportunity would occur shortly. Hence, drivers did not feel a need to pass immediately and so did not incur risk by trying to pass just before the passing lane ended.

Even in more congested conditions, traffic flow remained stable, as passing was reduced and drivers maintained more uniform speeds. Early skeptics, such as emergency responders who expected additional delays in going around median cable guardrail to get to crashes, became highly supportive of the 2+1 design because of the vast reduction in crashes they needed to respond to and the ease of removing the cable barrier when necessary.

Swedish experience with this design has been better than expected. Level of service has been equal or better at directional flows of up to 1,400 vehicles per hour, with a capacity of 1,500 to 1,600 vehicles per hour in one direction, some 300 vehicles per hour fewer than for an ordinary two-lane, 13-m (14.2-yd) road. Traffic safety effects also have been better than expected. By June 2004, there had been nine fatalities, compared to the normal 60, and an estimated 50 percent reduction in severe injuries. Chapter 5 of this report discusses speed management, which can be greatly influenced by roadway design. Higher standards for design tend to promote higher speeds.

Median cable barrier crashes are very frequent, but normally without personal injuries. Crashes are often caused by skidding, flat tires, or loss of control of the vehicle. Maintenance problems are fewer than expected, but barrier repairs are major concerns. Maintenance costs have increased almost 100 percent per year, although 70 percent of barrier and car repair costs are paid by insurance companies.

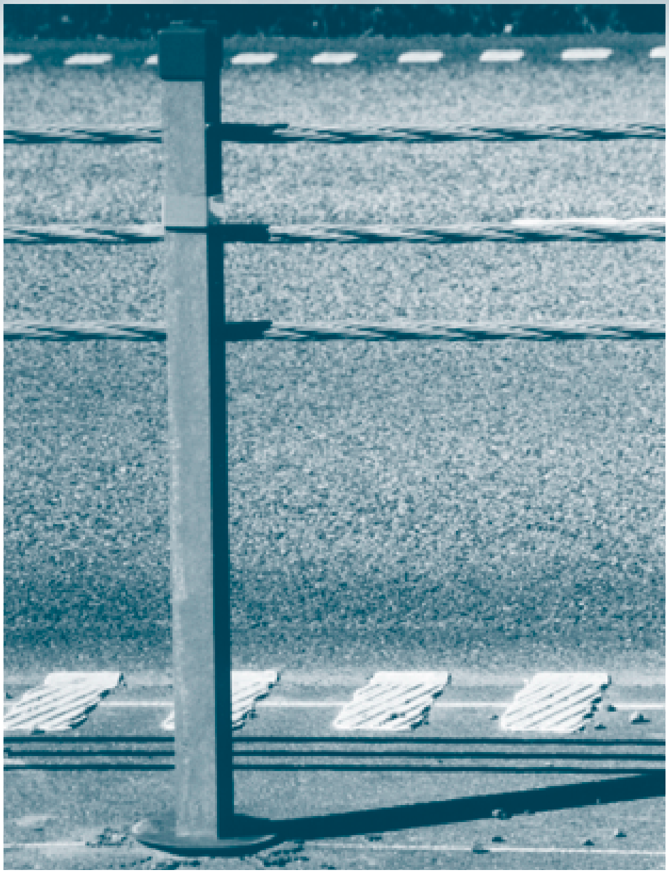

Figure 8. 2+1 cable barrier. The post is easily removed for maintenance. (Sweden)

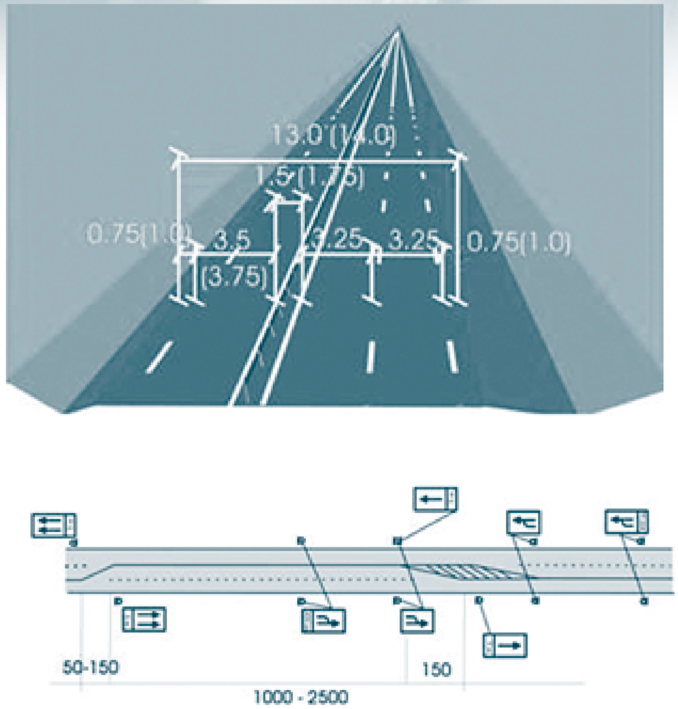

Figure 9. Proposed standard 2+1-cable barrier cross section within existing 13-m (14.2-yd) roadway. (SNRA)

Figure 10. Example of road narrowing in the Netherlands.

Urban Design

The concept of self-organizing roads applies equally to urban roads, where often the design goal is to induce drivers to maintain lower speeds. Streets and roads must be built according to desired functions and driver behaviors. For example, wide arterials encourage higher speeds. Lower speeds can be encouraged on local streets (e.g., at pedestrian crossings, school zones, etc.) by narrowing the road. Figure 10 shows how constricting a local road with barriers, signs, and pavement markings induces the driver to slow down. While traffic-calming techniques are widely used in the United States, European urban road designers sometimes apply such techniques more severely, even to the point of temporarily eliminating one lane. For example, in Europe it is common for a two-lane street to be narrowed for a short segment to a single lane. This compels drivers to either stop or slow down because of the possibility of oncoming traffic in the opposite direction (figure 10).

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CHAPTER 3

Driving Simulators: Roadway Design and Visualization

Driving simulators are often used in Europe to assist in the design of roadways, an application that is far less common in the United States. It is much simpler and cheaper to reject a design element in a driving simulator than to rebuild a road or tunnel to fix design errors. The level of fidelity of the simulators (e.g., degrees of motion, picture size and quality, etc.) at the agencies visited was comparable to the range of simulators in use in the United States at universities and FHWA's Turner-Fairbank Highway Research Center.

Simulators have been used both formally, with controlled experiments to conduct tests of driver behavior and approval of project features, and informally, with highway designers using the simulator to experience alternate roadway plans. For example, at VTI Sweden an informal simulator project was described in which highway designers had planned to visit for one day to view their new designs in the simulator, but stayed for three days and made several design changes based on their simulator experience.

Laerdal Tunnel Project

An excellent example of a formal evaluation of alternate roadway designs used a medium-fidelity driving simulator at SINTEF in Norway. SINTEF was asked to help design the longest tunnel in the world in western Norway (figure 11). Experiments were undertaken to evaluate four tunnel models (figure 12). Results showed that lighting strategies using blue, yellow, and green lights increased driver safety and comfort. A major challenge in constructing long tunnels is reducing driver anxiety, because many drivers feel uncomfortable in this environment. Changes in lighting every 2 km (1.2 mi) reduced driver anxiety. Including some large openings (figures 13 and 14) inside the tunnel also reduced driver anxiety and was useful for emergency operations.

These design strategies have proved to be successful with high ratings of driver comfort in the tunnel and no crashes. In addition, the Laerdal project has won two European lighting awards.

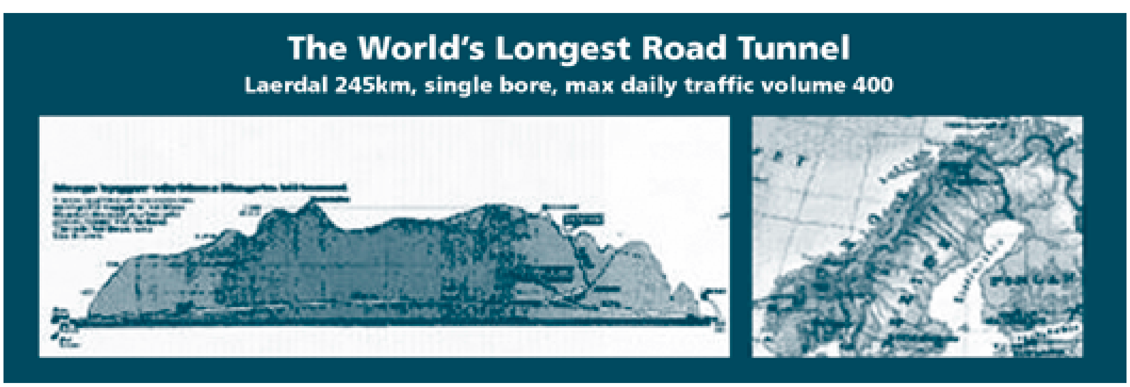

Figure 11. The Laerdal Tunnel project. (SINTEF)

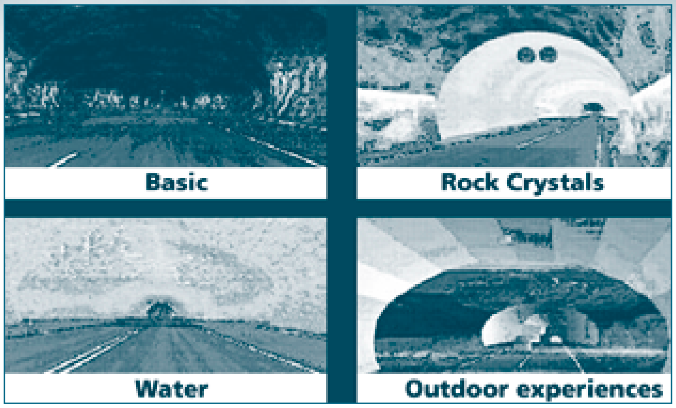

Figure 12. Alternate lighting models for the Laerdal Tunnel. (SINTEF)

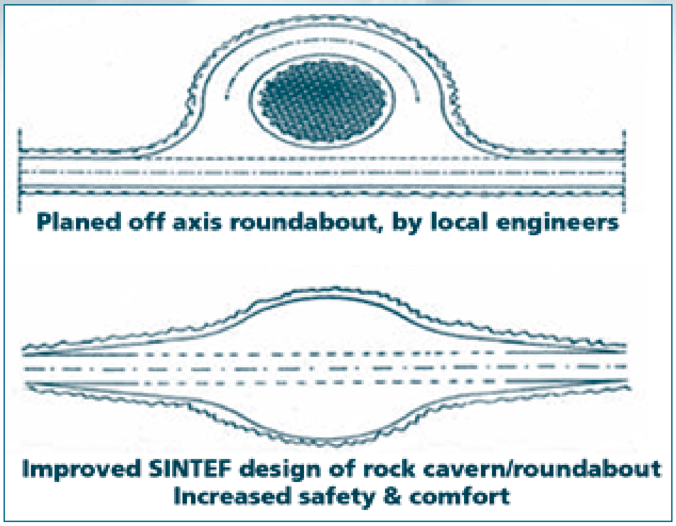

Figure 13. Improved design of rock cavern and roundabout increased safety and comfort. (SINTEF)

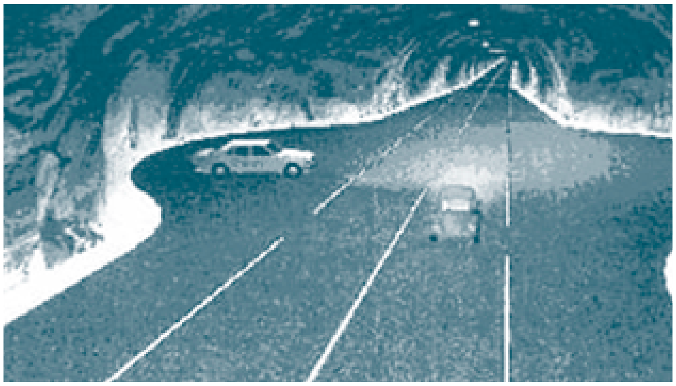

Figure 14. Rock caverns. (SINTEF)

Figure 15. Ernest Huckaby, Tore Knudsen, and Barry Kantowitz discuss SINTEF's mission.

Figure 16. Gunnar Jenssen explains self-organizing roads. (SINTEF)

Figure 17. Scan team members Tom Granda and Leanna Depue ride in the SINTEF driving simulator.

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Figure 18. The Stockholm Ring Road—25-km (15.5-mi) tunnels with underground junctions. (VTI)

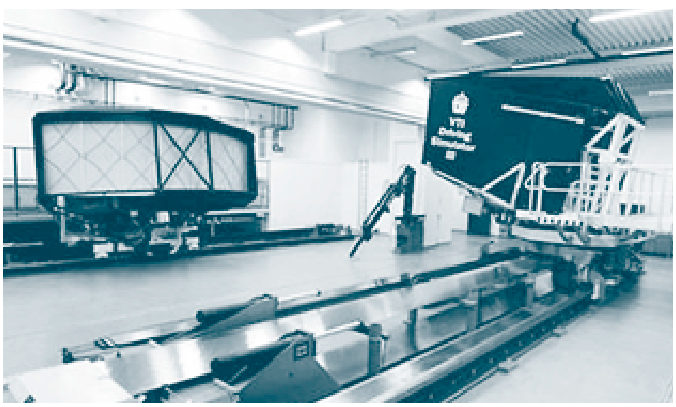

Figure 19. VTI's driving simulator hall. (VTI)

Figure 20. The virtual tunnel defined by combining data from several data sources: drawings, photographs, models, and discussions. (VTI)

Stockholm Ring Road

The Stockholm Ring Road (figure 18) is a major construction project including tunnels and underground junctions. The VTI simulator (figure 19) was used to help design this project. A virtual tunnel was created, based on drawings, photographs, models and discussions (figure 20). Simulation results were helpful in several ways:

- Served as a base for discussions between persons with different responsibilities in the project.
- Provided an excellent tool for positioning signs in the tunnel.
- Allowed improvements in the design in road geometry, lighting, and sign position.
- Checked the appearance of signs and artwork.

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Traffic Systems Studies

The INRETS driving simulator has been used in several projects with a four-step process:

1. Drivers' behaviors are identified in real situations or with the simulator for studying future onboard devices.
2. Results of experiments are used to model drivers' behaviors.
3. New behaviors are implemented in the behavioral traffic simulation model. Modified traffic flow can be simulated and traffic studies focus on issues of capacity and safety.
4. An optional final step consists of studying drivers' behavior in the new modified virtual traffic environment.

An example of this process is contained in the STARDUST project, which evaluates the impact of a lane-keeping system in an urban environment. When lanes are narrow, speed decreases, causing a decrease in system capacity. In the first step, simulator results demonstrated such speed decreases without lane-keeping assistance. In the second step, the lane-keeping system prevented a 15 percent decrease in speed. A traffic study corresponding to step three is now in progress. Table 3 summarizes other simulator studies performed at INRETS.

Table 3. Examples of simulator studies. (INRETS)

AIDA	Goal: Assess in simulation the impacts of the AIDA system on traffic and safety conditions.
ARCOS	Goal: Design new safety functions for managing distance gaps between vehicles; prevent collisions on fixed, stopped, or slow obstacles; prevent off-road crashes; alert vehicle to related crashes/incidents downstream on its route.
DIATS	Goal: Study deployment scenarios of telematic devices in interurban areas. Study features related to legal issues, market demands, and impacts of the introduction of such systems on traffic and safety.
MICADO	Goal: Study an alert anticollision system based on a multisensor. Develop tools for virtual prototyping of such a system.
NOR	Goal: Study a new concept of road infrastructure from the standpoints of user perception and traffic characteristics.
SAM	Goal: Study the impact of a transmission system for alert messages from vehicle to vehicle. Measure the efficiency of the system at the individual level on the driving simulator and at the collective level through simulation studies.
STARDUST	Goal: Study the deployment scenarios for driving aid devices in an urban environment, aspects of social and economic issues, and the impacts of introduction of such systems on traffic and safety.
VOIR	Goal: Extend the use of simulators to cover degraded driving conditions, day and night, because of reduced visibility. Ambient luminosity, secular reflexions, and dynamic light sources are simulated.

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Validity

People drive real cars on real roads; driving simulators create an artificial driving environment. Before results from driving simulators can be safely applied to road design and traffic systems, these results must be validated. Validity is accomplished by comparing simulator data to on-road data. Simulators must be validated anew for each research question. At TNO, an organization with almost 30 years of experience using driver simulators, the following points were made about validation:

- Validity should be defined in relation to a specific research question.
- This depends on the information used to perform the task.
- One does not always need a high-fidelity driving simulator.
- Absolute validity means same effect size in simulator and road data.
- Relative validity means same ranking of effect sizes.

Simulator research provides relative validity more often than absolute validity. What is more important is the ability to predict road behavior from simulator behavior. For example, a common finding is that people drive faster in simulators

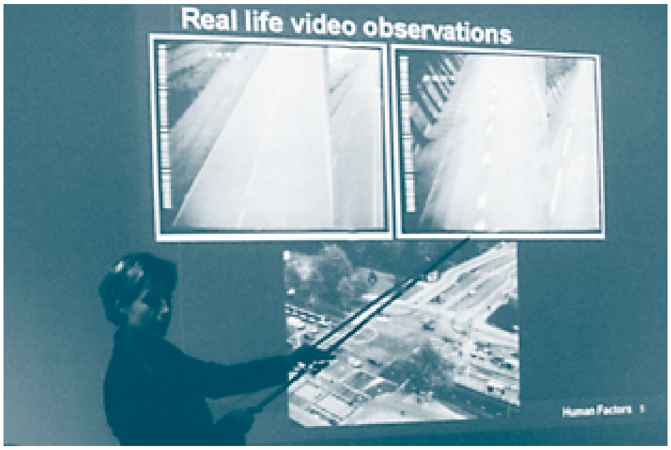

Figure 21. Researcher Selma de Ridder explains driver behavior.

than on the road. One explanation for this finding is that because simulators lack the visual detail of the real world (i.e., the real world has more pixels), drivers attempt to match the optical flow of the real world and so drive faster in the simulator. This lack of absolute validity is seldom a problem because speed corrections can be made when predicting real-world behavior from simulator behavior. For example, if it were known that drivers drive 5 km/h faster in the simulator, the real-world prediction would be obtained by subtracting 5 km/h from the simulator results. Furthermore, in many cases relative validity is sufficient to give useful direction to highway and traffic engineers.

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Influence of Fog on Driving Behavior

This study is an outstanding example of going to great lengths to achieve appropriate simulator validity. It is difficult to study the effects of fog on the road because fog is a rare occurrence. The image generation techniques used to simulate fog have limited realism, however, and most simulator manufacturers have not validated the effects of fog on driver behavior. This INRETS study went to an artificial fog chamber to investigate human perception in daytime and nighttime fog. Visibility of vehicle outlines (daytime) and rear light configurations (nighttime) were empirically evaluated. While the fog chamber has the considerable advantage of producing real fog, its limited dimensions prevent placing moving vehicles inside the chamber. Thus, the researchers reproduced the fog chamber experiments in the simulator to validate various fog image generation techniques. They were able to validate effects for daytime fog, but not for nighttime fog (probably because of the limited luminance range of the simulator projection device). This allowed studies of speed perception and control in daytime fog that offer greater validity than previous simulator fog studies, a most impressive accomplishment.

Figure 22. Researcher Viola Cavallo presents fog simulation results.

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Simulator Fidelity

The fidelity of a simulator is related directly to its cost. Simulators can be purchased for under $50,000 (low fidelity), from $50,000 to $250,000 (medium fidelity), and up to several millions of dollars (high fidelity). Higher prices add a moving base, more screens, better graphics, and faster system response

Figure 23. Barry Kantowitz, report facilitator, participates in meeting on high-fidelity driving simulators.

times (figure 23). If one wishes to simulate vehicle dynamics and control, a high-fidelity simulator (figure 24) is necessary. However, many important driver behaviors are studied successfully in medium-fidelity simulators, especially when driver cognitive behavior and decisionmaking are the objects of inquiry. Thus, medium-fidelity simulators are more cost effective for studying roadway design in most cases. Table 4 shows the benefits and costs among different classes of simulators.

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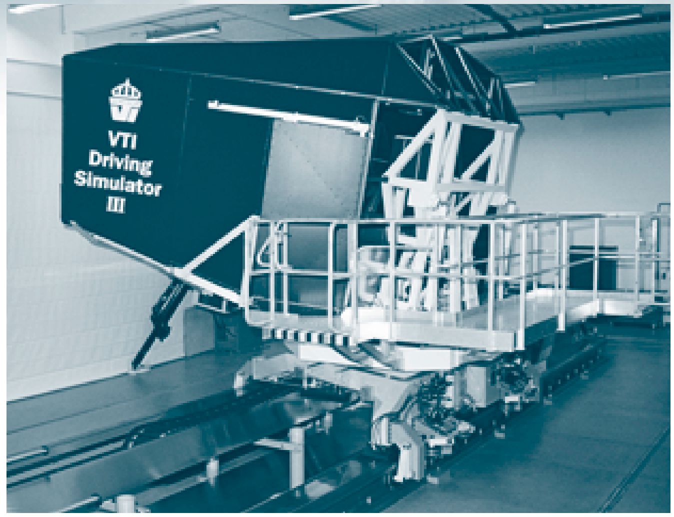
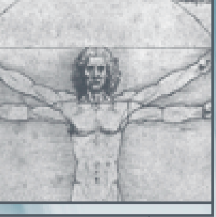


Figure 24. VTI Driving Simulator III.

Table 4. Benefit and cost considerations when selecting a driving simulator.

BENEFITS/COSTS	Low-Fidelity Simulation	High-Fidelity Simulation	On-the-Road Studies
Ability to study relevant driver behaviors	Medium-High	High	Medium
Ability to study range of highway geometrics	High	High	Medium
Ability to study range of traffic conditions	Medium	High	Medium
Control over experimental conditions	High	High	Low-Medium
Degree of realism	Medium	Medium-High	Very High
Relative cost	Medium	High	High
Risk to driver	Very Low	Very Low	Low-Medium



CHAPTER 4

Multidisciplinary Teams

At the University of Helsinki in Finland, the team learned that all fatal crashes in the country are investigated by a multidisciplinary team that includes a police officer, vehicle engineer, traffic engineer, physician, and sometimes a psychologist. The investigation results are documented in an original folder and database with more than 300 variables using a methodology from the Finnish Motor Insurers Centre. Results can vary, depending on the composition of the team. From the examples given, it appeared that the presence or absence of a psychologist on the team could critically alter conclusions and interpretation of data. Considering all perspectives provided by a multidisciplinary team improved the overall research program.

No data were presented on the statistical reliability of this method. Since multidisciplinary crash investigation has been criticized in the United States for lacking such reliability, this caveat must be kept in mind when evaluating European results.

VALT 2003 Method

The Finnish Motor Insurers' Centre (VALT) has developed a coherent set of procedures, including detailed forms to be completed, for traffic accident investigation teams. Two points central to this methodology are (1) the analysis of risk factors, and (2) the composition and responsibilities of the accident investigation team. Two kinds of risk factors are considered. Immediate risk factors are direct, often active, factors that have had an effect in the situation. They include such items as road users' mistakes, faults in the vehicle, and geometric or traffic control device failures. Background factors, by their existence or omission, promote the origin of the event. They include such items as road-user health and motives, vehicle features and loads, road and environmental conditions, and system factors such as laws, enforcement, and road norms. The team deals with the following questions:

- What took place?
- Why did it happen?
- Why were the consequences serious?
- How can the incident be prevented?
- How can the consequences be prevented?

As already noted, a multidisciplinary team is formed for accident investigation. Some of the functions of each team member, as outlined in the VALT 2003 document, are listed below:

All Team Members

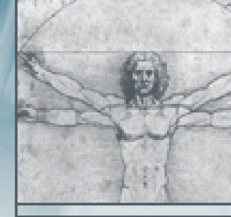
- Act as experts in their own fields on the investigation team.
- Function as contact persons to the authorities and organizations in their own areas of knowledge.
- Clarify the issues raised using the investigation forms in their fields for the accident being investigated.
- Examine other issues in their own areas if the crash investigation requires it.
- Participate in other ways to help the investigation team achieve its objective.

Police Member

- Assembles the investigation team to study the accident.
- Calls in the experts required for the accident investigation.
- Organizes photographs at the accident scene and makes sure required sketches are made at the location.
- Clarifies, especially for the parties involved, the risk factors related to the background, and produces corresponding proposals for improvement.

Vehicle Specialist Member

- Investigates the technical condition of the vehicles involved and the damage caused in the accident.



- Examines the use of safety equipment on the vehicles, and explains, mainly with the physician, the effect of the structure of the vehicle and safety equipment on injuries.
- Makes calculations of the sequence of events and of the preventive possibilities of the accident.
- Clarifies risk factors related to the vehicles and safety equipment, and produces corresponding improvement proposals.

Road Specialist Member

- Investigates, with other members, marks on the road and draws conclusions about the sequence of events.
- Evaluates the effect of the traffic environment on the origin of the accident and its consequences.
- Prepares a sketch of the scene of the accident.
- Explains the association of risk factors—especially the road in relation to the structure, the guidance of the traffic, the traffic environment, the weather and conditions—and produces corresponding improvement proposals.

Physician Member

- Investigates the vehicle and, with the vehicle specialist, the possible sources of injury.
- Investigates, with the police and psychologist, the physical and psychological state of the drivers and pedestrians involved.
- Examines the risk factors related to driving ability.

Psychologist Member

- Investigates, with the road specialist, issues related to the traffic environment and traffic control, and evaluates the actions of the parties involved.
- Investigates, with the police and physician, the psychological state of the drivers and pedestrians, obtains historical information about the health of the parties involved, and evaluates the effect of these on the origin of the accident.
- Functions as a consultant in investigation queries within the team.
- Examines the risk factors related to driving ability and produces improvement proposals.

Thus, information about the accident is collected systematically. This information is evaluated from the viewpoints of team members with different training, experience, and perspectives.

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CHAPTER 5

Speed Management

Everywhere the scan team visited, speed management was a key priority for improving highway safety. The "human" element was also a major consideration in methods to control speed. Countries first designed roadways to achieve the desired speed objective through the functional use of the roadway (self-organizing roads), but road speed management was also achieved through aggressive enforcement and public education.

Self-organizing roads (Chapter 2) help control driver speed. For example, drivers must slow down to enter a roundabout (figure 25).

The 2+1 roadway design discussed in Chapter 2 also has worked well for speed management. It has improved throughput and raised speeds on two-lane roadways. In Finland, travel speeds at low flow rates improved 1 to 2 km/h (0.6 to 1.2 mi/h), with gains of 4 to 5 km/h (2.5 to 3.1 mi/h) for higher flow rates. In Sweden, average passenger car spot speeds on two-lane sections are 4 km/h (2.5 mi/h) faster on a 2+1 roadway with a median cable barrier than on a 13-m (14.2-yd) roadway with wide lanes.

Speed Cameras

In Sweden, Norway, France, and the Netherlands, speed cameras were effective in controlling driver speed (figure 26). Multiple camera boxes were installed in Sweden with the driver unable to determine which box, if any, contained the speed camera, as is done in the United States with red-light-running enforcement cameras. Speeding tickets are sent to the driver of the vehicle if he or she can be identified. The police attempt to match the photograph of the car owner or the spouse stored in the driving licensing system to the speed camera photograph. If there is no match, the case is dropped. In France, installation of 100 speed cameras contributed to a 20 percent reduction in fatalities. In the Netherlands, photos are taken when a vehicle enters and leaves the roadway. Computers calculate the time it takes the vehicle to travel the roadway to determine if the motorist was speeding. This information is automatically forwarded to a processing center, where a notice of fine is mailed the next day. The immediacy of the sanction has a deterrent effect.

Evaluation of automatic speed monitoring in Sweden in 2002-2003 showed several impressive results. Of 4,801 photographed vehicles in 2002 and 9,402 vehicles in 2003, there were 2,565 approved photographs in 2002 and 6,073 approved photographs in 2003. Thus, the number of approved photographs and contact with drivers increased from 54 to 67 percent, primarily because of decreasing technical defects in the photographs. The average crash total decreased from 144.6 before cameras were used to 109.1 after cameras, and the average total of personal injuries decreased from 241.6 to 194.5. Fatal crashes decreased from 9.2 to 4.5 and fatalities from 12.6 to 5.4, although these small samples must be interpreted with caution. Vehicle speed

Figure 25. Roundabout entry in Sweden.

was reduced at the cameras by 8 km/h and by nearly 5 km/h between camera boxes. Socioeconomic calculations revealed a benefit/cost ratio of 3.7. These data reveal that speed cameras are very effective in improving traffic safety.

A pilot study of automatic speed enforcement in Denmark conducted at 20 camera sites and 10 control sites, primarily in the metropolitan cities of Copenhagen and Odense, also found substantial benefits. The Danish Traffic Code requires car owners to provide the name of the driver to the police or to be penalized with a fine. Results showed a 2.4-km/h reduction in speed. During the 12-month test period with equipment in operation about 2 hours a day, 105,000 fines with pictures were sent out. Of these, about 3,200 were taken to court and the police lost only three cases. Based on these pilot results, the Danish Parliament has decided to permanently implement automatic speed control throughout Denmark.

Figure 26. Sign indicating speed camera in Sweden.

Variable Speed Limits

In Finland, variable speed limits were successful in managing driver speed. Speed limits varied according to the season, with lower limits in winter than in summer. The Netherlands changed speed limits dynamically as a function of traffic.

Figure 27. Project Manager Bente Nielsen presents intelligent speed adaptation overview.

Intelligent Speed Adaptation

In Copenhagen, the team learned about a large-scale field operational test of intelligent speed adaptation conducted in Sweden. It used 4,000 test vehicles in Umea, 400 in Borlange, 290 in Lund, and 280 in Lidkoping. The project cost SEK75 million (US$12.7 million), and was conducted jointly by the Swedish National Road Administration and local authorities.

Intelligent speed adaptation presents in-vehicle warning signals (visual, auditory, and in some cases tactual from the accelerator pedal) when the vehicle exceeds the speed limit. Global positioning systems (GPS) were used to provide speed-limit information in Lund, Lynkoping, and Borlange, while roadside transducers were used in Umea. Both private and commercial vehicles were used in the test.

Results showed that drivers liked using the system in urban areas. A clear majority of the drivers believed the speed limit should be honored on 30- and 50-km/h (20- and 30-mi/h) streets, and appreciated the feedback provided by the system. About two-thirds of the drivers wanted to keep the system, if it were free, after the test ended. The drivers raised some interesting points on integrating the intelligent speed adaptation system into the vehicle:

- Users want to see the speed limit displayed inside the vehicle. Of course, this displayed value must match external speed signs.
- In-vehicle speedometers usually present a higher speed, with a margin of up to 15 percent higher than the actual road speed. Thus, the warning signal reacts at too high a speed. Drivers found this conflict to be irritating. This could be easily fixed by replacing the original speedometer with a more accurate speedometer as part of the intelligent speed adaptation system.

A 3-year field test of intelligent speed adaptation is underway in Denmark. It uses 300 volunteer drivers who are customers of a Danish insurance company. It will use auditory feedback if the vehicle exceeds the speed limit by 5 km/h (3 mi/h) combined with digital speed maps. Results may allow insurance companies to adjust rates for customers.

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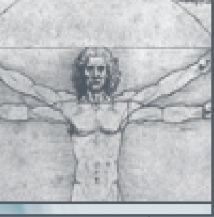


CHAPTER 6

Human-Centered Roadway Analysis and Design

Human-centered design starts with the limitations and preferences of the driver, and then derives appropriate technology from these human principles. This approach has been extremely successful for aviation and is slowly being incorporated into highway design in both the United States and Europe.

Of course, the general principles of human-centered design apply to many of the topics discussed previously. Self-organizing roads depend on human-centered design. The roundabout is a good example. Instead of expecting the human driver to stop at a signalized intersection, the roundabout minimizes the need for stopping. People inevitably make errors. Good design anticipates these errors and minimizes their consequences. An error at a signalized intersection can result in a 90-degree crash with drastic consequences to drivers and vehicles. A crash at a roundabout results in an angle much less than 90 degrees with consequently smaller risk and damage to vehicles and occupants.

The cable barrier in a 2+1 roadway also demonstrates human-centered design. Instead of blaming drivers for incorrectly crossing the median, the barrier prevents such a driver error. The Laerdal Tunnel lighting design is human centered because it anticipates and minimizes driver anxiety and boredom inside the tunnel. At TNO in the Netherlands, the team learned about efforts to reduce the number of words on traffic signs because drivers have a limited ability to assimilate language while driving down the highway.

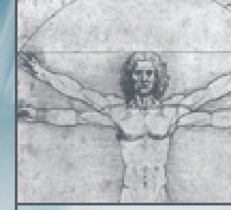
Two excellent examples of human-centered design and analysis were presented at SINTEF in Norway: design for pedestrians and human-based standards for geometric roadway design. The program of active-children pedestrian design derives from the Norwegian preference of having children walk to school instead of being driven by their parents. Observational studies of pedestrian crossings revealed that raised zebra crossings and signalized zebra crossings are best for young children. Studies of human reaction time helped formulate standards for geometric roadway design.

HUMANIST

HUMANIST is the acronym for a European Community (EC) project titled HUMAN-centered design for Information Society Technologies. The project started in March 2004 and will last 48 months; its EC subvention budget is EUR5.36 million (US$6.8 million). This project has two important lessons for U.S. research: the creation of a Virtual European Center to accomplish the work, and the selection and justification of the topic and research goals.

In Europe, competencies in human factors and cognitive science are scattered across several countries, so it is essential to integrate research capacities. This was accomplished by forming a network of excellence involving 108 researchers and 27 Ph.D. students at 22 research institutes. An annual program of researcher exchange and shared infrastructure promotes a harmonious research program with complementary and coordinated approaches. Integrating activities include the following:

- Promote the mobility of researchers and codirection of Ph.D. students.
- Share experimental infrastructure, such as driving simulators.
- Establish an electronic internal network to share knowledge quickly.



The research goals reflect the importance of driver information and communication systems, as well as advanced driver assistance systems. The new in-vehicle technologies will alter the traditional role of the driver. It is unclear how drivers will react to new mappings of allocation of function in which the vehicle becomes more of a partner to the driver and in some cases can introduce control actions automatically (e.g., an automated cruise control slowing the vehicle). Sharing of vehicle control, while common in aviation, is a revolutionary procedure in driving. Airplane pilots have extensive training and retraining to work effectively with automated systems. Most vehicle drivers lack such training and may not be as skilled in interacting with systems as pilots who have been carefully selected and trained. Human-centered design will be applied to such specific areas as the following:

- Identification of driver needs in relation to intelligent transportation systems (ITS)
- Evaluation of ITS potential benefits
- Joint-cognitive models of driver-vehicle-environment of user-centered design
- Impact analysis of ITS on driving behavior
- Development of innovative methodologies to evaluate ITS safety and usability
- Driver education and training for ITS use
- Use of ITS to train and to educate drivers

Both the approach of HUMANIST and its content should be of considerable interest to U.S. researchers and administrators. Plans for internal mobility of researchers and Ph.D. students are impressive. The inclusion of cognitive models of driving, an area only now being developed in the United States, as an integral component of the overall research plan merits careful examination.

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Children's Pedestrian Behavior

Since 1997, children in Norway have started school at age 6. Because Norway wishes to promote active children who walk or bike to school if possible, it is important to understand how children interact with traffic on their way to and from school. Thus, the Norwegian Public Roads Administration sponsored an observational study in Trondheim focusing on children ages 6 to 12.

The study used video recording as its observational method and examined zebra crossings, streets, and joint walkways for pedestrians and cyclists separated from car lanes. Results showed that the youngest children were most careful and follow the rules. Children walking alone, however, deviate from the rules more than children in a group. Young children had more difficulty deciding when to cross at a zebra crossing near a roundabout, although they did clearly understand how to push the button to obtain a green light. Additional research conducted on this topic used on-street interviews and surveys, qualitative in-depth interviews, and questionnaires for different age groups.

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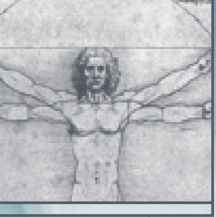


CHAPTER 7

Cognitive Models

The need for cognitive models of the driver was emphasized at the University of Helsinki in Finland, TNO in the Netherlands, and INRETS in France. Present methods and data permit us to know what drivers do, but not why they do it. Employing analytic methods to produce cognitive driver models will help us to develop an understanding of driver behavior. Such models are useful in several ways. They are part of microscopic traffic models that can be validated by observing traffic flow. Indeed, the driver models used for this purpose at INRETS are so detailed that they are referred to as "nanoscopic" driver models. Cognitive models are also useful when implementing human-centered design and analysis. Instead of having to perform a new experiment to answer each new question, the model itself can generate answers.

COSMODRIVE

Figure 28 shows the representation of driver cognitive processes developed at INRETS. This model is written in Smalltalk, a computer language well suited for artificial intelligence applications. INRETS has a considerable financial investment in this model, which has been developed over 10 years with a 3-year break because of other internal priorities. Only now are validation studies being conducted for the model. This delay in validation illustrates how important continuous funding is for high-risk, high-reward basic research. The team congratulates INRETS for seeking and funding such a long-term goal. INRETS researchers make an important distinction between behavioral models and cognitive models. A behavioral model focuses on what the driver does. Such models are often descriptive because they can predict behavior but cannot explain it.

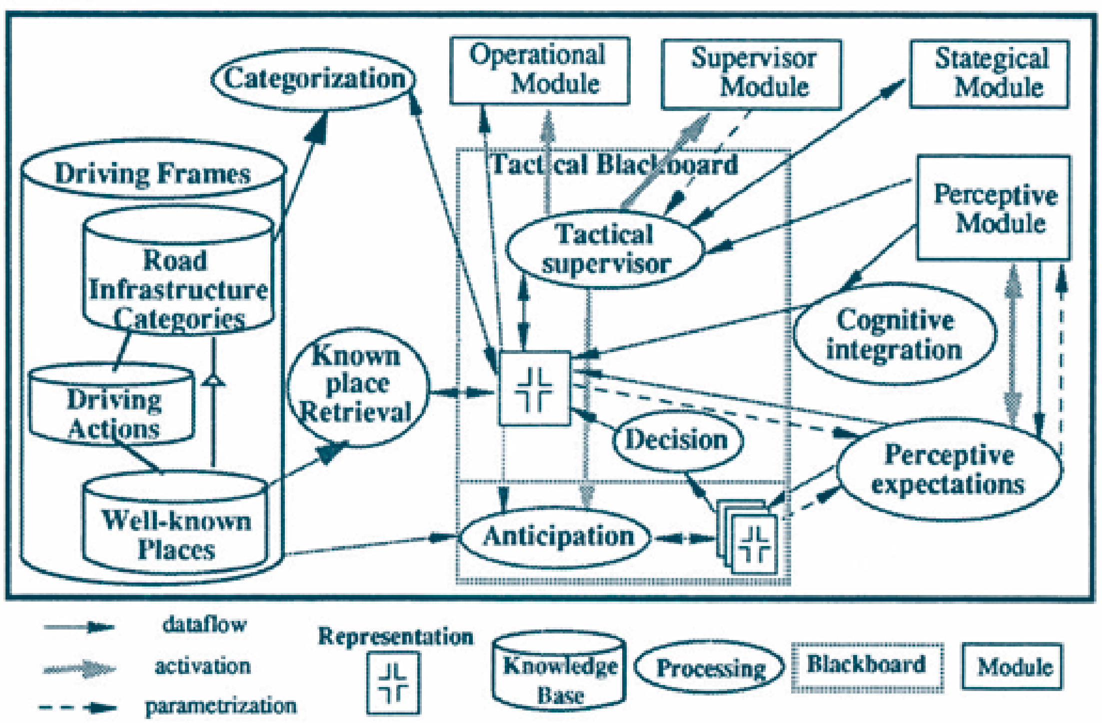
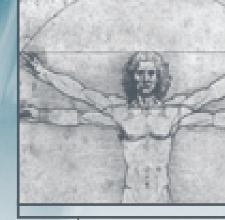


Figure 28. The COSMODRIVE cognitive model. (INRETS)



A cognitive model focuses on the mental activities carried out during driving. It explains why the driver undertakes certain actions. The researchers believe this level of analysis is necessary to understand human errors and difficulties, and to design driving assistance adapted to driver needs.

Many American human factors researchers would not entirely accept this dichotomy because behavior and cognition can be combined in a single model. In such a unified model, the control of the vehicle is called inner-loop control. The control of cognitive activities that guide the strategic reasons for undertaking a trip is called outer-loop control. The FHWA Interactive Highway Safety Design Model (IHSDM) quantitative driver model can combine behavioral and cognitive aspects, although most research to date has focused on inner-loop control.

The COSMODRIVE (Cognitive Simulation MOdel of the DRIVEr) model uses a computer to simulate human cognitive processes. As a computational model, it draws on a rich history of artificial intelligence models created by a team of computer scientists, psychologists, and engineers. Frames are used as the formalism for representing driver knowledge extracted from experimental results and controlled observation. Each mental process is implemented as a cognitive agent. The greatest strength of COSMODRIVE is its ability to make quantitative predictions. Because the emphasis is on outer-loop control, the model is less concerned with the behavioral mechanics of keeping the vehicle on the road.

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Driver Behavior Model

Figure 29 shows the driver behavior model that guides human factors research at TNO. It draws on the tradition of qualitative information-processing descriptions of behavior and emphasizes control of the vehicle. Research guided by this model stresses behavioral measures such as the following:

- Performance indicators: speed, headway, time to collision, steering angle and frequency, lateral placement, detection time, reaction time
- Visual attention: viewing time, number of glances
- Workload: peripheral detection task, subjective ratings, physiological measures
- Comfort: vertical acceleration, subjective ratings
- Acceptance: questionnaires

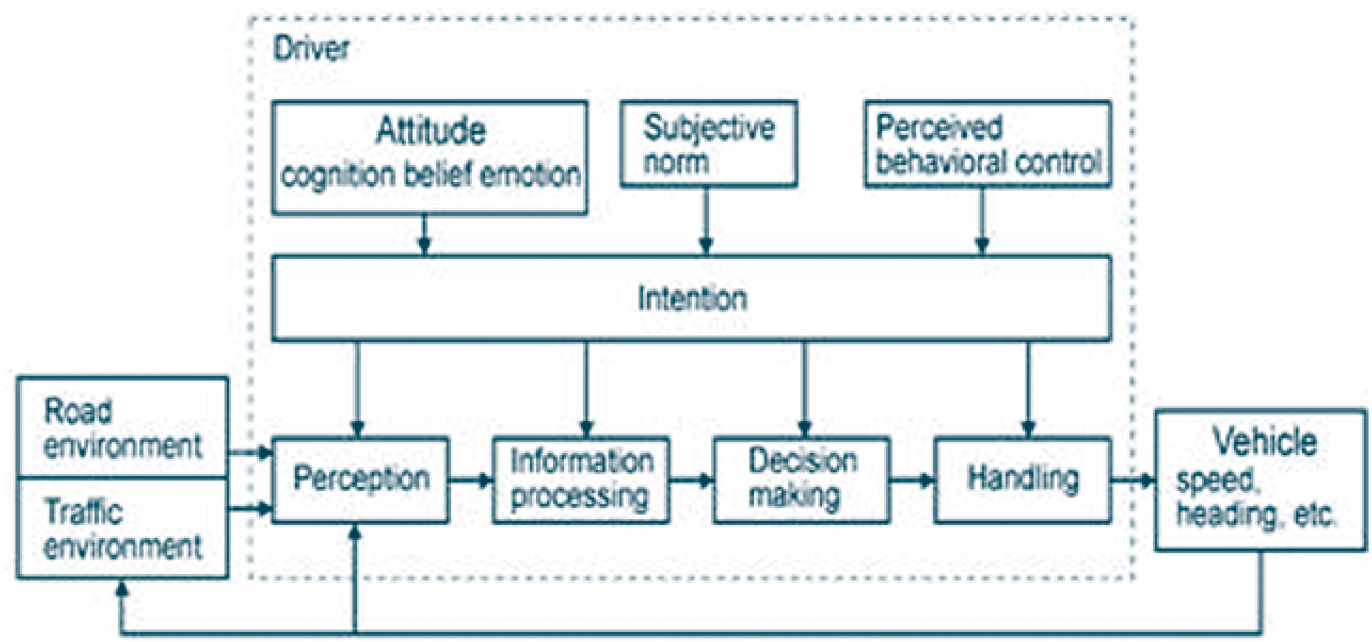

Figure 29. Driver behavior model used at TNO.

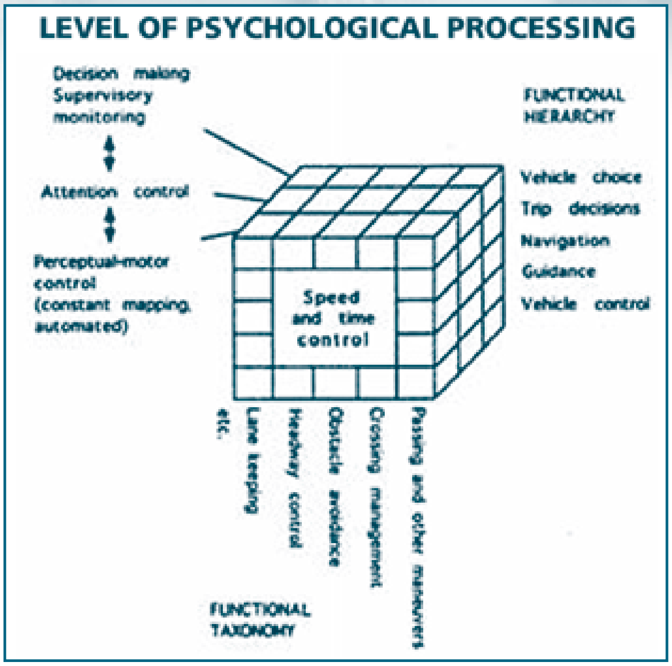

Figure 30. The driver task-cube model.

Hierarchical Driver Task-Cube Model

At the University of Helsinki, Professor Heikki Summala emphasized the importance of using behavioral models to guide roadway safety research. Indeed, in Europe a formal discipline called "traffic psychology" uses such models. Figure 30 shows one such model that relates the level of psychological processing to a functional hierarchy of vehicle control and a functional taxonomy of strategic behavior. These functional divisions are similar to inner- and outer-loop control in quantitative driver models based on the mathematics of control theory. Attention control is a key psychological process involved in driver distraction, overload, and underload.

This model has the advantage of combining the two types of control to make a variety of predictions from high-level trip decisions to low-level vehicle control. It is very helpful in providing a framework that integrates many results about behavioral adaptation, risk taking, maintenance of safety margins, and allocation of attention. Although the model is quite useful, it does not offer the quantitative predictions of a computational model.

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CHAPTER 8

Top-Down Leadership

The team was impressed with the coordination between research goals and the highest levels of government in Europe. The best example of this is Sweden's Vision Zero. The Swedish Parliament passed an act specifying that the country's official long-term traffic safety goal is zero fatalities. This provides extremely clear direction to researchers and agencies responsible for highway design and operation. Unlike the road safety guiding philosophy in the United States that tolerates a certain number of fatalities and injuries and mandates only a desired percentage decrease in death and destruction, Sweden has stated that no one should die on a Swedish road. SWOV in the Netherlands expressed similar goals. In France, road safety was a campaign issue in the national elections, and President Jacques Chirac has put major emphasis on road safety as a national priority. In general, Europe appears to be ahead of the United States in directing drastic improvements in roadway safety.

Vision Zero

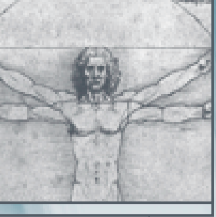
In October 1997, the Swedish Parliament passed a road traffic safety bill mandating a long-term goal that no one should be killed or seriously injured on a Swedish roadway. The design and operation of the Swedish road system, therefore, must be adapted to meet this new requirement. This is a drastic departure from the traditional cost-benefit analysis that controls road safety in the United States. It is based on the ethical principle that everything possible must be done to preserve human life so that safety dominates cost. For example, Vision Zero means that the best technical solution to improve safety should be implemented rather than the least expensive solution or even the most cost-effective solution.

In the United States, primary responsibility for safe driving rests with the driver. The Federal government provides standards and regulation for the design and construction of both vehicles and roadways, but it is up to the driver to avoid errors such as running off the road, entering an intersection when the signal is red, and crossing lanes into opposing traffic. The infrastructure is seldom fault tolerant, so a driver who makes a serious error is likely to suffer a serious consequence and also may inflict high costs on other nearby roadway users.

The Swedish National Road Administration is taking several steps to achieve Vision Zero. Speed limits have been reduced in built-up areas where pedestrians and bicyclists are in proximity, and principles of self-organizing roadways are used to encourage drivers to follow the lower speed limits. Roundabouts are used to calm traffic and minimize collision risk. Vehicle safety standards are promulgated with collision tests. Cable guardrails are being installed to replace conventional guardrails. Speed limits on national roads are under review because lower speeds are safer and safety dominates all other factors, including mobility. Seatbelt reminders are under consideration. Speed surveillance cameras are being installed. Companies are encouraged to include safety in their travel policies.

Vision Zero assumes that drivers will make errors and shifts responsibility to the roadway designers and operators, who are required to anticipate human error. For example, the center cable barrier in a 2+1 road protects the driver by absorbing the energy of a collision with the barrier without deflecting the vehicle back into traffic. It also protects other drivers by preventing incursions into oncoming traffic.

Vision Zero is an attractive concept that might have useful application in the United States. In August 2003, the Intelligent Transportation Society of America (ITS America) embraced an American version of Vision Zero that also includes a concept of zero delay. One potential challenge for applying Vision Zero here is related to cost. Vision Zero eschews cost-benefit tradeoff analysis that might imply a need for unlimited funds or unlimited time to achieve the goal. This can be illustrated by an extreme hypothetical example. Suppose the entire U.S. Department of Transportation budget was allocated to implementing Vision Zero. No funds would be available to support



air traffic control and inspection of aviation maintenance, so aviation fatalities would increase. Indeed, it is logically possible that the benefit of lives saved on the highway could be less than lives lost in the air, so this purist realization of Vision Zero could cause a net increase in total lives lost. Perhaps a U.S. version of Vision Zero could avoid this paradox by aiming for equality of fatalities and injuries across transportation modalities so driving would be as safe as flying. While not as conceptually attractive as no highway fatalities, this modified goal would still represent a huge improvement in traffic safety.

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Sustainable Safety

The vision for sustainable safety originated in the Netherlands in the early 1990s. The vision states that the next generation will not have a road system that tolerates thousands of people killed and tens of thousands injured in the Netherlands each year. It is based on three design principles: functionality, homogeneity, and predictability.

Functional use means that roads should not be used for unintended purposes, e.g., urban streets should not support the higher speeds used on arterials. This implies a need to categorize roads so that appropriate design standards can be applied to each part of the road network.

Homogeneity means that design characteristics should remain constant along a roadway. Road design should foster appropriate driver behavior, which is related to the concept of self-organizing roads discussed earlier in this report.

Predictability refers to both the road and the behavior of road users. For example, the unexpected appearance of a bicyclist or pedestrian on a road would be a violation of predictability.

Implementation of sustainable safety will require substantial human factors research relating the driver to the roadway. Explicit marketing efforts will be needed to gain public acceptance of the concept.

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Executive Direction

In 2002, President Chirac of France decided to make road safety one of three major initiatives to be undertaken during his five-year term. The result was a spectacular decrease in traffic fatalities. Compared to 2002 when 5,731 people were killed, 2003 spared 1,511 lives on French roadways. The main reduction in fatalities involved rural areas (-21.6 percent), interstate roads (-27.0 percent), pedestrians (-27.7 percent), drivers (-23.8 percent), and people between 25 and 44 years old (-23.7 percent). These are outstanding results, especially when compared to the United States, where fatalities increased over the past five years.

Several factors contributed to the success in France. Safety measures such as enforcing strict fines for not wearing seatbelts or helmets, using cell phones while driving, and driving under the influence of alcohol were increased, with strong media coverage of these changes. Speeding violations increased by 19 percent, including 8 percent from installation of automated camera ticketing. Almost 4.5 million driver points were assessed, an increase of 43.8 percent. Revocation of driver licenses increased 54.2 percent.

It seems clear that making traffic safety a national priority is effective. It is problematic to assess how this might work in the United States.

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CHAPTER 9

Implementation

While the scan team obtained many useful ideas during its European study, six specific topics were selected as potential high-reward areas of opportunity in the United States:

- Self-organizing roads
- Use of driving simulators
- Multidisciplinary crash investigation
- Human-centered roadway analysis and design
- Top-down leadership commitment
- Speed management

Since the team's observations in each of these six areas have been summarized in previous chapters of this report, this section only briefly sketches some implementation goals. More details can be found in the scan tour implementation plan.

Self-Organizing Roads and Evaluation of 2+1 Roadway Design

This is possibly the most important implementation recommendation formulated by the team. Widespread adoption of this new road design standard has great potential for improving safety and mobility on two-lane roads with only modest capital costs compared to four-lane roads. Implementation objectives are to promote awareness of self-organizing roads, assemble a group of States willing to implement this new road design, facilitate the flow of information from Europe to these States, and establish an evaluation mechanism to compare costs and benefits of the 2+1 design.

Driving Simulators: Roadway Design and Visualization

While the state of the art in driving simulators in the United States is at least equal to that in Europe, Europeans have gained substantial benefits by using their driving simulators to assist in the design and visualization of roadways. It is far easier and cheaper to identify design flaws in simulators than to rebuild roads and tunnels. Implementation objectives are to promote awareness of this use of driving simulators among the road-design community, establish a mechanism to aid road designers in using driving simulators, and demonstrate and document the benefits of this new application of driving simulators.

Multidisciplinary Crash Investigation Teams

The VALT standardized investigation protocol used in Finland is based on teams representing several disciplines. The implementation objective is to determine how and if such multidisciplinary teams could be used in the United States.

Human-Centered Roadway Analysis and Design

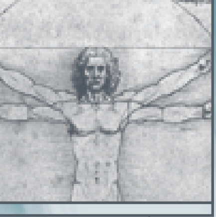
The United States has recognized the need to better understand the factors contributing to crashes, and to develop tools such as cognitive models that can predict driver behavior when roadway and vehicle configurations are altered. The European research community has organized to coordinate research efforts and create virtual networks, such as HUMANIST, that facilitate fundamental long-term research efforts. The implementation objectives are to assess benefits and opportunities for coordinating long-term research and development in the United States, and to explore whether human factors and cognitive model research and development can be a focus for an innovative mechanism for long-term coordinated research. A further objective is to increase awareness of one particular human-centered roadway project: the pedestrian research findings from SINTEF in Norway.

Top-Down Leadership Commitment

Great strides in road safety improvement have been accomplished in Europe because of commitments from the highest levels of government. Implementation objectives are to share European models of top-down leadership, and provide key governmental leaders with critical facts and information that will motivate a similar leadership commitment in the United States.

Speed Management

The team observed several effective tools in Europe that managed speed successfully. Implementation objectives are to increase awareness of these tools and strategies, and to promote the involvement of the insurance and motor vehicle manufacturing industries in intelligent speed adaptation systems.



APPENDIX A

Scan Study Site Information

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VTT Technical Research Centre of Finland is a private contract research organization that has been around for more than 60 years. With its 3,000 employees, VTT provides a wide range of technology and applied research services for its clients, private companies, institutions, and the public sector. Economic turnover in 2003 was EUR213 million (US$256.7 million), 70 percent of which was external income and 30 percent basic governmental financing.

VTT carries out three types of activities: commercial activities, joint projects, and self-financed projects. Commercial activities are performed according to direct demand from customers. Joint projects are initiated on the basis of need and typically are funded jointly by VTT, companies, research financers, and other research parties. Self-financed research consists of technology-based strategic research projects aimed at developing competitiveness, and acquiring knowledge and expertise to meet the future needs of customers.

The organization's wide expertise in behavioral studies allows it to study interactions of the driver/operator, vehicle, and environment. It typically analyzes human machine interfaces that must be designed so users can operate the system easily and without increased risk to traffic safety. Studies involve evaluations of driver behavior, development of advanced driver assistance systems, and investigation of road and railway crashes, to name a few.

Projects underway include the following:

- A review of the speed-crash relationship for European roads
- Efficient improvement of road safety
- Developing transport policy assessment methods
- Performance of composition technology in road or other traffic area structures
- Human-centered design for information society technologies (HUMANIST)
- Development of transport system impact assessment methods
- Development of road marking and road user behavior research methods

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Academic research and higher learning that rests on it are the two basic functions of the University of Helsinki. Research conducted in facilities and separate institutions covers all fields represented at the university.

About 50 percent of the research is financed by the university's operating expenditure, and the rest is financed by external funds. Most external funds still come from public sources, such as the Academy of Finland, National Technology Agency of Finland, Ministries, and European Union (EU). In the past few years, the commercialization of research results has reached an important position, and new forms of cooperation with business and industry have been developed.

The activities and interests of the Traffic Research Unit cover

practically all areas of traffic psychology and road safety, although since the early 1970s it has specialized in driver behavior theory, drivers' task analysis, and experimental real-life, on-road research.

Projects underway include the following:

- Driver behavior on major two-lane roads of different design, with specific emphasis on causes of head-on crashes.
- Effects of the use of a hand-held versus hands-free mobile phone on safety and understandability of the message while driving in the city.
- The role of exposure and visibility in deer-vehicle crashes.
- Driving behavior in two countries that largely differ in traffic and safety culture (Finland and Russia), looking at drivers who cross the border.
- Driving ability of different patient groups, as well as theoretical analysis of driver behavior.

The Traffic Research Unit also contributed to the Finnish governmental traffic safety plan for 2001-2005.

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The acronym SINTEF stands for the Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology (now the Norwegian University of Science and Technology).

SINTEF is the largest independent private research organization in Scandinavia. Fields of research are technology, natural science, medicine, and social science. The organization's turnover in 2003 was NOK1.7 billion (US$261 million). Contracts for industry and the public sector generated more than 90 percent of income, while almost 8 percent came as basic grants from the Research Council of Norway.

SINTEF works with all modes of transport, and research deals with the local, national, and international levels. Examples of research areas are development and design of infrastructure for all transport modes, maintenance of such infrastructure, transport planning, traffic management, safety, logistics, and ITS systems of the future.

Projects underway include the following:

- **Transport planning**—Activities include data collection, development of models, and analysis of demand for person and freight transport on national, regional, and local levels, as well as cost/benefit analysis and estimation of effects of changes in transport infrastructure. SINTEF also develops tools for route planning and fleet management for business customers.
- **Traffic management**—Traffic management is both general and detailed regulation of the transport infrastructure to create an efficient, safe, and environmentally friendly traffic flow.
- **Road planning**—Road planning includes the spectrum from analysis and evaluation to find the right alternatives on a preliminary stage to detailed plans and solutions, including specification and design of road elements and the landscape. The goal for road planning is to improve transportation effectiveness, safety, and environmental conditions by generating solutions giving positive total results for the community.
- **Traffic safety**—Safety in the transport field includes road, railway, ship, and air transport. The national transport plan has a goal of reducing the number of people killed in traffic to 200 per year, compared to the present level of about 300 people.

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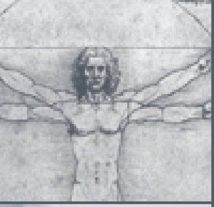
The Danish Transport Research Institute (DTF) is a research institute under the Danish Ministry of Transport. The purpose of the institute, established in August 2000, is to strengthen transport research with special focus on such fields as transport safety and risk, as well as transport economics and modeling.
The institute has a broad research basis, and activities are planned with special focus on the interdisciplinary aspects of transport problems. In these research fields, DTF carries out academic research, applied research besides working with innovation, consultancy services, and communication of know-how with a view to making the results of research and development available for practical exploitation.
Projects underway include the following:

- **Distractions in the traffic environment**—Study of



whether distractions along roads and inside cars may have an influence on traffic safety, with special focus on advertising signs.

- **Arterial Streets Towards Sustainability (ARTISTS) project**—Holistic analysis of problems and methods for improving traffic safety, environment, mobility, etc., on major arterial streets in European towns.
- **Accident Investigation Board (HVU)**—Participation in the National Accident Investigation Board.
- **Social characteristics of road users involved in crashes**—Study based on combining information from some crash databases and databases on income, education, and other relevant social parameters.
- **Use of IT systems**—Study on the use of IT systems, especially mobile phones, in heavy vehicles and the effect on traffic safety.
- **Intelligent speed adjustment as a traffic safety technology**—Ph.D. project on the effect on traffic safety of various crash prevention technologies in cars.
- **Road users in urban areas**—Ph.D. project on traffic in cities of the future, particularly elderly drivers.
- **Transport system of the future**—Study of road users' need and requirement for traffic safety, mobility, and accessibility in future traffic, with special focus on elderly road users and survey of ongoing developments.
- **Methods for influencing car drivers' choice of speed**—Test of variable signposting and interviews with car drivers on the investigation and speeding in general.

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VTI, the Swedish National Road and Transport Research Institute, is a public national research institute organized under the Ministry of Industry, Employment, and Communications. Since 1975, VTI has been located on the university campus in Linköping, some 200 km south of Stockholm. In 1998, VTI opened a branch office in Borlänge, where the headquarters for the Swedish National Road Administration and Banverket (the National Rail Administration) are located. This establishment demonstrates the institute's desire to deepen contacts with its largest clients.

VTI performs advanced applied research and development aimed at contributing to the national transport policy objective for sustainable development. The Swedish National Road Administration is the principal client. Extensive research and development are also conducted for the Swedish Agency for Innovation Systems (Vinnova), and to an increasing extent for the EU. Other clients include the National Institute for Communications Analysis (SIKA), Banverket, Civil Aviation Administration, Swedish Environmental Protection Agency, road contractors, and the automotive industry.

Projects underway include the following:

- **TREE**—An EC project with the aim to stimulate cooperation and more efficient use of laboratory resources for road and transport research in Europe.
- **HARMONOISE**—An EC project to develop methods to predict community noise levels from road and railway traffic. VTI takes part in the project.
- **AGILE**—An EC project with two general aims: to help the elderly to continue to drive safely for as long as possible, and to develop knowledge to establish rational EU policies for delivering certification of fitness to drive.
- **Driver licensing in Ghana**—Development of a national program for driver examination and licensing in Ghana.
- **TRAINER**—An EC project aimed at improving young drivers' skills and training.
- **ADVISORS**—An EC project on advanced driver assistance and vehicle control systems.
- **REFLEX**—An EC project to develop a new methodology of road construction and rehabilitation using steel reinforcement fabrics, with a goal of making road structures more cost effective by extending their lifetimes.

TNO Human Factors

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TNO is the abbreviation for the Dutch Nederlandse Organisatie voor toegepast-natuurwetenschappelijk onderzoek. The English name is the Netherlands Organization for Applied Scientific Research. In 1930, the Dutch Parliament passed the TNO Act, which regulates applied scientific research in the Netherlands. TNO was established by law in

1932. A revised and updated TNO Act became operative in May 1986.

TNO Human Factors develops knowledge focused on human behavior and performance in demanding environments. The organization applies this knowledge to the innovation of processes, products, and services for the Netherlands' armed forces, private enterprise, and government. In 2004, TNO Human Factors had a turnover of EUR16.5 million (US$20.8 million). Fifty percent of this turnover related to projects for the Netherlands Ministry of Defense, including explorative research and concrete projects.

A primary focus area is that the safety and efficiency of today's road traffic is highly dependent on human behavior. Traffic fatalities and road congestion make it clear that the present system does not function optimally. It is possible to influence driver behavior by structural changes in traffic control strategies, road design, and vehicle characteristics. Knowledge of driver perception of road environments can be applied to radically change roadway categories and improve safety. Human reaction and adaptation to modern road traffic control systems is quantified by experimentation in instrumented cars and driving simulators. Specifications for intelligent driver support systems such as navigation and collision avoidance systems are developed on the basis of knowledge about traffic participants' reactions to these systems.

Projects underway include the following:

- **Visual perception and road design**—Basic perceptual processes in road traffic, legibility and comprehensibility of roadside information, relation between design characteristics and road user behavior, and principles of self-explaining road design.
- **Traffic control systems**—User requirements for dynamic traffic information and control systems, and modeling of behavioral and safety effects of these systems.
- **Driver support systems**—Cognitive ergonomics of in-vehicle supports, assessment of visual and mental load, modeling expected behavioral and safety consequences of supports, and normalization and standardization of supports.
- **Driver skills**—Interaction between individual characteristics and the design of roads, traffic information and control systems, support systems, and the effects of stressors and other impeding factors on driver performance and safety.

SWOV—Institute for Road Safety Research

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SWOV is an independent scientific institute with an objective to contribute to road safety by means of scientific research and dissemination of the results.

Anticipatory research has always played an important role in analyzing basic road safety problems and arriving at possible solutions. This research also contributes to improving road safety. During the next few years, SWOV will carry out anticipatory research on the following 10 subjects:

- Road safety explorer
- Infrastructure and road crashes
- Analysis of the relationship among speed, speed variation, and crashes
- Measures for speed management
- Choice of route in a road network
- Recognizable layout and predictable behavior
- Novice drivers and driver training
- Effects of education and information campaigns
- Optimal investments
- Use of information in decisionmaking on road safety

Projects underway include the following:

- **EU SafetyNet project**—The project aims to collect data on crashes and casualties in all 25 EU member states. The data will be made available through the Internet, allowing comparison on an international level.
- **SUNflower continuation**—The goal of the original study was to discover what had made the road safety policies of three countries (Sweden, the United Kingdom, and the Netherlands) so successful. The method and results of the first study will be used to analyze the road safety problems in a number of other countries. The goal is to determine the most effective measures. Meanwhile, the continuation study has started under the name of SUNflower+6. In addition to the original three SUNflower countries, six more countries will take part in this study: Catalonia (Spain), Czech Republic, Greece, Hungary, Portugal, and Slovenia.

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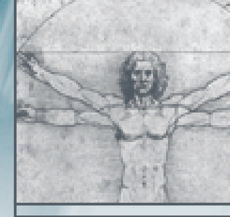
www.noehumanist.org

The French National Institute for Transport and Safety Research was created by interministerial decree on September 18, 1985. INRETS is a state-financed scientific and technological body under the dual administrative supervision of the Ministry of Research and the Ministry of Transport. The institute's activities involve such diverse fields as economics, sociology, psychology, physiology, ergonomics, biomechanics, acoustics, mechanics, mathematics, computer science, and electronics.

Projects underway include the following:

- **Road safety**—crash analysis, prevention, road users' protection, and rescue
  - Analysis of the road system and its components (man, vehicle, infrastructure)
  - Factors and consequences of road crashes
  - Biomechanics and road user protection
  - Road safety policies, education, regulation, incentive strategies, and penalties
- **Driving aids**—information, assistance, and automation
  - Intelligent systems, driving aids, and automated highways
  - Modeling and simulation for driving case studies
  - Urban and interurban guided transport systems
  - A technological approach to safety, security, and quality
  - Telecommunications and the new information technologies in transport
- **Transport networks and services**
  - Modeling and traffic management in transport networks
  - Intermodality and multimodality in passenger transport
  - Freight intermodality
  - Socioeconomic analysis and assessment of infrastructures and networks
  - Transport professionals
  - Sustainability and environment
- **Transport and the environment**
  - Sustainable mobility in large conurbations
  - Electric and hybrid vehicles and power components
  - The dynamics of guided systems and their maintenance



APPENDIX B

Scan Study Site Agendas

Finland Itinerary

Monday, June 14
a.m. Finnish Program (Helsinki)
p.m. Working Lunch (Helsinki)
p.m. Finnish Program/ Site Visit (Helsinki)

Tuesday, June 15
a.m. Finnish Program (Helsinki)
p.m. Working Lunch (Helsinki)
p.m. Finnish Program (Helsinki)

Juha Luoma June 11, 2004 1 (1)
Roadway Human Factors International Scanning Tour to Finland
PROGRAM (Monday June 14, 2004)
VTT Building and Transport (Lämpömiehenkuja 2 C, Espoo)

8:30 a.m.	Welcome to VTT *(Research Manager Heikki Kanner)*
8:45 a.m.	Human Factors research at VTT Building and Transport *(Chief Research Scientist Juha Luoma)*
9:00 a.m.	Road markings *(Senior Research Scientist Veli-Pekka Kallberg)*
9:25 a.m.	Winter maintenance *(Research Scientist Mikko Malmivuo)*
9:50 a.m.	Grade crossings *(Senior Research Scientist Veli-Pekka Kallberg)*
10:15 a.m.	Coffee break
10:45 a.m.	Variable message signing *(Senior Research Scientist Pirkko Rämä)*
11:10 a.m.	Road weather information service *(Research Scientist Anna Schirokoff)*
11:40 a.m.	Intelligent speed adaptation *(Senior Research Scientist Harri Peltola)*
12:05 p.m.	Traveler information service *(Research Scientist Merja Penttinen)*
12:30 p.m.	Lunch
1:30 p.m.	Shuttle bus leaves to Pasila, Helsinki
2:00 p.m.	Visit to Finnra's Traffic Information Centre
4:00 p.m.	Shuttle bus leaves to the hotel

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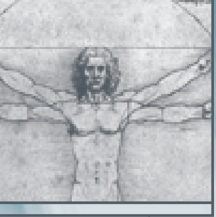


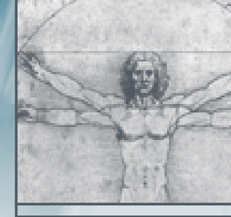
Norway Itinerary

Wednesday, June 16

a.m.	Norwegian Program/ Site Visit (Trondheim)
p.m.	Norwegian Program/ Site Visit (Trondheim)

Program June 6 at SINTEF

8:45 a.m.	Opening of the meeting and a short presentation of the participants from SINTEF and the U.S. Panel
9:00 a.m.	*Research Director Tore Knudsen:* Presentation of our department, our HF staff, visions, goals and cooperation with other professionals (topic 5)
9:20 a.m.	*Senior Behavioral Scientist Gunnar Jenssen:* Presentation of research projects concerning the interaction of in-vehicle and roadway technologies and the utility of self-organizing roads (topic 1)
9:50 a.m.	*Behavioral Scientist Trine M. Stene:* Presentation of a project where cognitive models of the driver and results of HF research projects will be incorporated into manuals and guidelines for road design and traffic regulations (topic 2)
10:15 a.m.	*Research Engineers Liv Ovstedal/Eirin Ryeng:* Presentation of a project concerning children's behavior in traffic and the importance for roadway design and traffic regulations (topic 6)
10:45 a.m.	Break—walk to the driving simulator
11:00 a.m.	*Senior Behavioral Scientists Gunnar Jenssen and Terje Moen, Research Engineers Terje Giaever and Hans Skjelbred:* Presentation of the driving simulator and projects concerning driving behavior and roadway design (topic 3) • Testing of different designs of roundabouts • Measures of driver's reaction times related to new roadway design (Soknedal) • Simulator road design of E-39, Orkdalsvegen
12:00-1:00 p.m.	Luncheon—SINTEF
1:00-3:00 p.m.	Guided tour to two road construction projects. *Chief Engineer Svein T. Pedersen* • E39-Orkdalsvegen, *Ann J. Tinnmannsvik* • E6-Melhus, *Gunnar Knagg*
3:00-3:30 p.m.	End of the meeting—time to say goodbye



Sweden Itinerary

Thursday, June 17
a.m. Swedish Program (Linkoping)
p.m. Working Lunch (Linkoping)
p.m. Swedish Program (Linkoping)

Friday, June 18
a.m. Swedish Program/ Site Visits (Linkoping)
p.m. Working Lunch/ Site Visits (Linkoping)

Study visit by the Roadway Human Factors & Behavioral Safety International Scanning Tour, USA

June 17-18, 2004

Guests: Michael Trentacoste, *FHWA Co-Chair, FHWA Turner-Fairbank Highway Research Center;* Kevin Keith, *AASHTO Co-Chair, Missouri Department of Transportation;* Dr. Barry Kantowitz, *Report Facilitator, Transportation Research Institute, University of Michigan;* Dr. Leanna Depue, *Missouri Safety Center, Central Missouri State University,* Dr. Thomas Granda, *FHWA Turner-Fairbank Highway Research Center;* Ernest Huckaby, *Office of Transportation Operations, FHWA;* Bruce Ibarguen, *State Traffic Engineer, Maine Department of Transportation;* Wesley Lum, *Division of Research and Innovation, California Department of Transportation;* Terecia Wilson, *Director, Safety Office, South Carolina Department of Transportation;* Jake Almborg, *ATI, Inc. Delegation Coordinator;* Mats Petersson, *SNRA*

Hosts: Dr. Urban Karlström, *Director General,* and Dr. Hans Erik Pettersson, *Research and Marketing Director, Region Goteborg*

Meeting room: Vättern

Thursday, June 17

9:00 a.m. Welcome and introduction to VTI
Dr. Urban Karlström, Director General

9:15 a.m. Introduction of U.S. Delegation
Mr. Michael F. Trentacoste and Mr. Kevin Keith

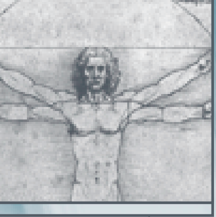
9:30 a.m. Overview of VTI human factors research within road design and vehicle systems
Dr. Hans Erik Pettersson and Dr. Lena Nilsson

10:00 a.m. Road safety and safety trends on the national rural road network
Dr. Göran Nilsson

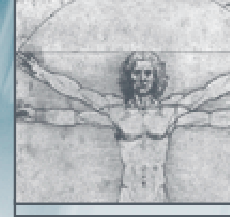
10:20 a.m. Coffee

10:30 a.m. Presentations of research in road design measures for safety
- Road equipment
  Dr. Sven-Olof Lundkvist
- Experiences of development of roundabouts in urban and rural areas
  Mr. Jörgen Larsson
- New road design: 2+1 roads
  Mr. Arne Carlsson

12 Noon Lunch at the Lilla Skafferiet



1:00 p.m.	Presentation of the VTI driving simulator *Dr. Staffan Nordmark*
	The VTI driving simulator as a tool for road design *Mr. Mats Lidström*
1:30 p.m.	Demonstration of the VTI driving simulator and presentations of other resources for human factors research as the VTI instrumented car, etc. *Dr. Staffan Nordmark, Mr. Mats Lidström, Dr. Lena Nilsson, Ms. Ulla Kaisa Knutsson*
2:30 p.m.	Research and experiences of milled rumble strips *Ms. Anna Anund*
	VTI recommendations for road design based on studies of old drivers' needs *Mr. Per Henriksson*
3:10 p.m.	Coffee Break
3:20 p.m.	Examples of other studies; roadwork furnituring, transition curves *Dr. Lena Nilsson and Mr. Sven Dahlstedt*
3:40 p.m.	Discussion and summing up of the day *Dr. Urban Karlström, Dr. Hans Erik Pettersson, Dr. Lena Nilsson, Mr. Sven Dahlstedt, Dr. Staffan Nordmark, Mr. Mats Lidstrom, Mr. Jörgen Larsson and Mr. Arne Carlsson*
6:30 p.m.	Dinner hosted by the U.S. Panel at Stangs pm & Co.
Friday, June 18 **9:00 a.m.-3:00 p.m.**	The Swedish National Road Administration, SNRA, Region Southeast, will be host to site visits to rural and urban sections with new design features in the Southeast Region *Mr. Mats Petersson, SNRA and Mr. Arne Carlsson, Mr. Jörgen Larsson and Ms. Ulla Kaisa Knutsson, VTI*



Denmark Itinerary

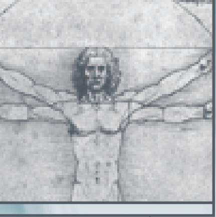
Monday, June 21

a.m. Danish Program (Copenhagen)

p.m. Danish Program (Copenhagen)

Roadway Human Factors & Behavioral Safety International Scanning Tour Programme

9:00-9:15 a.m.	Welcome and programme *Kurt Petersen, DTF*
9:15-9:45 a.m.	Presentation of the Scanning Tour
9:45-10:00 a.m.	Introduction to Danish Transport Research Institute (DTF) *Kurt Petersen*
10:00-10:30 a.m.	Coffee break
10:30-11:30 a.m.	Intelligent Speed Adaptation *INFATI/Bente Schmidt Nielsen, University of Aalborg* *ISA/Christer Hydèn, Technical University of Lund*
11:30 a.m.-12 noon	Other speed management options Variable speed signs *Lotte Larsen, DTF*
12 noon-1:30 p.m.	Lunch break
1:30 p.m.-3:00 p.m.	Mini-workshops: • Collision avoidance—A safety tool for the driver? • Analysis of conflicts in a complex traffic environment—Analysis method



The Netherlands Itinerary

Tuesday, June 22
a.m. Dutch Program (Soesterberg)
a.m. Working Lunch (Soesterberg)
p.m. Dutch Program (Soesterberg)

Wednesday, June 23
a.m. Dutch Program/Site Visits (Leidsche Rijn)
p.m. Working Lunch/Site Visit (Leidschendam)
p.m. Dutch Program/Site Visits (Leidschendam-Rotterdam)

France Itinerary

Thursday, June 24
a.m. French Program (Lyon-Bron)
p.m. Working Lunch (Lyon-Bron)
p.m. French Program (Lyon-Bron)

INRETS Provisional Programme

INRETS, Lyon Bron, 25 Avenue Francois Mitterrand—
case 24, 69675 Bron cedex
Contact person: Mrs. Corinne Brusque, Phone +33 (0)4 72 14 24 36

M. Jean Pierre Medeville, INRETS Deputy Managing Director and INRETS Director for International Affairs; Mrs. Claire Plantie Niclause, INRETS Deputy-Director for International Affairs; and M. Jean Luc Ygnace, Research Engineer in ITS socio economic assessment, will attend part of the meeting.

9:00 a.m. Welcome and presentation of the INRETS Lyon-Bron site
M. Dominque Cesari, Director of the INRETS, Lyon Bron site

9:15 a.m. Laboratory Ergonomics & Cognitive Sciences in Transport
Presentation of the Laboratory
Mrs. Corinne Brusque, Head of LESCOT

9:45 a.m. In-depth analysis of driving activity for the assessment of elderly drivers' competency: a first step for the standardization of road tests.
- Comparison between elderly drivers involved or not involved in accidents during the last three years.
- Comparison between elderly and younger driver's behaviour during turn across traffic intersections.

Mme Claude Marin-Lamellet, Mme Catherine Gabaude, Mme Laurence Paire-Ficout

11:00 a.m. Road infrastructure and mental load evaluation from Heart Rate Variability measurement
M. Andre Chapon

11:30 a.m. Mental model of the driving situation: dual task effect on event versus road characteristics detection
Mme Beatrice Baillly

12 noon Cognitive models of the drivers
Mrs. Helene Tattegrain-Veste, M. Thierry Bellet

12:30 p.m. An example of integration of European research capacities on Human Factors: the "Humanist" network of excellence
Mrs. Corinne Brusque

1:00 p.m. Lunch

2:30 p.m. Presentation of the laboratory for biomechanics and crash test and visit of its installations on the INRETS—Lyon Bron site
M. Dominique Cesari

4 p.m. End of meeting

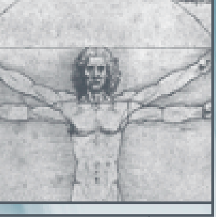
Friday, June 25

a.m.	French Program (Paris/Arcueil)
p.m.	Working Lunch (Paris/Arcueil)
p.m.	French Program (Paris/Arcueil)

INRETS—Paris-Arcueil

2 avenue du General Malleret Joinville
94114 Arcueil cedex (RER station Laplace–line B)
Contact person: Mrs. Claire Plantie Niclause + 33 (0)6 81 48 67 64

9:00 a.m.	Pick up at the Laplace RER station (INRETS vehicles)
9:15 a.m.	Welcome and presentation of the INRETS Arcueil site *Mrs. Marlene Choukroun, Head of communication*
9:25 a.m.	Presentation of INRETS scientific programmes *Mrs. Helene Fontaine, Director of the INRETS–Arcueil site*
9:45 a.m.	Urban transport policies impact on health *M. Sylvain Lassarre*
10:30 a.m.	Driving simulator usages in INRETS *M. Pierre Gauriat*
11:15 a.m.	Visit of installations: driving simulator *M. Pierre Gauriat*
12:15 p.m.	Lunch, Restaurant Le Pavillon Montsouris, 20 rue Gazan, 75014 Paris, +33 (0)1 43 13 29 00 with: M. Jean Panhaleux, French Ministry of Transport-Deputy Director for Traffic and Road Safety; M. Guy Bourgeois, INRETS Managing Director; M. Mathieu Goetzke, French Ministry of Transport, Directorate for Scientific and Technical Affairs-Head of international relations
2:30 p.m.	User behaviour and visual perception in fog—fog simulation *Mrs. Viola Cavallo*
3:15 p.m.	Simulator use and road crossing by aged pedestrians *M. Regis Lobjois*
4:00 p.m.	In-depth analysis of road situations and driver activities. The cases of intersections crossing and motorway driving *Mme Farida Saad*
4:45 p.m.	Discussion
5 p.m.	End of visit



APPENDIX C

Team Members

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APPENDIX D

Amplifying Questions

The scan team wishes to learn how countries plan, develop, and conduct human factors studies and research pertaining to roadway design and operations, and how the results are put in practice by design and traffic engineers and others responsible for roadway infrastructure and operations. The team wishes to meet highway researchers, research psychologists, and others involved with human factors research of highway design and operations, as well as transport managers responsible for considering and incorporating human factors results in the actual practice of roadway design and operations.

The team wishes to spend about equal times in discussions with these two groups. The team further desires to spend equal time within these two groups in discussions, as well as viewing actual practices. Accordingly, time would be spent with researchers in viewing simulators and other research methods. For roadway engineers and practitioners, the team would benefit from viewing how human factors research is incorporated into their work products, such as roadway design and traffic control devices plans, or from visiting actual roadways where human factors studies resulted in a redesign or special treatment to the roadway.

The following are the amplifying questions for the scan study:

Topic 1: To assemble information on how human factors (HF) issues are considered in the practice of design and operations of roadways.

A. How is HF research used to evaluate existing or new roadway design and operation countermeasures to improve safety and mobility?
B. What specific HF research projects have yielded the highest payoff for roadway design and operations?
C. How do in-vehicle and roadway technologies interact?
D. Have any HF research projects demonstrated the utility of the concept of self-organizing roads?

Topic 2: To find out how human factors issues are communicated to roadway design and operations engineers and practitioners and how users communicate their needs.

A. How are HF research needs defined and prioritized?
B. How are results of HF research incorporated into national roadway design and operations standards, guidelines, and recommended practices?
C. What specific HF research projects, if any, have had consideration given to implementation/deployment strategies as part of the research process?

Topic 3: Driving simulators as a human factors research tool.

A. What specific projects have used simulators to study roadway design and operations?
B. How have simulators been used to evaluate traffic control devices or warning devices?
C. How have simulator studies been validated?
D. What levels of simulator fidelity are necessary for this research?
E. How do "good results" on simulator studies get used in real-world situations?
F. How have simulators been used to train novice or older drivers?

Topic 4: Other human factors research methods useful in studying roadway design and operations.

A. What are the relative costs and benefits of focus group, test track, on-road, and simulator HF research?
B. What specific projects, if any, have used cognitive models of the driver?
C. What human factors research methods are used?

Topic 5: To learn how the human factors research process is sustained and improved.

A. How are HF research projects monitored for quality?
B. Is there a methodology to predict anticipated benefits

resulting from HF research?

C. How is the proficiency of the HF staff maintained and improved?

D. How does HF staff interact with other roadway design and operations professionals?

E. What are the vision and goals of the HF group?

F. What is the role, if any, of multidisciplinary teams in the development of research topics and plans?

Topic 6: To discover human factors success stories that can be used to quickly improve roadway design and operations.

A. What specific HF projects have yielded the highest payoff?

B. What roadway design and operation improvements have been implemented based on HF research?

C. Are there any specific human factors research results that can be applied to the following:

- Users (pedestrians, bicyclists, persons with disabilities, older and younger drivers, etc.)
- Traffic control devices (signs, markings, etc.)
- Operations (intersections, speed management, etc.)

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FHWA/US DOT (HPIP)
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