Proceedings of the Conference
STRATEGIC HIGHWAY RESEARCH
PROGRAM AND TRAFFIC SAFETY
ON TWO CONTINENTS in
Gothenburg, Sweden,
September 18 – 20, 1991, Part 1

- Opening
- Motorist Information Systems
- Accident Studies and Safety Management
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– Opening
– Motorist Information Systems
– Accident Studies and Safety Management
Papers presented at the seminar were as follows:
Getting SHRP's Products Into Practice (Kulash, D J);
Federal Highway Administration's Role in SHRP Product Implementation (Carlson, E D);
Research Collaboration: New European Initiatives (Cornelius, D F);
Changes in Driver Behaviour as a Function of Handsfree Mobile Phones: A Simulator Study (Alm, H and Nilsson, L);
Variable-Message Signs: Legibility and Recognition of Symbols (Colomb, M, Hubert, R, Carta, V, Bry, M and Dore-Picard);
Man and His Wheel: Cognitive and Perceptual Aspects (Wierda, M);
Measuring Effects of Variable Message Signing on Route-Choice and Driving Behaviour (van der Horst, R, Janssen, W and Korteling, J E);
Acceptance and Benefits of the Berlin Route Guidance and Information System (LISB) (Sparmann, J M);
Automobile Navigation Safety Issues (French, R L);
Economic Appraisal and Ranking of Road Safety Measures (Hedman, K-O);
Traffic Safety on Two Continents - A Ten-Year Analysis of Human and Vehicular Involvements (Lamm, R and Choueiri, E M);
Description and Testing of a Side Impact Protection System (Ivarsson, J);
Methodology for the Development of Collision Avoidance Strategies Based on Accident Data (Campbell, K L and Massie, D L);
Critical View of Traffic Safety Management in a Developing Country: A Case Study of Jordan (Katamine, N M and Hiyassat, M A S);
Comprehensive Safety Management (Collins, M S);
Future of Road Traffic Management: Urgent Global Harmonization Will Affect All Governments (Olin, A R);
Implications of Litigation for Safety Research (Knaff, P R);
Impact of Litigation on the Federal Highway Administration's Highway Safety Program (Werncrantz, S E).
PREFACE

The Swedish Road and Traffic Research Institute (VTI) and the US Transportation Research Board (TRB) of the National Research Council were jointly organising this international conference. The objective was to cover the present and future road research with special emphasis on the Strategic Highway Research Program (SHRP), as well as the research concerning drivers and vehicles as related to highway safety.

SHRP is a fully funded, $ 150 million (US), five year program of research directed at asphalt, concrete and structures, highway operations, and long term pavement performance.

In the sessions on roads there were presentations which highlighted differences between European and US practices and needs, and the discussions were concentrated on how to promote international involvement in SHRP and application of its research, within the areas of Asphalt, Long Term Pavement Performance (LTPP), Highway Operations and Concrete and Structures.

In the different road safety sessions there were presentations of actual research in different countries and discussions of the differences that exist between Europe and the USA, trying to explain the reasons for them and examine whether they are reasonable and acceptable.

Linköping October 1991

Kenneth Asp

Proceedings of the Conference STRATEGIC HIGHWAY RESEARCH PROGRAM AND TRAFFIC SAFETY ON TWO CONTINENTS in Gothenburg, Sweden, September 18-20, 1991:

VTI RAPPORT 372A, Part 1
- Opening
- Motorist Information Systems
- Accident Studies and Safety Management

VTI RAPPORT 372A, Part 2
- Roadside Safety Features
- Human Engineering, Training and Traffic Safety

VTI RAPPORT 372A, Part 3
- Operational Roadway and Workzone Research
- Safety and Mobility of Older Drivers

VTI RAPPORT 372A, Part 4
- Simulation and Measurement of Operator and Vehicle Performance
- Strategies to Increase the Use of Restraint Systems

VTI RAPPORT 372A, Part 5
- Asphalt
- Highway Operations and Concrete and Structures

VTI RAPPORT 372A, Part 6
- Long-Term Pavement Performance
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Critical View of Traffic Safety Management in a Developing Country; A Case Study of Jordan
N M Katamine and M A Salem Hiyassat, University of Jordan, Jordan

Comprehensive Safety Management
Michael S Collins, Ergotrans, United Kingdom

Future of Road Traffic Management: Urgent Global Harmonization Will Affect All Governments
Arthur R Olin, Sweden

Implications of Litigation for Vehicle Safety Research
P Robert Knaff, KB & A, Inc, USA

Impact of Litigation on the Federal Highway Administration’s Highway Safety Program
Steven E Wermcrantz, Federal Highway Administration (FHWA), USA
STRATEGIC HIGHWAY RESEARCH PROGRAM AND TRAFFIC SAFETY ON TWO CONTINENTS

Gothenburg, Sweden

September 18-20, 1991

WEDNESDAY SEPTEMBER 18

OPENING

9.00 - 11.30

Chairman: Mrs Gunnel Färm, Director General, Swedish Road and Traffic Research Institute (VTI), Sweden

Opening Speeches
Mr Kjell A Mattsson, Governor of the Province of Gothenburg and Bohus, Sweden
Mrs Gunnel Färm, Director General, Swedish Road and Traffic Research Institute (VTI), Sweden

Research and the International Transportation Community
Dr C Michael Walton, Chairman, Executive Committee, Transportation Research Board, National Academy of Sciences and Engineering, USA

Transport Policies and Traffic Safety in an Integrated Europe
Dr Jan C Terlouw, Secretary General of the European Conference of Ministers of Transport (ECMT), France

Getting SHRP's Products Into Practice
Dr Damian J Kulash, Executive Director, Strategic Highway Research Program (SHRP), USA

FHWA Role in SHRP Implementation
Mr E Dean Carlson, Executive Director, Federal Highway Administration, USA (presented by Charles L Miller)

Recent European Initiatives in Research Collaboration
Mr David F Cornelius, Director, Transport and Road Research Laboratory (TRRL), United Kingdom
Chairman: Tord Lindahl, Swedish Road and Traffic Research Institute (VTI), Sweden

The Asphalt Model: Results of the SHRP Asphalt Research Program
D R Jones and T W Kennedy, University of Texas, Austin, Texas, USA

SHRP Asphalt-Aggregate Mix Analysis System
T W Kennedy and R J Cominsky, University of Texas, Austin, Texas; E T Harrigan and R B Leahy, Strategic Highway Research Program, Washington, USA

An Investigation of Asphalt-Aggregate Interaction and Their Sensitivity to Water
C W Curtis, L M Perry and C J Brennan, Auburn University, Auburn, Alabama, USA

Thermal Fatigue Cracking of Asphalt Concrete Pavements — An Experimental Approach
N W Jackson, T S Vinson, and V Janoo, Oregon State University, Corvallis, Oregon, USA

Development of Test Methods for a Performance-Related Bitumen Specification
D A Anderson, The Pennsylvania State University, USA

Characterization of Self Assemblies in Asphalt by NMR Spectroscopy and High Performance Gel Permeation Chromatography
P A Jennings, J A S Pribanic, T M Mendes, and J M Smith, Montana State University, Bozeman, Montana, USA

Asphalt Research in The Netherlands
P C Hopman, Delft University of Technology, Delft; P A J C Kunst, Netherlands Pavement Consultants bv, Hoevelaken; A C Pronk and J M M Molenaar, Roads and Hydraulic Department of Rijkswaterstaat, Delft, and A A A Molenaar, Delft University of Technology, Delft, The Netherlands
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WEDNESDAY SEPTEMBER 18

MOTORIST INFORMATION SYSTEMS

13.00 - 17.00

Chairman: Conrad Dudek, Texas A&M University, College Station, USA

Changes in Driver Behaviour as a Function of Handsfree Mobile Phones: A Simulator Study
Håkan Alm and Lena Nilsson, Swedish Road and Traffic Research Institute (VTI), Sweden

Variable-Message Signs: Legibility and Recognition of Symbols
Colomb, Huberg, Bry, Carta, Laboratoire Central des Ponts et Chaussées, Dore-Picard, Institute National de Recherche sur les Transport et leur Sécurité, France

The Man and His Wheel: Cognitive and Perceptual Factors
Marcel Wierda, Traffic Research Centre, The Netherlands

Measuring Effects of Variable Message Signing on Route-Choice and Driving Behavior
Richard van der Horst, Wiel Janssen and J E (Hans) Korteling, TNO Institute of Perception, Soesterberg, The Netherlands

Acceptance and Benefits of the Berlin Route Guidance and Information System (LISB)
Jürg M Sparmann, SNV Studiengesellschaft Nahverkehr mbH, Berlin, Germany

Automobile Navigation Safety Issues
Robert L French, R L French & Associates, Ft Worth, Texas, USA

(16.30-17.00 Short business meeting of TRB Committee A3B08, User Information Systems - visitors welcome)
WEDNESDAY SEPTEMBER 18

ACCIDENT STUDIES AND SAFETY MANAGEMENT

13.00 - 17.00

Chairman: Gunnar Carlsson, Swedish Road and Traffic Research Institute (VTI), Sweden

Economic Appraisal and Ranking of Road Safety Measures
Karl-Olov Hedman, Swedish Road and Traffic Research Institute (VTI), Sweden

Traffic Safety on Two Continents - A Ten-Year Analysis of Human and Vehicular Involvements
Rüdiger Lamm, University of Karlsruhe, Germany and Elias M Choueiri, North Country Community College, New York, USA

Description and Testing of a Side Impact Protection System
Jan Ivarsson, Volvo Car Corporation, Sweden

A Critical View of Traffic Safety Management in a Developing Country; A Case Study of Jordan
N M Katamine and M A Salem Kiyassat, University of Jordan, Jordan

Development of a Collision Topology for Evaluation of Collision Avoidance Strategies
Kenneth L Campbell, Daniel F Blower, Dawn L Massie, Patricia F Waller and Arthur C Wolfe, UMTRI, Ann Arbor, Michigan, USA

Comprehensive Safety Management
Michael S Collins, Ergotrans, United Kingdom

The Future of Road Traffic Management: Urgent Global Harmonization Will Affect All Governments
Arthur R Olin, Sweden

Implications of Litigation for Highway and Motor Vehicle Safety Research
P Robert Knaff, K B and Assoc., Silver Spring, MD, USA

The Impact of Litigation on the Federal Highway Administration’s Highway Safety Program
Steven E Wermcrantz, Federal Highway Administration, USA
THURSDAY SEPTEMBER 19

ROADSIDE SAFETY FEATURES

9.30 – 17.30

Chairman: Thomas Turbell, Swedish Road and Traffic Research Institute (VTI), Sweden, co-Chairman: Hayes E Ross, Texas Transportation Institute (TTI), USA

Roadside Safety - A Knowledge-based Approach
Abdelkrim Ramache, University of Newcastle Upon Tyne, United Kingdom

Safety Barriers Systems in Germany
Bernd Wolfgang Wink, Volkmann & Rossbach GmbH & Co KG, Germany

Side Impact Crash Testing of Highway Safety Hardware
John F Carney and Malcolm H Ray, Vanderbilt University, Nashville, USA

Safety Assessment of Highway Designs
Malcolm H Ray, Standard & Ray Assoc., Franklin, USA (presented by J F Carney)

The Importance of Using a Range of Vehicle Weights when Testing a Crash Cushion
Michael G Dreznes, Energy Absorption Systems Inc, Chicago, USA

Reliability of Results of Crash Testing Small and Medium Size Cars into Two Segmented Concrete Barriers
Francis P D Navin, University of British Columbia, Vancouver, Canada

13.00 Luncheon

Safe Road Design as Limit State
Francis P D Navin, University of British Columbia, Vancouver, Canada

Status of the United States Efforts in Promoting International Harmonization of Test and Evaluation Procedures for Roadside Safety Features
Harry W Taylor, FHWA, Washington DC, USA

Occupant Risk by Different Severity Criteria
Vittorio Giavotto, Politecnico di Milano, Milan, Italy

Hayes E Ross Jr, Texas Transportation Institute, Texas A&M University, USA

Status of the European Work on Harmonizing Requirements and Test Procedures for Roadside Safety Features
Jacques Boussuge, SETRA, France

WORKSHOP on International Harmonization
Status reports from the ongoing update of the US test procedures and the development of a European Standard within CEN
(This workshop will be followed up in non-public informal meeting between TRB committee A2A04(2) and CEN/TC226/WG1 on Friday morning)

VTI RAPPORT 372A
THURSDAY SEPTEMBER 19

HUMAN ENGINEERING TRAINING AND TRAFFIC SAFETY

9.30 - 13.00

Chairman: Alison Smiley, Human Factors North Inc, Toronto, Canada

Development of a Methodology for Measuring Improper Seat Belt Use
Brian A Grant, Road Safety Directorate, Transport Canada, Jocelyn Pedder and Nicholas Shewchenko, Biokinetics and Assoc. Ltd, Ottawa, Canada

Mandatory Hazard Perception Testing as a Means of Reducing Casualty Crashes Amongst Novice Drivers
Michael Hull and Peter Lowe, Vic Roads, Australia

Eye Scanning Rules for Drivers - How Do They Compare With Actual Observed Eye Scanning Behavior?
Helmut T Zwahlen, Ohio University, Athens, Ohio, USA

The Effects of Moderate Heat on Driver Vigilance in a Moving Vehicle
D P Wyon and F Norin, Volvo Car Corporation, Sweden

Position Accuracy When Pushing Pushbuttons in a Car as a Function of Car Speed and Location: Implications for Design
Helmut T Zwahlen, Nuruddin Abdullah and David Kellmeyer, Ohio University, Athens, Ohio, USA

(9.00-9.30 Short meeting of TRB Committee A3B02, Vehicle User Characteristics - visitors welcome)
THURSDAY SEPTEMBER 19

OPERATIONAL ROADWAY AND WORKZONE RESEARCH

14.00 - 17.30

Chairman: Karl-Olov Hedman, Swedish Road and Traffic Research Institute (VTI), Sweden

Overtaking Behaviour on Single Carriageway Roads in the United Kingdom
J G Hunt and T A Mahdi, School of Engineering, UWCC, Cardiff, United Kingdom

Overtaking Behaviour on Two-Lane Rural Roads
Arne Carlsson, Swedish Road and Traffic Research Institute (VTI), Sweden

Time and Space Criteria of Column Following
Milan Vujanic, University of Belgrade, Yugoslavia

Passing Operations on a Recreational Two-Lane, Tow-Way Highway
A R Kaub, University of South Florida, Tampa, USA

Reducing Risk Taking in Passing on Two Way Roads
Krsto Lipovac, Higher Shcool of Internal Affairs, Yugoslavia

Guidelines for Railroad Preemption at Signalized Intersections
Peter S Marshall, Barton-Aschman Ass Inc, Minneapolis, MN and William D Berg, University of Wisconsin-Madison, USA

VTI RAPPORT 372A
THURSDAY SEPTEMBER 19

SIMULATION AND MEASUREMENT OF OPERATOR AND VEHICLE PERFORMANCE

9.30 – 13.00

Chairman: R Wade Allen, Systems Technology Inc, USA

Traffic Measurements by Means of Computer Vision Techniques
N O Jørgensen, Institute of Roads, Transport & Town Planning, Denmark

Dynamic 3-D Highway Modelling
Arthur Roberts, NJDOT Research, Trenton, USA (Presented by R Pain)

Validation of Real-Time Man-In-The-Loop Simulation
R Wade Allen, David G Mitchell, Anthony C Stein and Jeffery R Hogue, Systems Technology Inc, Hawthorne, USA

Measurement of Driver Performance in Training Simulators
J E Korteling, TNO, The Netherlands

Litigation and Driving Simulators
Slade Hulbert, Ph D, Consultant, Danville, USA

STRATEGIES TO INCREASE THE USE OF RESTRAINT SYSTEMS

WORKSHOP

14.00 – 17.30

14.00 Opening

14.05 Illustration of background paper

14.15 National reports on seat belt use and countermeasures (10 minutes each)
  - Canada
  - Finland and other Nordic countries
  - France
  - Germany
  - Great Britain
  - Netherlands
  - United States
  Brian A Grant
  Juha Valtonen
  Yves Page & Sylvain Lassarre
  Hanns Ch Heinrich
  Jeremy Broughton
  Marjan Hagenzieker
  Robert Knaff

15.45 Coffee break

16.00 Discussion with speakers and audience

17.00 Concluding remarks and closure

(17.00-17.30 Short business meeting of TRB Committee A3B06, Simulation and Measurement of Operator and Vehicle Performance)
THURSDAY SEPTEMBER 19

LONG-TERM PAVEMENT PERFORMANCE

9.30 - 17.30

Chairman: Hans Jørgen Ertman Larsen, Danish Road Institute, Denmark

Early Evaluations of SHRP LTPP Data and Planning for Sensitivity Analyses
J B Rauhut, Brent Rauhut Engineering, Austin, Texas; M I Darter, Eres Consultants Inc, Savory, Illinois; O Pendleton, Texas A&M University, College Station, Texas; and N F Hawks, Strategic Highway Research Program, Washington, USA

The Specific Pavement Studies: Key Issues and Potential Products
A N Hanna and N F Hawks, Strategic Highway Research Program, Washington, USA

Expected Changes to the AASHTO Design Guide
N F Hawks, Strategic Highway Research Program, Washington, USA

Cost Effectiveness of Asphalt Concrete Overlays - The Canadian Approach
G A Sparks, Clayton, Sparks & Ass Ltd, Saskatoon, Canada; D M Nesbitt, Decision Focus Inc, Los Altos, California; and G Williams, Roads and Transportation Association of Canada, Ottawa, Canada

Long Term Pavement Performance Trials and Data Analysis in The United Kingdom
H R Kerali, University of Birmingham and J F Potter, Transport and Road Research Laboratory, United Kingdom

SHRP-NL: A Research Project Parallel to SHRP
G T H Sweere, SHRP-NL, Delft, The Netherlands

Structural Assessment, Performance and Economic Maintenance of Minor Roads
J Roger Duffell, The Hatfield Polytechnic, United Kingdom

Treatment of Bearing Capacity Results
B Leben and A Petkovsek, Institute for Geotechnic and Roads, Ljubljana, Yugoslavia

A Model of IRI for Jointed Plain Concrete Pavements
P Ceza, J David, J Gonzalez and M Poblete, IDIEM, University of Chile; and P Gutierrez, National Highway Administration, Chile

The High Speed Road Deflection Meter
P W Arnberg and G Magnusson, Swedish Road and Traffic Research Institute (VTI), Sweden

PAVUE: A Real-Time Pavement Distress Analyzer
M W Burke and K Råhs, OPQ Systems AB, Linköping; and P W Arnberg, Swedish Road and Traffic Research Institute (VTI), Sweden
FRIDAY SEPTEMBER 20

SAFETY AND MOBILITY OF OLDER DRIVERS

8.30 – 12.30

Chairman: John Eberhard, TRB Task Force on Safety and Mobility of Older Drivers, USA

Old Hands on the Wheel: Exposure, Accident Experience and Problems of Elderly Drivers
M L Chipman, C G MacGregor, A M Smiley, University of Toronto, M E H Lee-Gosselin, Universite Laval, Quebec, and L Clifford, Ministry of Transportation, Toronto, Canada

More Safety Thanks to Good Orientation – Nothing Works Without Traffic Signs
Henriette Reinsberg, 3M Germany, Germany

Elderly People and Mobile Telephone Use – Effects of Driver Behaviour?
Lena Nilsson and Hakan Alm, VTI, Sweden

Driving Performance in Mild Senile Dementia of the Alzheimer Type (SDAT)
Linda Hunt, Dorothy Edwards, John C Morris and Ada Mui, Irene Walter Johnson Rehabilitation Institute at Washington University Medical Center, St Louis, USA

Discussant:
Robin Barr, National Institute on Aging, US Department of Health and Human Services, Bethesda, Maryland, USA

SYMPOSIUM SESSION:

VISUAL AND COGNITIVE CAPABILITIES IN OLDER DRIVERS: PREDICTING ACCIDENT RISKS

Visual Function and Eye Health: Their Relationship to Older Driver Problems
Michael Sloane, University of Alabama at Birmingham, USA

Attentional and Cognitive Factors in Predicting Older Driver Problems
Karlene Ball, Western Kentucky University, Bowling Green, USA

Attention and Driving Performance in Alzheimer's Dementia
Raja Parasuraman, Catholic University of America, Washington, USA

Older Drivers Handling Road Traffic Informatics: Divided Attention in a Dynamic Driving Simulator
Peter C van Wolffelaar, Wiebo H Brouwer and Talib Rothengatter, Traffic Research Centre, University of Groningen, The Netherlands

Discussant:
Harvey Sterns, Institute for Life-Span Development and Gerontology, University of Akron, Ohio, USA
FRIDAY SEPTEMBER 20

SAFETY AND MOBILITY OF OLDER DRIVERS

13.30 - 16.00

PANEL DISCUSSION:

FEASIBILITY OF INTERNATIONAL PERFORMANCE STANDARDS FOR OLDER DRIVERS

Presiding Officer: John Eberhard, Chairperson, TRB Task Force on Safety and Mobility of Older Drivers, USA

1. A USA Perspective
   Robin Barr, National Institute of Aging, Bethesda, MD, USA

2. A European Community Perspective
   Margaret Greico, Oxford University, United Kingdom
   Kay Axhausen, Imperial College of Science, Technology and Medicine, London, United Kingdom

3. A Scandinavian Perspective: Older Drivers — A Problem for Whom?
   Krister Spolander, Central Bureau of Statistics (SCB), Sweden

4. A Multi-continent Perspective
   Martin Lee-Gosselin, Université Laval Quebec, Canada

Discussion: Invited from prior presenters and all session attendees

(16.00-16.30 Short meeting of TRB Task Force A3T52, Safety and Mobility of Older Drivers, visitors welcome)
FRIDAY SEPTEMBER 20
HIGHWAY OPERATIONS AND CONCRETE AND STRUCTURES
8.30 - 12.30

Chairman: Torkild Thurmann-Moe, Road Research laboratory, Norway

Closed Track Testing of Maintenance Work Zone Safety Devices
S C Shah, Strategic Highway Research Program, Washington and F R Hanscom, Transportation Research Corporation, Haymarket, Virginia, USA

Innovative Materials for Pavement Surface Repairs: Field Installation and Evaluation
S C Shah, Strategic Highway Research Program, Washington, USA

MINSALT - A 5-Year Study to Minimize the Negative Effects of Salt
Kent Gustafson and Gudrun Öberg, Swedish Road and Traffic Research Institute (VTI), Linköping, Sweden

Deicing Salt - Its Use and Effect on Road Safety and the Living Conditions of Roadside Trees and Shrubs
Siegfried Giesa, Technical University of Darmstadt, Germany

Improving Concrete Pavements Through SHRP Research
Amir N Hanna, Strategic Highway Research Program, Washington, USA

Optimization of Highway Concrete Through Combined Use of Particle Packing Modelling, Rheological Studies, Computer Simulations and Compaction Simulations
J Holm and P J Andersen, G M Idorn Consult A/S, Birkerød, Denmark

High Performance Road-Surfacing Concrete with Good Resistance to Wear by Tyre Studs
Mårten Nilsson, Swedish Road Administration, Sweden

Maintenance and Repair of Highway Concrete Bridges: A Case Study
I Al-Babatain and A M Abbas, Ministry of Communications, Riyadh, Saudi Arabia
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Getting SHRP's Products Into Practice

Damian J Kulash
Executive Director
Strategic Highway Research Program
U S A
GETTING SHRP'S PRODUCTS INTO PRACTICE
Damian J. Kulash
Executive Director
Strategic Highway Research Program

SHRP's Progress in the Past Four Years

When the first VTI/TRB conference was held four years ago, several speakers discussed SHRP's plans and objectives. They expressed enthusiasm about this new $150 million program, which focused narrowly on four areas of highway technology: asphalt, concrete and structures, pavement performance, and highway operations. These materials and activities account for more than half of the $70 billion that is spent on highways in the United States each year. Improvements in these four areas can save large amounts of money by improving the durability and economy of highway construction and maintenance. Nevertheless, these subjects had generally been ignored in U.S. research programs in the years preceding SHRP. Four years ago, we were excited that this period of neglect was ending, and that we were starting a series of research activities related to these important subjects.

Two years ago, when we met here for the second time, SHRP's research plans had become reality. Most of SHRP's contract research teams had been assembled, and many of them came here to present their work, and to exchange results and ideas with experts from around the world who had been working in these areas.

We have learned a lot from these meetings. Each of you contributed unique and valuable insights related to the technical areas SHRP is concentrating on. No researcher can explore every combination of factors, and none can afford to duplicate previous research when there are so many new topics that we need to address. By sharing your experiences--what has worked and what went wrong--you have helped to steer SHRP toward productive research approaches.

Now, at this third meeting, we have reached a new juncture. All of SHRP's planned research contracts have been awarded; and the only new additions that we will make to the research team will be through our SHRP-IDEA program, which funds unsolicited proposals. Several contracts are completed, and many more are in their final stages. The pace of research activity has been intense. During the last fiscal year, SHRP spent $35 million on research--more than one-quarter of the total highway research funded in the United States by federal agencies, states and industry. SHRP has now expended 60 percent of its research funds, and the end of the program--March 1993--is very near and very real.
SHRP and the Future Highway Research Strategy

Before another VTI/TRB conference is held, SHRP's research will be completed, and the SHRP offices will close. Two continuing elements of SHRP—the Long-Term Pavement Performance program, and implementation activities, will be transferred to the Federal Highway Administration. Arrangements for this organizational transition are already in progress, and I believe this transfer will be so continuous that it will be invisible to the numerous states and countries that are now actively participating in SHRP. It will place the long-term activities of SHRP in a stable, permanent organization that understands them and is eager to continue them.

This is as it was planned, and I believe that it is a wise plan because SHRP's short life contrasts clearly with the negative perception that research is unending and unmanageable.

Although many of us in the research field think of research as intrinsically good and beneficial, we are a prejudiced minority! To most people in the highway industry, research is a cost: a dollar spent on research is a dollar less spent on stone or asphalt.

Worse yet, research is seen as an unmanageable cost. To many, it seems that it never ends... it cannot be directed... it frames its own questions... it is not responsive to new, outside priorities... it does not bend to fit construction schedules and resource limits... it is unmanageable.

SHRP has helped to change that negative image. As our most recent five-year legislative cycle was drawing to an end in the United States, during this past summer, our legislators voiced unprecedented support for highway research as they drafted the national highway program for the next five years. This was an extraordinary change from their attitude of five years ago. I believe this positive attitude toward highway research has evolved because research is now perceived as a manageable tool for progress, not just a self-interested plea from those whose source of livelihood is research.

This is an important distinction. It imposes tough demands on the way we manage highway research. In particular,

- we must be willing to scrub the research slate clean periodically, and
- we must develop useful products within the available time and budget.

These are key features of a manageable research program, painful though they may be at times. Closing down the SHRP organization in 1993 is part of this strategy. The tough decisions regarding which research projects can be completed and will produce useful results are part of this strategy. If we had unlimited time and
money for research, we could avoid these difficult steps. But we do not. To use our resources effectively and to maintain professional credibility, we must take the difficult actions that are required to move the focus from yesterday's needs to tomorrow's priorities.

The attention that will be given to the technical research areas addressed by SHRP's subjects will decline in the future, but the research attention given to other high priority topics in the highway area will increase substantially. Maintaining the health of highway research as a whole requires us to make real changes in research program emphasis as priorities change.

This targeted overall approach to research has renewed the interest of federal, state, and industry managers in U.S. highway research. This management interest will help hasten the difficult process of research product implementation.

Product Implementation

More than 100 different products are now being developed by SHRP. Many of these are new test methods or specifications that will help highway agencies and contractors to select materials and designs that will perform better. They range from tests for the field-aging-propensity of bitumen, to tests for the freeze-thaw susceptibility of aggregates. Some of SHRP's products are new equipment, such as automated maintenance equipment and more efficient snow-plow blades. SHRP's products also include new materials, diagnostic manuals, and other aids to improvement of construction and maintenance practices. During the next three days, we will have a chance to examine many of these products.

As SHRP enters its final years, we are more convinced than ever that the use of these products can save highway agencies far more than they have spent for SHRP research. SHRP's proposed specifications for bitumen and asphalt-aggregate mixtures, by themselves, could yield improvements in durability worth hundreds of millions of dollars a year. Huge savings also can be gained through improvements growing out of SHRP's research on protection and rehabilitation of chloride-contaminated reinforced concrete structures, the use of more effective maintenance materials, avoiding premature distress in concrete pavements, and better ways to control snow and ice. In the longer term, the improvements in pavement design that will result from the Long-Term Pavement Performance project will provide engineers with a new generation of powerful techniques for selection of design approaches that match the unique conditions at a particular site.

None of these benefits are automatic and none are easy. Users cannot reap the benefits unless they invest in the tools. They may need to buy new test devices, train engineers and technicians to use new approaches, or pay more to specify high-performance ingredients. They will make some mistakes when they first apply unfamiliar techniques. In addition, many of the people who can
benefit from SHRP do not know about it, or are not authorized to make the short-term investments needed for technological improvement. Overcoming barriers like these has always required sustained effort in the highway field, and implementation of SHRP’s products will be no exception.

SHRP does, however, enjoy some advantages in this regard:

- it is a state-oriented program, and state governments, which control two-thirds of highway expenditures in the United States, have high confidence in SHRP’s recommendations;

- it is a participatory program. State engineers and construction contractors have guided the choice of topics, the design of research projects, the selection of contracts, the progress of research, and the evolution of products. Further, they have often pilot-tested SHRP’s products within their own laboratories or projects.

- it is a product-oriented program. From the start, and at every stage, SHRP’s objectives have been defined in terms of useful products. Research specialists and product users are speaking the same language.

- management has sustained its interest in SHRP. Highway agencies and industry leaders are aware that they have made a huge financial commitment to SHRP, and they are aware that they could make substantial improvements by using SHRP’s products. Their support will speed the front-end investments in equipment and training needed to exploit SHRP’s products.

In spite of these special advantages, we recognize that full implementation of SHRP’s products is an immense job—bigger than the SHRP research program itself. SHRP’s Executive Committee identified seven areas of implementation activity, and these are the blueprint for the Federal Highway Administration’s program for SHRP implementation.

Field trials and demonstrations. State engineers and their contractors need hands-on opportunities to learn about and evaluate new products under local conditions. SHRP is providing extensive opportunities for this. There are about 40 instances where SHRP is working with a specific state agency or construction contractor to use one or another of SHRP’s products. This builds familiarity with the products, and it opens the door to wider implementation. It also provides the SHRP research team with valuable information on how well products perform, and how they need to be modified.

If SHRP’s products are to be widely accepted, thousands of working-level engineers will need to be aware of the product, convinced of its advantages, and able to use it effectively. These engineers work in hundreds of state regional offices and construction companies. As a group, they are more impressed by hands-on experience than they are by research reports or lectures. In cooperation with their agencies and managers, SHRP is working to
give these engineers an opportunity to use SHRP products in uncontrolled field settings. This activity has received a lot of time and attention, but far more is necessary if we are to reach enough of these users.

We believe that an aggressive program to encourage this sort of working-level involvement is essential in the years following SHRP, and are working with the Federal Highway Administration to ensure that this becomes a top priority for them as they assume responsibility for SHRP implementation activities.

Training. Reaching the thousands of engineers who are the ultimate users of SHRP's products also requires the development of new special-purpose courses through industrial and government training programs. SHRP is working with the Federal Highway Administration implementation staff to identify the range of courses required, and to ensure that they are ready when SHRP research concludes.

Audio-visual materials. Good, succinct videotapes are one of the most far-reaching formats for spreading know-how to the decentralized staff of highway agencies and contractor's staff. SHRP is producing a number of videos in the highway operations area, and has plans for others as well. SHRP also has begun to publish "Product Alerts" which briefly summarize why each product is necessary, and how to use it. These are distributed widely among private contractors and governmental agencies. They help build initial awareness of new research products, and the potential benefits of using them.

New test equipment. States making large investments in new test equipment will need financial assistance. Otherwise, expenditures for new laboratory equipment could drain sources of funding for research. Next month, we will be displaying our proposed testing equipment at the annual meeting of the American Association of State Highway and Transportation Officials (AASHTO). This will be part of an organized process for alerting state management to the need for special capital investment for this equipment, and to plan early in their budgetary cycles for future expenditures in this area.

Acceleration of standards adoption. A very large number of new tests and draft standards will be emerging from SHRP almost simultaneously, and these threaten to bog down conventional standards-setting processes unless special steps are taken to expedite their advancement. This past summer, SHRP staff met with the AASHTO Subcommittee on Materials, which is the leading source of standards for highway materials and practices in the United States. We discussed some 94 separate procedures, tests, or materials coming out of SHRP that may go through the AASHTO standard-setting process. We are working actively with this group to ease the huge workload that this volume of activity will bring. As a result, I believe that we can avoid undue delays in adoption of SHRP's products as AASHTO standards. This, in turn, will speed their acceptance by states, cities, and counties.
Adaptation to changing conditions. Public and legislative concerns about the health and safety of workers, about the ability of highway construction to assist in the recycling of waste materials, and other changing social priorities may require further changes in SHRP's products. Part of the implementation strategy must anticipate and address these changing requirements. SHRP recently intensified its response to growing demands for recycling of various waste materials in highway construction by stressing this topic in the SHRP-IDEA program. As we start to receive proposals on this subject, we see more creative thinking on this important topic as a result.

Commercialization. Some SHRP products will not be brought to market unless patent, licensing, and marketing issues are resolved successfully. SHRP is working with the inventors of new products to involve potential manufacturers. Further support of this activity also will be needed after the conclusion of SHRP's research.

The Next Five Years. Taken together, the above seven implementation activities--
- field trials and demonstrations,
- training,
- audio-visual materials,
- new test equipment,
- acceleration of standards adoption,
- adaptation to changing conditions, and
- commercialization

can help to remove many of the barriers that could impede the use of new SHRP products. Many decisions affecting implementation will be made by state managers, industry executives, district engineers in field offices, and crew foremen. They do not attend many conferences, and do not often visit agency headquarters. Strong support for implementation is essential in order to make a substantial impact on this decentralized audience. The SHRP Executive Committee has recommended that $50 million be devoted to the seven activities sketched above during the next five years. The Federal Highway Administration has endorsed this plan, and we anticipate that it will be incorporated in the next five-year legislative authorization, scheduled for action by the U.S. Congress before October 1991.

International Cooperation in Highway Research

Many nations have contributed to SHRP actively--by lending staff, by monitoring pavement test sections in accordance with SHRP's plans, by conducting laboratory research programs on topics related to SHRP's, by direct participation as SHRP contractors, and by appointment of international coordinators to boost two-way communication with SHRP.

The extent of international cooperation has been exceptional, and it has certainly increased the thoroughness and effectiveness of
SHRP's research. To date, 10 countries have loaned 19 professionals to SHRP for periods of one to three years. These loaned staff members contribute their expertise to steering and managing the research. They have contributed knowledge of technologies, design procedures, test equipment, and contracting approaches that have proven effective in other parts of the world. SHRP has been able to incorporate many ideas provided by these international participants.

International cooperation has been particularly outstanding in the Long-Term Pavement Performance project. Twelve countries now plan to monitor test sites in cooperation with SHRP. Most of the diagnostic equipment that SHRP is using to monitor its U.S. sites was developed outside the United States, and the nations cooperating in the Long-Term Pavement Performance program are using many unfamiliar measures and tests in order to achieve a high degree of international consistency in the data that are collected. In brief, we are moving closer to speaking a single language when it comes to pavement diagnostics. This will make it easier for us to apply research and experience from other areas, and will increase the speed and effectiveness of research.

The United States appreciates the value of international cooperation in this area, and the Federal Highway Administration will maintain the mechanisms that SHRP has adopted, and will continue to encourage and cooperate with international coordinators, loaned staff, and parallel Long-Term Pavement Performance experiments.

Converging on Future LTPP Products

SHRP's Long-Term Pavement Performance project (LTPP) will continue for 20 years. As we approach the end of the first five-year period, we are extremely pleased with and thankful for the cooperation of the many highway agencies that have enabled this large project to move forward. All 50 U.S. states have sections included in the LTPP experiment, as do all 10 Canadian provinces, and as many as 11 other countries. For each participant, this means doing some things differently: collecting traffic data that were not being collected, closing lanes to get test cores, using a falling-weight deflectometer, conforming to a different set of visual distress definitions, running different tests, or building a test section using materials or techniques outside normal practice. But, by sticking to the plan--by using the same designs, tests, and measurements--all of these cooperating agencies are, for the first time in history, producing a wealth of consistent, comparable information. This offers a sound basis for developing relationships that predict how different pavement designs can perform in sites with various climate, soil, traffic, and other conditions. Use of relationships like this would allow engineers to design and build pavements that are more durable and more economical. They would be extremely valuable, because they could yield substantial savings from the $20 billion that the United States spends on pavements each year.
In short, the LTPP program has enjoyed fantastic organizational and professional cooperation from the many participating state, provincial, and national governments. It has the potential to produce performance relationships of great value. But that potential will not be realized simply because cooperation occurred and data exist. Reducing the mountain of LTPP data to useful, reliable relationships will be a herculean task. It requires:

- **aggregation** of the many complex data elements into simple forms so that pavement-performance models can be based upon the most reliable summary data. Experts on each aspect—materials, traffic, condition, structure, or design—do not always like to do this. They are attuned to the significance of variation. But if they do not, statisticians with less understanding of the data will be forced to produce these summary measures. SHRP has started this process, developing or adapting models, programs and algorithms to turn trillions of axle records into load histories; distress photographs and maps into measures of distress density; deflection results into layer moduli; and so on, but the process must continue. Innovative ways to aggregate and summarize the various data elements must be found, so their true significance will be revealed.

- **accessing** the improved reliability that new pavement-performance relationships can bring, without sacrificing the simplicity needed to make them useful in practical applications. There will be a gold mine of opportunity in the LTPP data for graduate students’ dissertations, engineering companies’ proprietary design models, and industry’s advocacy of specific materials and technology. Many will analyze the LTPP data and make important discoveries. They will not agree. They will generate an ever-expanding technical literature and professional debate. To help stimulate convergence, SHRP and its sponsors will themselves be evaluating these analyses, reconciling key differences, and filling analytic gaps. The challenge will be to sort out fact from artifact, the important from the unimportant. The resulting relationships must be reliable and practical. Demands for unrealistic testing or data collection, or complex formulations, will put the results out of the reach of practicing pavement designers. Frequent changes to "official" design procedures will diminish credibility.

- **blending** new information and old; statistical trends and engineering experience; judgment and fact. SHRP is producing powerful new information on how pavements behave, but other sources of information will continue to be required. Judgement based upon seasoned experience, factors not addressed in the LTPP experiment, results from accelerated tests, laboratory tests, and many other important data must continue to be assessed and used. Pavement design never will be an exact science. To progress in this area, we must build
a strong technical and institutional capacity to evaluate, select, and apply the best of the available evidence, from all sources.

I believe that the highway profession can meet these challenges, but I do not underestimate the difficulty of meeting them. We need the experts, but we cannot rely on them alone. Industry, users and managers also must contribute to an effective resolution.

To bring these important issues to the professional community, SHRP has begun its own data analysis very early in the process. The early results of this process may be flawed, but they will begin to focus professional attention on those aspects of the design practices and performance relationships where significant early improvements are possible. This early analysis will help to build the professional forum that will be needed to weigh these issues in the future. That is why, on the program at this conference, you will see discussions of sensitivity analyses, expected changes to the AASHTO Design Guide, and potential products of SHRP's specific pavement studies.

In closing, I would like to thank Volvo, VTI, and TRB for sponsoring this conference. Through good planning or good luck, these conferences have coincided perfectly with SHRP's life stages. It has helped us reach higher levels of international cooperation and participation. We appreciate the valuable contribution that these conferences have made to this cooperation.

As we approach the final year, we are pleased that much of SHRP's research has gone well. We know that much hard work lies ahead. Implementation of SHRP's products used will require commitment, energy, and resources on a scale similar to that of SHRP itself. Condensing the massive LTPP database into a few useful tools will test our professionalism and our patience. By working together, we have met the challenges thus far, and I am confident that we will also do what it will take to overcome the obstacles that lie ahead.
Federal Highway Administration’s Role in SHRP Product Implementation

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THE FEDERAL HIGHWAY ADMINISTRATION’S ROLE IN SHRP PRODUCT IMPLEMENTATION
by E. Dean Carlson
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INTRODUCTION

I am pleased to join you this morning to discuss a subject that is significant to all of us, highway research. In particular, I’ll give you an overview of Strategic Highway Research Program (SHRP) product implementation and the Federal Highway Administration’s role in that activity as well as a summary of highway research in the United States, its status now, and what we anticipate for the future.

Highway research in the United States is healthy. The future promises a growth that reflects the prevailing attitude of the importance of highway research to the preservation of the transportation network and the economic stability of the United States. In many respects that current emphasis and interest in future highway research is a direct result of the SHRP experience and success.

As you know, the SHRP program is a program of finite limits in time and funding. Thus, as it approaches its last fiscal year, the products are becoming clear in many of its interest areas. This then becomes an exciting time in the project as the first of the products are beginning to find their way into practice.

It is also a time of challenge to all of us in the highway transportation delivery business, at the Federal, State, and local governmental levels. It is also a challenging time for the private sector as well. That challenge is to ensure that the results and products of SHRP get put into practice. There is yet another major challenge offered by the SHRP experience; a continuation of interest in highway research.

First, the challenge of product implementation and FHWA’s role in that activity. To meet this requirement and other technology transfer demand, the FHWA has changed its organization structure to include a specific Office of Technology Applications under a newly created office of Associate Administrator for Safety and Systems Applications. Additionally FHWA is working with the Transportation Research Board (TRB) to acquire the services of a TRB panel to monitor SHRP products and the conduct of continuing Long Term Pavement Performance activities. It is the intent of these efforts to ensure a smooth and continuous implementation of these products after SHRP ceases to exist.

But what about the big challenge - keeping the momentum in highway research established by SHRP alive? To point the way, one needs to consult the U.S. National Transportation Policy.

NATIONAL TRANSPORTATION POLICY

The U.S. transportation program was broadly defined in the National Transportation Policy issued in 1990. The preservation and vitality of the U.S. transportation system and its role internationally are key elements in the Policy.
The National Transportation Policy includes six themes that encompass the full scope of the direction of the policy.

- Maintain and expand the Nation’s transportation system.
- Foster a sound financial base for transportation.
- Keep the transportation industry strong and competitive.
- Support public safety and national security.
- Protect the environment and the quality of life.
- Advance U.S. transportation technology and expertise.

While all of the themes have some bearing on our research program, the sixth theme addresses most specifically the necessity for and the mission of transportation research and the development of new technology and expanded expertise. This theme directs increased Federal spending and attention on innovation and technology. In addition, it calls for improved transportation education and a better trained work force, not only to meet today’s needs but future high technology needs. The technology that is developed will be shared within the United States and internationally in the highway community.

A NEW TIME FOR RESEARCH AND TECHNOLOGY

Our renewed emphasis on highway research has had a good start. During the fiscal year nearly over, we saw the beginning of the expansion—an 82 percent increase between fiscal year 1990 and fiscal year 1991. We have also proposed an additional 114 percent increase between fiscal year 1991 and fiscal year 1992.

FHWA has received broad support for expanding our research program. The expansion of the current research program and the proposals for the 1990’s have resulted in large part from the strong support there is from the FHWA, the Secretary of Transportation, the American Association of State Highway and Transportation Officials (AASHTO), other highway organizations, the private sector, universities, and the U.S. Congress over the last few years.

THE FHWA RESEARCH AND TECHNOLOGY PROGRAM

Our research program has been defined by identifying critical national issues. To respond to these issues, we have established high priority areas for our research and have mapped out the products and the benefits we expect to obtain from the program. Through our program, we will work to relieve traffic congestion; improve the quality of the highway infrastructure, its pavements and structures; and make highways safer for drivers, pedestrians, and bicyclists, young and old, during the day or night.

The FHWA’s Research and Technology Program addresses four critical national issues: Safety; Congestion, which will be addressed through the National Intelligent Vehicle-Highway Systems program; Infrastructure Preservation and Productivity; and Technology Transfer.
SAFETY

The human and economic cost of traffic fatalities is too high. According to Transportation Research Board Special Report 229, "The annual burden to [U.S.] society of the lost productivity of crash victims, the medical costs of injured survivors, and the property damage to vehicles is nearly $70 billion."

The late 1980's showed a general trend toward an increase in traffic fatalities. It is tempting to make a correlation between the increase in traffic during this time, but it is not an inevitable correlation. In 1988, there were approximately 47,000 highway fatalities, 2.4 per 100 million vehicle miles. But in 1990, highway fatalities had dropped to 44,500, less than 2.2 per 100 million miles of travel. While we are encouraged by these decreases, any number of fatalities is too high.

The FHWA's safety research program consists of Highway Safety Research and Development and Motor Carrier Safety Research. In our current program and in our plans, we have a broad spectrum of safety activities. We will continue to perform crash tests of sign supports at our Federal Outdoor Impact Laboratory at the Turner-Fairbank Highway Research Center. In our Highway Driving Simulator, we will be studying driver behavior, including the needs of older drivers.

We are also studying signs and lighting for improved night visibility, which is of particular importance to older drivers, but certainly affects all drivers to varying degrees. To better manage and analyze safety data, we are developing computer systems that will use data provided by the States and will allow the dissemination of the broad data base of excellent safety information.

In future years, we will be performing research on highway safety design procedures; highway travel for an aging population; risk and night driving, and highway lighting requirements for older drivers; and pedestrian and bicycle safety. We will also begin new activities identified by the TRB Strategic Transportation Research Study: Highway Safety. This study, jointly commissioned by the FHWA and the National Highway Traffic Safety Administration, recommends additional annual Federal funding of $30 to $40 million over the next 5 to 10 years for focused safety research.

CONGESTION: INTELLIGENT VEHICLE-HIGHWAY SYSTEMS

A major element in our expanded Research and Technology Program is the Intelligent Vehicle-Highway Systems (IVHS) Program. Traffic congestion is a growing problem in U.S. urban areas as it is internationally. We lose 2 billion person-hours through delay caused by traffic congestion, a 60 percent increase over 1984. In 39 of our cities, the cost totals $41 billion. Predictions of traffic gridlock in some of our cities reinforce the need for solutions.

The IVHS program consists of four elements: advanced traffic management systems; advanced traveler information systems; commercial vehicle operations; and advanced vehicle control systems.

1 Safety Research for a Changing Highway Environment Strategic Transportation Research Study: Highway Safety, Transportation Research Board, 1990
The IVHS program has significant congressional support, philosophically and economically. We have a head start on this program, with a number of public/private cooperative installations around the country. In Los Angeles, the Pathfinder project is in operation on the Santa Monica Freeway; this project is cosponsored by the FHWA, the California Department of Transportation, and General Motors. In Orlando, Florida, the FHWA, the Florida Department of Transportation, the city of Orlando, the American Automobile Association, and General Motors are cooperating in the TravTek project for the entire Orlando area.

In northern Illinois, Advance Driver and Vehicle Advisory Navigation Concept, or ADVANCE, a proposed 5-year, $40 million smart car/smart highway project, will equip 4,000 passenger and commercial vehicles with instruments allowing motorists to select the best route in the Chicago area.

A commercial vehicle operation activity, Heavy Vehicle Electronic License Plate, or HELP, is in operation in a number of States: Arizona, California, Idaho, Iowa, Minnesota, Nevada, New Mexico, Oregon, Pennsylvania, Virginia, and Washington and through the Port Authorities of New York and New Jersey. The HELP system automatically weighs, classifies, and identifies heavy vehicles at strategic locations. The resulting data can then be stored, processed, and retrieved to provide government and the trucking industry with useful and consistent information.

In the near term, advanced vehicle control systems are expected to be largely vehicle-based and therefore a private sector function. The U.S. Department of Transportation’s role will be limited to infrastructure-based counterparts and safety standards.

In the upcoming fiscal year, we are proposing a 250 percent increase in funding for IVHS research and application. We also anticipate that this program will continue to be supplemented by matching State and private funding to be comparable to that being used in Europe.

In the following fiscal year, we will propose an even greater increase in the IVHS funding to move the program ahead vigorously. Initiatives will include: development of a microscopic Optimal Routing Model for Advanced Traffic Management Systems; development and implementation of an Advanced Permit Purchase System in the commercial vehicle operation area; and alternative displays and controls for advanced traveler information systems.

International IVHS activities

We continue to try to stay in touch with IVHS activities internationally. We hope to benefit from technological advances in other countries as well as contribute to the world technologies. European countries have committed $1 billion to IVHS R&D over the next 3 to 7 years. Japan has also made a substantial commitment to the program.

INFRASTRUCTURE PRESERVATION AND PRODUCTIVITY

The safe and efficient operation of highways is certainly important to the Nation, but the facilities or infrastructure itself must also hold up to the demands placed on it. We have 850,000 miles of pavements on the Federal-aid highway system; and a total of 3.87 million miles in the United States, including 577,710 bridges. Each year, motorists travel 2 trillion vehicle miles on these highways.
The FHWA is addressing a variety of areas in its Preservation and Productivity program: pavements and structures research and development; long-term pavement performance, continuing where the SHRP leaves off; motor carrier productivity research; right-of-way and environment research; and policy and planning research.

Current preservation and productivity activities include accelerated testing on various pavements at our Pavement Testing Facility, studies of flexible binders, the effects of trucks on pavements through dynamic testing, and European asphalt technology. One technology we brought from Europe is stone mastic asphalt pavement. We are evaluating the use of the technology in Michigan and Georgia now and will be drafting guidelines for design and construction of stone mastic asphalt and equipment used in Europe during this coming year.

We will also research ways to provide cost-effective and reliable bridge foundations, retaining structures, and ground improvements techniques; and to provide environmentally acceptable and cost-effective corrosion protection of steel bridges. We will implement techniques for mitigating detrimental highway operations impacts; provide performance-related construction tests and associated test methods and apparatus; and develop programs to implement technology on alternative deicers, waste utilization, soil stabilization, and recycling.

In the future, we will evaluate and enhance present local and global nondestructive evaluation systems for structures; develop a second generation accelerated loading facility device to test pavements; study the application of advanced technology, new materials, and management systems; continue research and development required for 94 SHRP products; and research national environmental concerns, such as hazardous wastes, wetland preservation, and air quality.

Planning research will be designed to ensure efficiency of future urban transportation systems, and critical policy research will include a truck size and weight policy, highway cost allocation, revenue issues (including alternative fuels), the relationship of transportation investment to economic productivity, and the refinement of investment management tools.

Long-Term Pavement Performance Program

Within the Infrastructure Preservation and Productivity Program, the Long-Term Pavement Performance (LTTP) Program will be a major element when the FHWA picks it up from the SHRP. We propose to include $10 million in our fiscal year 1992 budget for LTTP. The program will continue, with the support of State highway agencies and Canadian provinces, to establish a pavement performance data base for North America. To help manage the continuation of the program, the FHWA has established an LTTP Division. This division will administrate the LTTP Program for the remaining 15 years of the program.

Strategic Highway Research Program Implementation

Just as there was once a strong need for the highway research which was performed under the SHRP, there is now an equally strong need to make a commitment to implement the products of SHRP. This is not a commitment for any one organization to make alone. We must all make this commitment and work together to incorporate the products of SHRP into the highway community.
The FHWA has been a dedicated supporter of the SHRP, and this will continue after the program ends. We recently reorganized, and in the process we added a special staff position in our new Office of Technology Applications to address the FHWA’s role in implementing SHRP products. This staff person will coordinate the development of SHRP products and the marketing of these products. We have included funding in our fiscal year 1992 budget request for efforts to implement SHRP products.

Everything researched under the SHRP won’t produce a marketable product. To advance highway technology we must develop products that fulfill a critical need and are cost effective; are packaged in a final implementable form ready to be used; and are readily available to anyone who wants to voluntarily use them.

OFFICE OF ADVANCED RESEARCH

In addition to the LTPP Division, we will be establishing an Office of Advanced Research under our Associate Administrator for Research and Development. This new office will be directed by a nationally recognized senior researcher and will be the nucleus for strategic planning and special technical expertise for the U.S. highway community. The office will plan, administer, conduct, and coordinate fundamental research and innovative adaptations for emerging and advanced technologies. We will do this through contracts and cooperative arrangements with domestic and international public and private sector organizations.

TECHNOLOGY TRANSFER

The fourth element of the Research and Technology Program is the Technology Transfer Program. Innovations and new technology will result from the Research and Technology program, but it is just as critical that those innovations and new technology reach the practitioners. The Technology Transfer Program consists of technology applications; education and training; and international programs.

Under technology applications, we will identify and evaluate products emerging from research; examine research products to determine additional opportunities for application; perform market and product analyses; refine and package innovative technology and products to ensure timely adoption; and ensure the timely delivery and widespread use and adoption of innovative technology through effective delivery systems.

One of the most popular and successful programs over the years has been the National Highway Institute (NHI). The NHI will continue what it has done for the last 20 years, that is, provide significant and timely, high technology training to the States and to the FHWA throughout the United States. The NHI will also identify, create, enhance, and implement programs required to qualify key highway personnel for leadership roles, and it will conduct unique programs with national and world experts.

We are also opening up our short course program to allow foreign university representatives to attend sessions, see how the material is presented, and take back student and instructor information. This will pick up on the train-the-trainer concept of sending course attendees to instruct others.

To reach the universities, we will continue to recruit graduate and undergraduate students to our Grants for Research Fellowships Program. Since the first fellowships were awarded in 1984, 141 students have participated in the program, 27 in 1991. The majority of these fellowships have been awarded to Masters or Ph.D. candidates. About 20 percent have been awarded to undergraduates.
Through another university program, the U.S. DOT's University Transportation Centers Program, we have established over the last few years, a network of Centers of Excellence at 10 regional centers. These centers, which comprise consortia of 67 universities, attract the Nation's best talent to the study of transportation as a discipline. We anticipate that these centers will develop new strategies and concepts to effectively address existing and future transportation issues. In line with the general expansion of the Research and Technology Program, Secretary Skinner has authorized three additional Centers of Excellence where the focus will be on achieving greater diversity. These centers not only let us reach the best and the brightest at the universities but also the students, the future best and brightest; through the program, students will participate in the innovation and the discovery of new technologies, expanding, broadening, and updating the expertise and technology base of the highway community.

In addition to the Federal and State staffs, we need to reach out to the local transportation agencies. Through our Local Transportation Assistance Program, we will identify, package, and deliver modern highway technology to rural and urban local transportation agencies; assist local transportation agencies in developing and expanding their ability to deal effectively with road related problems; and establish and operate, in cooperation with State highway departments, universities, and technology transfer centers for local transportation agencies. A key element in the local outreach effort is the Rural Technical Assistance Program, under which 49 Technology Transfer Centers have been established.

International Programs

On the global scale, the FHWA has been active internationally over the years. Under the Research and Technology Program, we are establishing channels for importing foreign technology and will increase the transfers of U.S. technology to developing regions of the world.

Also, we have developed an International Research Fellows Program that will allow professionals from other countries to spend time at the Turner-Fairbank Highway Research Center performing research that responds to problem statements created by the FHWA or in some cases by the candidates themselves.

We continue to offer invitations to our international counterparts to visit the United States to interact with the Federal and State highway community. On average, we have visitors from about 25 different countries each year to our Turner-Fairbank Highway Research Center. This visitor program also allows foreign professionals to visit State highway agencies, universities, and other organizations in the transportation field. This type of interchange allows foreign highway professionals and their U.S. counterparts to exchange ideas and experiences on technical subjects of common interest.

We also have a continuing program of direct technical assistance to other countries from the FHWA. In the last 60 years, the United States has contributed to the road programs in more than 70 countries. FHWA's technical assistance efforts are oriented toward highway programs projects, or problems.

In the last year, FHWA has provided a significant amount of direct technical assistance to Turkey, Pakistan, Eastern Europe, and Nigeria, to name a few. In Nigeria, for example, the NHI is assisting in the development of a first class training program. The project, funded by the World Bank, involves Nigerian delegates visiting our NHI facility.
in Virginia and FHWA staff reviewing the existing training resources in Nigeria. "Face-to-face" exchanges such as this provide the best sharing of technology possible.

We anticipate continuing a strong Technology Transfer Program. We will be testing, evaluating, and marketing research products, including SHRP products. We will provide technical assistance and will deliver useful technology to local highway agencies. We also propose to increase the funding to support highway technology training through the NHI.

PARTNERSHIP

To implement and support this program, we will need a broad based partnership with the members of the highway community--Federal, State, and local government agencies; highway and transportation associations; private industry; universities; and others in the United States and internationally.

Our goal is to reduce fragmentation of transportation research efforts by coordinating the research among Federal and State governments, professional organizations, and the private sector. A solid coordination and communications framework will enhance opportunities for major breakthroughs and for sharing research results; maximize the effectiveness of an expanded FHWA Research and Technology Program to address critical transportation issues; increase roles for States and the private sector in identifying, contributing to, and strengthening FHWA research and technology; and ensure major transportation research and technology problems are addressed with adequate resources.

PRODUCTS AND BENEFITS

The expanded national Research and Technology Program will result in a broad array of products and benefits. We anticipate producing improved accident and analysis methods; multimodal transportation management; improved freeway incident detection and management; increased safety and mobility for older drivers; highway designs to better accommodate large trucks; onboard navigation, route guidance, and highway warning systems; savings in time and fuel cost savings; reduced bridge maintenance frequency and costs; long lasting, corrosion resistant new materials; protection for cables on cable-stayed bridges; durable crack-free concrete structures; improved earthquake vulnerability assessments; new materials with enhanced performance; early answers to pavement performance through accelerated testing; a uniform, national pavement performance data base; and durable, rut resistant asphalt surface courses.

SUMMARY

We are entering a new age for the U.S. highway research program. After a decade of programs that have seen diminishing resources that resulted in a deteriorating infrastructure, traffic congestion, a growing disparity between the sizes of automobiles and commercial motor vehicles, increased negative environmental effects from highways, etc., the Nation is prepared to respond with a program that produces innovation and increased national expertise in highway technology. Both will have a revitalizing effect on the national transportation system, the Nation's economy, and in preserving the lifestyle of citizens of the United States in the 1990's and well into the 21st century. And equally important, we will be a stronger partner in the international highway community.
Research Collaboration:
New European Initiatives

David F Cornelius
Director
Transport and Road Research Laboratory (TRRL)
United Kingdom
I am grateful for the opportunity afforded to me by the organisers of this Conference to make a short presentation on recent developments in research collaboration in Europe. It is significant that the two new areas of collaboration are in highway research and traffic safety - the twin themes of this intercontinental Conference.

As we all know, road transport is of fundamental importance to social and economic development; it is the most important mode of surface transport in Europe; some 40bn ecu are invested in the European Road Network each year, and on it each year some 55,000 of our citizens are killed and 1,600,000 are injured at an annual cost of 70bn ecu. In the saving of lives and the more effective investment of financial resources, research can play a vital role.

Our national laboratories and institutes undertake the whole range of research from basic, through applied, and onto application and exploitation. Our researchers command a comprehensive range of specialist large-scale experimental facilities and have access to public roads on which to carry out experiments and monitoring. It is this broad spectrum of research activities, undertaken in laboratory-scale, pilot-scale and full-scale experiments, that places our research laboratories and institutes in a strong position to make a major contribution to road transport research in Europe.

The European Community recognises the need for a multi-national European programme of research on all matters pertaining to transport - and to highways in particular. This has led to new initiatives being taken by Directors of national research organisations (whose sponsors are mainly, though not exclusively, in central and local government) to create two collaborative organisations: the Forum of European National Highway Research Laboratories (FEHRL) and the Forum of European Road Safety Research Institutes (FERSI). I should now like to tell you a little about each of these.
Forum of European National Highway Research Laboratories (FEHRL)

This Forum, created in October 1989, is a grouping of the Directors of the national road research laboratories of the 18 countries of the European Community and the European Free Trade Area.

The purpose of FEHRL is to encourage collaboration between European national highway research laboratories and institutes in the field of highway engineering infrastructure so as to provide relevant knowledge to European Governments, the European Commission, the road industry and road users.

Collaboration between such laboratories will ensure the efficient provision of advice in a cost effective and timely manner. It will reduce duplication of effort and lead to proper integration of European research resources, whilst at the same time permitting a measure of productive competition.

In June 1990, following a presentation to the European Commission to seek official recognition, FEHRL was encouraged to propose a strategic European programme of road research that would be both inter-sectoral and inter-disciplinary, and this it has done.

The Strategic European Road Research Programme, comprising a road information system, a research programme and an implementation phase, is aimed directly at the policy and technical needs of the EC and will help, inter alia, to

- inform EC policy on highway matters and regional development
- secure better value for money in road construction and maintenance
- contribute towards an efficient and safe road network in Europe
- protect the environment from road-related pollution.

Implementation of the research will be:

- by advice to the highway authorities of European countries;
- by dissemination to those responsible for formulating standards;
- by technology transfer through conferences, workshops, demonstrations, training courses and publications.

Overall the Strategic Research Programme will provide a framework for developing European cooperation in the field of highway research, ranging from longer-term participation in strategic studies to more highly focused research projects as part of an EC framework programme.
Forum of European Road Safety Research Institutes (FERSI)

This safety forum was inaugurated in March 1991 and membership is open to national road safety research institutes in member-countries of the Council of Europe; non-national research institutes which could act as a national clearing house for all aspects of road safety can also apply for membership.

Most of the research institutes which are members of FERSI are within, or funded wholly by, Government Departments, but several are independent institutes with funding from both central and local government and from the private sector such as insurance and motoring organisations.

The mission of FERSI is to provide research-based scientific input to the road safety policies and practices of inter-governmental bodies and central and local governments in Europe; and to promote closer collaboration between European institutes undertaking research into road safety.

The objectives of FERSI, as those of FEHRL, will be achieved by:

- regular exchange between member institutes of information, experience, trends and new initiatives in research;
- the identification of research needs and opportunities for collaboration;
- undertaking joint research projects and sharing special research facilities;
- furthering the development of European requirements and standards in the field of road safety;
- dissemination of the results of research by all means possible to policy makers, administrators, professionals and researchers in road safety and to the general public.

In addition, the institutes will encourage the exchange of researchers and will set up and maintain appropriate databases.

FERSI has been in existence for only a short time, but it is already assembling a portfolio of projects which are suitable for collaborative research.

These recent initiatives in collaborative research in Europe are to be welcomed. Our task now is to ensure that the mechanisms proposed for collaboration under the aegis of FEHRL and FERSI become effective. Partly this can be done by ensuring that those who sponsor our research are aware of what FEHRL and FERSI can offer in the opportunities that they create for multi-national research.
Of course we shall still need to conduct research on a national basis in projects for local customers, or for projects within a particular national context; but international collaboration is best for large projects and those requiring wide application. Moreover it enables us to offer more research for a fixed budget to those who sponsor our research and use its results. Our customers should be pleased with that.

However, where we may need to strengthen our performance is in the interpretation of the results of research to non-technical audiences - to Ministers, senior officials in central and local government and to top management in the private sector. Our role is to provide them with relevant and timely advice on the basis of our present knowledge in order to assist their technical, economic, planning and policy decisions. As researchers we must become more practiced at that. In this way decision-makers will receive and, more importantly, will feel that they have received a good return on their financial investment in research and that their society has benefitted thereby.

And who knows how FEHRL and FERSI may develop in future? Already some members are seeking and establishing contacts with research institutes in central and eastern Europe. Many of these countries are close neighbours - closer in fact than Britain is to many of its co-members of FEHRL and FERSII.

As I have already mentioned, the growth in road traffic and the need to improve the highway infrastructure and provide safer roads in western Europe encouraged new initiatives in research collaboration and the creation of FEHRL and FERSI. In the next few years we could see corresponding needs developing in central and Eastern Europe following recent and continuing dramatic political developments. Increased traffic throughout the whole of Europe will require an improved highway infrastructure and safer roads in Europe as a whole.

This is a dynamic situation and it may not be long before other national research institutes seek to join FEHRL and FERSI. With these exciting developments in prospect, I wish you a rewarding Conference and new opportunities for collaborative research.

Transport and Road Research Laboratory
Crowthorne, UK

September 1991
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Changes in Driver Behaviour as a Function of Handsfree Mobile Phones: A Simulator Study

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ABSTRACT


The effects of a mobile telephone conversation on drivers' reaction time, lane position, speed level, and workload in two driving conditions (easy versus hard driving task) were studied in an advanced driving simulator. 40 subjects, experienced drivers in the ages 23 to 61 years, were randomly assigned to four experimental conditions. It was found that a mobile telephone conversation had a negative effect on drivers' reaction time, when the driving task was easy. It led to a reduction of speed, when the driving task was easy. It had a negative effect on drivers' lane position, most pronounced when the tracking component of the driving task was hard. Finally, it led to an increase in workload for both the easy and hard driving task. The effects were discussed in terms of what subtask, car driving or telephone conversation, the drivers gave the highest priority. Some implications for information systems in future cars were discussed.
Changes in Driver Behaviour as a Function of Handsfree Mobile Phones: A Simulator Study
Håkan Alm (PhD) and Lena Nilsson (PhD)
Research leaders at VTI

INTRODUCTION

The number mobile telephone users is steadily increasing in many European countries. This increase has made researchers and authorities worry about the effects of mobile telephone use on traffic safety. A driver using a telephone while driving may be tempted to have the eyes directed at the telephone for some time, especially when dialing a number. A driver can also be mentally absent from the road scene, with the consequence that the drivers processing of driving related information may be negatively affected. There is a worry that these effects may lead to an increase in accidents due to what generally is called "internal distraction" (Treat, 1980).

Some earlier studies have raised the question about the effects of mobile telephone use on traffic safety. In an early study Brown, Simmonds, and Tickner (1969) investigated the effects of divided attention resulting from the use of mobile telephones. A conclusion from the Brown et al. study was that overlearned tasks of car driving were not affected by the use of a mobile telephone, but that some perceptual and decision-making tasks were negatively affected. Zwahlen, Adams, and Schwartz (1988) investigated lateral path deviations when drivers were dialing a long distance telephone number. They found that 2-12 percent of the drivers made lateral deviations of a dangerous nature. In a study initiated by California Highway Patrol (1987) both negative and positive effects were found. It was found that dialing a telephone number had a negative effect on drivers' lane position. They concluded that when the telephone was mounted on the dashboard the probability for an accident was lower compared to when it was mounted on the console. On the positive side it was found that mobile telephones were used to report accidents, and fires. Stein, Parseghian, and Allen (1987) used a driving simulator to study the effects of mobile telephone use on drivers' traffic safety related performance. It was found that the drivers' lane position was severely affected when a telephone call was initiated manually. This effect was especially pronounced when the telephone was mounted on the console, and not so severe when it was mounted on the dashboard. The effect was also more pronounced for old than for young drivers. The probability of striking an obstacle was increased if the telephone was mounted on the console, and if the driver was middle-aged or older.

The purpose of the following study was to continue the study of the effects of divided attention on drivers' performance. Earlier studies have not included variations in driving task complexity. On theoretical grounds it seems reasonable to assume that a mobile telephone conversation will have different effects upon driver behaviour depending upon the complexity of the driving task. A complex driving task makes more demands upon the drivers information processing abilities, and may leave less "spare capacity" to deal with a secondary task. A common assumption is that the introduction of a secondary task may increase the risk for an accident when the
driving task is complex. Furthermore, earlier studies have not used the drivers subjective experiences as a dependent variable. One safety related subjective variable of interest is the drivers workload.

Purpose of the study. The purpose of the study was to address the following questions. First, is there an effect of a mobile telephone conversation on drivers' ability to quickly detect an object in a traffic environment? Second, is there an effect of a mobile telephone conversation on drivers' ability to monitor and adjust the performance of the vehicle? Third, is there an effect of a mobile telephone conversation on drivers' workload. Fourth, is there an effect of a mobile phone conversation on drivers' speed level? Fifth, is there an effect of driving task complexity on the drivers safety related behaviour, as mentioned above?

Predictions. To simplify the situation we decided to only look at a situation where a driver receives a telephone call, and uses the handsfree function of the telephone during the conversation. It was predicted that the drivers reaction time would be negatively affected when the driver was engaged in a telephone conversation. This effect was predicted to be stronger when the demands of the driving task increased.

The second question had to do with the effects of mobile telephone calls on drivers' ability to monitor and adjust the performance of the vehicle. It was predicted that there would occur such an effect, and that this will be manifested in drivers' ability to keep a consistent lateral position. The effect was predicted to be stronger when the demands of the driving task increased.

The third question had to do with the effects of mobile telephone calls on drivers' workload. It was predicted that workload will increase due to the telephone call, and that the addition in workload will be higher in proportion to the complexity of the driving task. The increase in workload was predicted to lead to a reduction of speed.

METHOD

Subjects. Forty subjects, 20 men and 20 women, aged 23 to 61 years (mean age 32.4, std. 9.5 years) participated in the study. They all had a driving license, and were experienced drivers meaning that they had had their driving license for at least 5 years, and that they were driving at least 10,000 km per year. The subjects were recruited via advertisements at various public places, like the university and the hospital in Linköping. They were paid (250 SEK) for their participation in the experiment. The subjects were randomly assigned to four experimental conditions.

Apparatus. The VTI driving simulator was used for the study. It is an advanced simulator which consists of a moving base system, a wide angle visual system, a vibration-generating system, a sound system, and a temperature-regulating system (Nordmark, Jansson, Lidström, Palmkvist, 1986, 1988, Nilsson, 1989). These five subsystems can be controlled to operate in a way that gives the driver an impression which is very much alike real driving.

Driving tasks. The road type that was presented to the subjects in the simulator was a two-lane, seven meter wide asphalt road.
It contained both horizontal and vertical curves. The road surface was characterized by high friction corresponding to dry summer roads, and the visibility condition was similar to a cloudy summer day.

Three different routes, one practice route and two test routes were used in the experiment. All three routes had the same general characteristics as described above, but differed in length and in the number and radius of the curves. The practice route was 20 km long, rather straight and easy to drive. It was used to make the subjects familiar with simulator driving. The two test routes were both 80 km long. The easy one was rather straight, and was not expected to cause the subjects any problems with the choice of speed and steering strategy. The workload imposed upon the driver was thus supposed to be very low. The hard route was very curvy, which forced the subjects to monitor the road continuously and make decisions about a suitable speed level and steering strategy. These requirements were supposed to impose a high level of workload upon the driver.

Vehicle. The car body used in the experiment was an ordinary Volvo 740 with an automatic gearbox. The simulated physical environment in the "car" corresponded to that in modern passenger cars. Thus, the noise level, the infrasound level, and the vibration level were all within the respective intervals for modern passenger cars during driving in real traffic. The thermal environment was according to normal indoor climate.

Visual stimulus. A red square, with the size four by four cm, was used as a visual stimulus. It always appeared in the same position on the left shoulder of the road at a rather long distance in front of the "car". As the position was fixed relative to the road, the sight angle perceived from the driver's position varied a little according to the road curvature.

Mobile telephone. The mobile telephone used was an Ericsson Hot Line device with handsfree facility (Ericsson Radio Systems AB, Sweden). It was mounted at the height of the steering wheel, over the ventilation controls, on the instrument panel to the right of the steering wheel.

When a subject answered the telephone by pressing a button, one of the tape recorders was activated and "read" the telephone task to the subject. Tasks for eight telephone calls were consecutively pre-recorded on one of the tape recorder channels. The presented telephone tasks were, together with the subjects' answers recorded on the second tape recorder.

Telephone task. The Working Memory Span Test (Baddeley, Logie, Nimmo-Smith and Brerefon, 1985) was chosen for the telephone (communication) task. This test contains a working memory part and a decision part. The subjects in the experimental groups were exposed to a number of sentences. Each sentence had the form "X does Y", and contained three to five words. For instance: "The boy brushed his teeth" and "The train bought a newspaper". After each sentence a subject was supposed to answer "yes" if the sentence was seen as sensible, and "no" if it was perceived as nonsense. The test contains 50% sensible and 50% nonsense sentences. When five sentences had been presented the subjects were required to recall the last word in each sentence, in the order they were presented. This completed the task of each telephone call. During the experiment this procedure was repeated eight times for the experimental groups, each time with different sentences.
Presentation of the telephone task. The Working Memory Span Test sentences were pre-recorded on a tape. Each call started with an instruction, telling the subjects how to perform the task. Each presentation took roughly 60 seconds.

Position of telephone call and visual stimulus along the route. Eight telephone calls were presented to the subjects in the experimental groups during the experiment. Therefore, eight specific positions (distances between 0 and 80,000 m) along each of the two test routes were randomly selected. When the "car" passed these fixed points a telephone call was initiated. At four of these eight positions, also randomly chosen, the visual stimulus appeared in connection to the telephone calls. For two of these four occasions, randomly chosen, the visual stimulus, appeared shortly after the telephone had rung, while for the remaining two occasions the visual stimulus appeared later, when the driver concentrated on solving the telephone task. The random procedure was used to make it impossible for the subjects to correctly anticipate when the telephone should ring, if the visual stimulus should appear in connection to the telephone call and in case it did, what the temporal relation between them should be.

Driving performance measures. Speed, lateral position and reaction time were used as performance measures. Both measurements and stimulations were controlled by the main computer controlling the simulator.

Subjective measures. To measure the subjects’ workload the NASA-TLX rating scale (Hart & Staveland, 1988) was used.

Communication measures. The number of correct sentence judgments (sensible/nonsense) was used as a measure of the decision part of the telephone task. For the working memory part of the telephone task the number of correctly recalled last words in the order they were presented was used as a measure.

Design. The study was performed as a two by two factorial design, where one factor concerned the type of route driven (easy versus hard), and the other factor the RTI system used (telephone versus control).

Procedure

The subjects had to fill in a questionnaire about background variables (sex, age, driver license, distance driven each year, experience of car driving, and of mobile telephone). After that each subject was randomly assigned to one of the four experimental conditions, and given a written instruction, describing the experimental task. The subjects in the experimental groups were told that they were supposed to drive an 80 km long route in the simulator. They were asked to "drive" the simulator in the way they normally drive a car, and avoid to "play" with it. They were told to brake with their right foot. They were also told that when they were driving, two things would happen. The mobile telephone would ring, and a red square would appear on the screen. When the telephone was ringing, the subject was instructed to answer by pushing the button for the handsfree function. After doing so they should listen to the instructions
that followed, and solve the task presented over the telephone. When the read square appeared they were told to brake as fast as possible. After reading and asking questions about the instructions the subjects in the experimental groups had some training on the telephone task. They practiced on three tasks of varying difficulty (two, three, and four sentences respectively) sitting at a table. The subjects in the control group were exposed to an identical instruction, but without the part containing the mobile telephone.

In the next training phase, all subjects were introduced to the driving simulator. For the experimental groups the handling aspects of the mobile telephone were repeated, and they could practice to locate and push the button for the handsfree function. Thereafter all subjects drove a 20 km long practice route. For all subjects the red square appeared three times, (at the same location for all subjects) and the subjects could practice to brake as fast as possible.

For the subjects in the experimental groups the mobile telephone also rang three times, and the subjects could solve the same problems as they did before, but now via the telephone and while driving. When the training phase was over, all subjects had a short brake during which they were offered coffee, tea, or juice.

After the brake, the test phase began. During the test phase the subjects performed the driving, reaction, and telephone (only experimental groups) tasks. For the experimental groups the subjects’ answers to the pre-recorded telephone tasks were recorded on tape. The driving performance measures were recorded via the main computer under the test. After completing the 80 km long testroute each subject had to complete the NASA TLX. Finally the subjects were thanked for their participation in the study, and paid 250 SEK. The running of a subject took 2-2.5 hours in total.

RESULTS

The following results will be presented. The subjects’ reaction time to the simulated danger situation, the subjects’ lateral position in connection to the telephone call, the subjects’ workload and speed, followed by the effects of driving task complexity on subjects’ performance on the telephone task.

Reaction time. It was predicted that the subjects in the experimental conditions would react slower compared to the subjects in the control telephone) conditions, and that there would be an interaction with driving task difficulty. A two-way ANOVA showed a significant interaction between route and RTI system, F(1,36)=6.40, p=.0124. Figure 1 shows the nature of this interaction.
Figure 1 indicates that there is a difference in the predicted direction for the easy route. A mobile telephone conversation seems to have affected the subjects' reaction time towards longer ones. The difference in reaction time between the two groups in the easy driving task is also rather large (0.385 seconds). For the hard route the situation is different. No significant effect of mobile telephone conversation on the subjects' reaction time could be shown. Thus, the hypothesis is supported for the easy, but not for the hard route.

**Lateral position**
To check the hypothesis about an increased variation in lateral position due to the mobile telephone calls we measured the lateral position of each subject in the experimental groups for a distance of 500 and 2.500 meters from the onset of each telephone call. During the first distance (0-500 m) the subjects must initiate the hands-free function of the mobile telephone, and it is therefore of interest to inspect that distance closer. It is also of interest to analyze the entire period during which the telephone conversation is run in parallel with car driving. The second distance (0-2500 m) covers that period. For the control groups corresponding measures were made. If the hypothesis is correct we should expect a greater variation in lateral position for the experimental groups, and the effect should be more pronounced when the tracking component of the driving task is demanding. Figure 2 and 3 shows the results for the 500 meter distance after each call, for the respective driving task.
Figure 2. Lateral position 0-500 m after each telephone call for experimental and control groups in the easy condition.

Figure 2 shows that the difference between experimental and control groups for the easy driving condition is very small. The difference was tested with a two-way ANOVA, and did not reach statistical significance, $F(1,144)=2.32, p=.1302$.

Figure 3. Lateral position 0-500 m after each telephone call for experimental and control groups in the hard condition.

Figure 3 shows that the difference between experimental and control groups was larger for the hard driving condition. There was a significant main effect of RTI system, $F(1,144)=10.97, p=.0012$, and a significant interaction between RTI system and calls, $F(7,144)=19.89, p=.0001$. This interaction had to do with the fact that the position of the telephone calls were randomly generated, and some calls occurred on straight sections of the road. Thus the hypothesis was confirmed for the hard route, but not for the easy.
Figure 4 and 5 shows the corresponding results for the 2.500 meter distance after each call.

![Graph showing lateral position](image)

Figure 4. Lateral position 0-2500 m after each telephone call for experimental and control groups in the easy condition.

Figure 4 shows that for the entire 2.500 meter period there exists a difference between experimental and control groups for the easy driving task. A significant main effect of RTI system was found, $F(1, 144) = 5.67$, $p = .0185$.

Figure 5 shows the corresponding results for the hard driving task.

![Graph showing lateral position](image)

Figure 5. Lateral position 0-2500 m after each telephone call for experimental and control groups in the hard condition.

There is a significant main effect of RTI system $F(1, 144) = 22.95$, $p = .0001$, and a significant interaction between calls and RTI systems $F(7, 144) = 6.78$, $p = .0001$. So, the hypothesis is fully supported when we look at the entire distance where the telephone conversation was performed.

**Workload.** The use of NASA-TLX rating scales give scale values, weights, and the combination "scale values*weights" for six different factors. These factors are: Mental demand, physical
demand, time pressure, operator performance, operator effort, and frustration level. The rating value of each factor multiplied by the weight for the respective factor was used for further analysis. A two way ANOVA was performed on each factor. Table 2 shows the results from ANOVAs performed on each factor.

Table 2. Results of ANOVAs performed on the subscales in the NASA-TLX rating scales.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Source</th>
<th>df</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mental demand</td>
<td>RTI</td>
<td>1,36</td>
<td>30.40</td>
<td>.0001</td>
</tr>
<tr>
<td>Physical demand</td>
<td>RTI</td>
<td>1,36</td>
<td>5.18</td>
<td>.0289</td>
</tr>
<tr>
<td>Time pressure</td>
<td>RTI</td>
<td>1,36</td>
<td>6.72</td>
<td>.0137</td>
</tr>
<tr>
<td>Operator performance</td>
<td>RTI</td>
<td>1,36</td>
<td>7.01</td>
<td>.0119</td>
</tr>
<tr>
<td>Operator effort</td>
<td>RTI</td>
<td>1,36</td>
<td>5.05</td>
<td>.0308</td>
</tr>
<tr>
<td>Frustration level</td>
<td>RTI</td>
<td>1,36</td>
<td>5.18</td>
<td>.0198</td>
</tr>
<tr>
<td>Frustration level</td>
<td>RTI*ROU</td>
<td>1,36</td>
<td>5.95</td>
<td>.0198</td>
</tr>
</tbody>
</table>

Table 2 shows that there is a significant main effect of RTI system on the factor "mental demand" ($F(1,36)=30.40; p=.0001$). Thus the telephone conversation had a significant effect upon the subjects estimation of the mental demands in their task. The same main effect was found for every factor. It should also be emphasized that the factor "physical demands" also showed a significant main effect of RTI system ($F(1,36)=5.18; p=.0289$). So the introduction of the physical demands associated with the activation of the handsfree function seems to have produced a higher subjective rating of physical demand. Finally for the factor "frustration level" there was a significant main effect of RTI system ($F(1,36)=5.95; p=.0198$), and a significant interaction between RTI system and route ($F(1,36)=5.18; p=.0198$). The subjects were more frustrated during mobile telephone use, and this effect was influenced by route difficulty. In summary, the hypothesis about higher workload due to the use of mobile telephone was supported, but the hypothesis that workload should increase with the complexity of the driving task was refuted.

Speed level. For the experimental groups the subjects' speed was measured from the onset of each mobile telephone call and 80 seconds forward. This covered the entire telephone conversation for all subjects. For the control groups corresponding measures were taken. According to our hypothesis the subjects in the experimental groups should have a lower speed due to the extra workload introduced by the telephone task. Figure 6 shows the speed levels relevant for this hypothesis.
As can be seen from Figure 6 a difference in speed exists between experimental and control groups for both routes. As predicted the speed is lower for the experimental groups. The difference is rather large and also statistically significant ($F(1,144)=14.65, p=.0002$) for the subjects driving the easy route, thus supporting the hypothesis.

The difference for the subjects in the hard route is very small, and did not reach statistical significance ($F(1,144)=1.36, p=.2453$). In this case the hypothesis is rejected.

Effects of driving task complexity on achievement in telephone task. To investigate if the complexity of the driving task had any effect upon the subjects' performance in the telephone task, the number of correct judgments, and correctly recalled last words in correct order for the respective driving conditions were counted.

Table 3. Performance in the telephone task as a function of driving task complexity.

<table>
<thead>
<tr>
<th>Correct judgments</th>
<th>Correct recall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Easy</td>
<td>Hard</td>
</tr>
<tr>
<td>38</td>
<td>40</td>
</tr>
<tr>
<td>39</td>
<td>39</td>
</tr>
<tr>
<td>38</td>
<td>38</td>
</tr>
<tr>
<td>37</td>
<td>40</td>
</tr>
<tr>
<td>39</td>
<td>40</td>
</tr>
<tr>
<td>40</td>
<td>39</td>
</tr>
<tr>
<td>37</td>
<td>40</td>
</tr>
<tr>
<td>40</td>
<td>38</td>
</tr>
<tr>
<td>40</td>
<td>38</td>
</tr>
<tr>
<td>39</td>
<td>40</td>
</tr>
</tbody>
</table>

Table 3 shows that there is practically no difference between the tasks when considering the number of correct judgments of the sentence sensibility. There is a small difference in the
number of correct recall of the last words (in the correct order) in each sentence. That difference is however very small, and does not reach statistical significance. Consequently, the hypothesis was not supported.

DISCUSSION

Reaction time. It was predicted that the physical and mental distraction caused by a mobile telephone conversation should have a negative impact upon drivers' ability to react quickly to an unexpected event in the driving environment. This effect was predicted to be stronger when the complexity of the driving task increased. It was, however, found that when the driving task was easy a mobile telephone conversation had a negative impact on drivers' ability to react quickly, but when the driving task was complex no negative impact was found. These results are somewhat surprising. A rather common assumption is that non driving related information (secondary tasks) can be given to a driver when his or her workload is low. The addition of a secondary task is often supposed to have a positive effect, by alerting the driver. The results from this study do not support that assumption.

One possible way to explain these results is to consider how the subjects may have made their priorities between the task of driving (the primary task), and the task of coping with the telephone conversation (the secondary task). The task demands of the hard driving task may have forced the subjects to concentrate on the tracking task. This involves attention to, and judgments of the road geometry, and judgments of how to adapt the speed and steering strategy to the road geometry. In other words, the task demands may have forced the subjects to regard the tracking task as their primary task. (See Rumar 1987 for a discussion of drivers priorities between different subtasks of driving). Consequently, the telephone task may have been given the status of a secondary task, and was therefore not allowed to influence the drivers' maneuvering behaviour to any greater extent. This could explain the lack of difference between experimental and control groups in the hard driving task condition.

In the easy driving task the subjects did not have to allocate much attention to the tracking component, and this may have led the subjects to give the telephone task the highest priority. Consequently, the task demands of the telephone task may have influenced the drivers' maneuvering behaviour to a much larger extent. This could explain the large difference in reaction time between experimental and control groups in the easy task condition. If this explanation is correct, then the introduction of a non driving task can have different effects depending upon what priority the drivers give the non-driving task. This in turn depends upon the drivers' judgment of the complexity of the driving task, and their own ability to cope with that complexity. If the driving task is perceived as very easy, then the non driving task may be treated as the primary task, and this may have negative effects upon the drivers' ability to react quickly to some emergency event. On the other hand, if the driving task is perceived as hard, then it will presumably still remain the primary task even if a non driving
task is introduced. If this line of reasoning is correct it means that RTI systems for non driving information should not give their information when the driver's driving task is extremely simple. Instead it seems better to provide the driver with information when the driving task has a medium complexity. This explanation does not deny the possibility that a secondary task may have an alertness arousing effect. But, it argues that an increase in alertness not by definition will have positive effects upon the drivers primary task. Instead it may sometimes be used to improve the performance on the secondary task.

Other explanations of the reaction time results fail in one way or another. For instance, another possible way to understand these results is to take a closer look at the task demands of the respective driving tasks. Common for both tasks is that the subjects must detect the "brake stimuli", and perform a braking maneuver. To detect the "brake stimuli" they must direct their attention to the field where it occurs, and to brake quickly they must shift their foot from the accelerator to the brake pedal.

In the easy driving task the tracking component was fairly easy, which probably led the subjects to have their visual attention focused straight ahead most of the time, that is in the area where the "brake stimuli" occurred. In the hard driving task the subjects drove a rather curvy road which most likely led them to sometimes focus their visual attention on areas where the "brake stimuli" did not occur. Thus it seems reasonable to assume that the subjects' detection of the brake stimuli was somewhat faster in the easy (straight), compared to the hard (curvy) driving task. Another aspect also speaks for this conclusion. It seems reasonable to assume that the subjects' stress level was somewhat higher in the hard driving task, due to the more complex tracking component. The results from the NASA-TLX also speak for this conclusion since the subjects in the hard driving task were more frustrated than the subjects in the easy driving task. When the stress level goes up this normally leads to a narrowing of attention, in extreme cases to "tunnel vision". This presumed narrowing of attention could have made it somewhat harder for the subjects in the hard driving task to detect the "brake stimuli".

The next phase in the reaction time measurement involves the action of moving the foot from the accelerator to the brake pedal. Since the mean speed for the easy versus hard route was different, we should also expect a time difference between the groups due to the differences in relative position between accelerator and brake pedals. Earlier studies, for instance Davies and Watts (1969), have indicated such a difference. Since the subjects in the easy condition were driving faster, and thus had a somewhat longer relative distance between accelerator and brake pedal, it seems reasonable to assume that they needed somewhat longer time to initiate the brake maneuver.

Consequently, the subjects in the easy condition may detect the "brake stimuli" quicker, but should need a somewhat longer time to initiate the brake maneuver. The subjects in the hard condition may detect the "brake stimuli" somewhat slower, but may be slightly quicker to initiate the brake maneuver. If the detection time is the largest component then these two components can be used to explain the results for the control groups in both driving tasks. But, to apply the same logic to
explain the opposite results for the experimental groups is not possible. Another possible way to explain the results would be in terms of arousal level. It would be possible to assume that the subjects in the easy driving condition had a very low level of arousal caused by the rather boring task of driving straight ahead. This could have explained their relatively slow reaction to the "brake stimuli" in the experimental group. In the hard driving condition the subjects' level of arousal may have been higher due to the rather complex tracking component. This could explain their somewhat quicker reaction to the "brake stimuli" in the experimental group. The problem is, however, that this cannot explain the opposite results for the control groups.

Lateral position. It was predicted that a mobile telephone call would negatively affect drivers' ability to monitor and adjust the vehicle's position on the road. The effect was predicted to be stronger when the demands of the driving task increased. The results from this study mainly confirm the hypothesis. It seems that the physical and mental distraction imposed by the telephone task actually had an effect upon drivers' ability to maintain a steady course on the road, and that this effect was more pronounced when the tracking task was complex. This is possibly caused by the pressure on the driver to time-share between the monitoring of the vehicle, and the telephone conversation.

Workload. The prediction was that workload would be increased due to the mobile telephone call. Also this prediction was confirmed. A somewhat surprising finding was that even physical workload was increased, despite the fact that the only physical maneuver the subjects had to do was to activate the handsfree button. This may mean that the activation of the handsfree button should be improved. A first improvement could be to make it larger, more distinct, or both. Another possible improvement would be to change its position to, for instance the steering wheel. A third possible improvement would be to make the function voice activated. It was also predicted that workload would be more increased when the driving task was complex. This hypothesis was not supported, with the exception of a higher frustration level. This can be interpreted to mean that the subjects in the hard driving task gave the task of "driving" the car the highest priority, and that the demands from the secondary task (the telephone calls) were not allowed to interfere with the driving task. When workload is increasing and threatens to be higher than drivers capacity, one strategy is to concentrate the efforts on the most important task. This will result in an increased frustration level, since the driver must pay secondary attention to some tasks, and partly ignore other tasks.

Speed level. It was predicted that increased workload should lead to decreased speed, and that the decrease in speed should be proportional to the increase in workload. It was found that there was a significant difference in the predicted direction for the subjects in the easy, but not for those in the hard driving task. Again, these results are somewhat surprising, but can be explained in the same way as the results concerning the subjects' reaction time. That is, the subjects in the easy driv-
ing task may have turned the telephone task into their primary task. Because of the high workload devoted to the telephone task this may have led to a decrease in speed. The subjects in the hard driving task may, according to this hypothetical explanation, have devoted most of their workload to the task of driving, and less to the task of solving the telephone task. Consequently, the decrease in speed was not made to the same extent.

However, it is also possible to explain these results in a completely different way. The decrease in speed may simply have been an attempt to reduce the noise level in the car, in order to hear the message better. Since the drivers in the easy condition were driving faster, they also had to reduce the speed more than the subjects in the hard condition. From this study it is not possible to determine if any or both of these explanations are valid. However, the low noise level in modern cars which was simulated here, makes this explanation less plausible.

**Effects of driving task complexity on achievement in the telephone task.** Analysis of the decision and memory component in the telephone task did not reveal any significant differences due to the complexity of the driving task. It was also noted that the subjects performance on the decision aspect of the task was close to perfect. In other words we had a ceiling effect, meaning that this part of the test may have been too simple. On the short term memory aspect there was a tendency for the subjects in the easy task to perform better, but this tendency was not significant. This can be interpreted in many ways. One possible interpretation is that the test used is not sensitive enough to detect any difference in performance. Another possible interpretation is that the difference in driving task complexity was too small. Manipulation of the tracking component can be the wrong way to increase task complexity since the tracking task of driving should be one of the most overlearned tasks. It would be of interest for future studies to vary driving task complexity in other ways, and to investigate the effect(s) on a secondary task.

**CONCLUSIONS**

In contrast to the conclusions drawn by Brown et al., 1969, we found that even very simple tasks of car driving can be affected by a secondary task like a mobile telephone conversation. New is also the finding that the most severe effect on reaction time was found when the driving task was very simple. If this finding can be replicated it has implications for when RTI systems for non-driving information should offer information to a driver. It must be emphasized that the effect on simple reaction time, and all other effects were obtained on a sample of skilled drivers. This probably means that the effects can be much more pronounced for other categories of drivers.

**Implications for traffic safety.** Under some circumstances the increase of brake reaction time may cause problems. A driver on a straight and lonely road who is engaged in a tricky telephone conversation may react too slowly when some animal suddenly crosses the road. These kind of accidents are common in some European countries.
A sudden decrease in speed for some drivers may or may not increase the risk of accidents. It can be argued that anything that increases the variation in speed in a traffic stream has the potential to increase the risk of an accident. Increased variation in speed will make the predictability of the traffic stream lower, which in turn will make it harder for drivers to make judgments of a correct distance to other drivers. It is also easy to imagine situations where the risk would be increased, and also not increased. For instance, a driver driving in fog on a motorway, and being the first car in a platoon of cars may be one cause of series of collisions, if the driver suddenly slows down. If the driver is the last one in a platoon of cars, nothing dangerous will happen.

Variations in lateral position can contribute to an accident if the variations are so large that the driver is leaving the correct lane. In this context it must be noted that the increased variation in lateral position found in this study was rather small, and hardly can be regarded as dangerous.

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REFERENCES


CHP: Mobile telephone safety study (1987). Department of California Highway Patrol, USA.


Variable-Message Signs:
Legibility and Recognition of Symbols

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Variable-Message Signs
Symbol Legibility and Recognition

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Abstract

Variable-message signs are used for a number of applications. In terms of the techniques used, luminous signs using optical fibres and light-emitting diodes are gradually replacing more conventional signs using prisms, rollers, retroreflecting films, and the like. Applications concern danger, prohibition, indication, lane assignment, directional, and information signs, which are being used more widely.

Whatever the application, road users must be able to see, read, and understand these signs.

The first two properties, visibility and legibility, depend on physical factors, in particular photometric criteria of luminance at night and contrast in daylight.

An experiment using observers determined values for these criteria that are now incorporated as requirements in French specifications. They apply to all types of pattern and to all of these technologies. A specific measuring method has been developed in the photometric laboratory; it is completed by definitions of "equivalent area" for discontinuous luminous signs. These make it easy to go from a measurement of luminous intensity to a luminance value, which is better correlated with visual performance.

"Intelligibility" is the third property used to qualify a sign. It concerns the last stage in the perception of a signal. We considered the special case of danger and prohibition signals, which in some cases are displaced in matrix form on variable-message signs. Here, understanding the sign depends on recognizing the usual symbol.

It may be assumed that most of the population understand these signs in their usual form, with a continuous pattern. Converting the symbol from a continuous pattern to a discontinuous form, a
form that varies with the technology, degrades the information transmitted, even though, otherwise, the luminous character of the sign may make it more attention-getting, more conspicuous.

A laboratory study of the understanding of six types of sign was conducted using transparencies produced by the EDGAR graphic software developed for the purpose. The signs were presented to observers for a limited time. The influences of the number of points in the matrix and of the shape of the symbol were investigated.

The first factor of influence is the complexity of the graphics displayed. For example, "dangerous descending gradient", which is difficult to represent by a matrix structure, is much harder to understand than a simpler symbol such as "left-hand bend".

This study raises the problem of specifying matrix symbols. It should be continued in an attempt to arrive at simple recommendations for the main symbols. It would be best to discuss this question at the international, or at least the European, level, since the symbols on road signs should be the same in all countries.
1. INTRODUCTION

Providing information about traffic conditions and road and motorway operating measures has become an essential service to users.

Variable-message signs are now one of the main means of conveying information to users. To function properly, they must be visible, legible, and intelligible to all and deliver a credible message.

We shall deal here primarily with the legibility of VMSs, but also touch partly on questions of understanding.

The first property a VMS needs to be effective, visibility in the sense of detectability, is generally more than adequately provided, because VMSs are often large and so have a good visual impact, especially when luminous.

VMSs must be legible both in daylight and at night. A study was conducted to determine the photometric criteria of legibility. The geometric criteria were also investigated (character height, for information signs bearing alphanumeric messages, and the shapes of pictograms, for matrix symbol messages).

This last study of symbols also touched on understanding them, as well as reading them, by investigating the recognition of different shapes of matrix patterns representing different conventional symbols.

Before describing these two experiments and their results, we shall review the main technologies used today, dividing them into two main categories: signs with continuous patterns and signs with discrete patterns.

2. TYPES OF PATTERNS AND TECHNOLOGIES OF VARIABLE-MESSAGE SIGNS

Various technologies [DUDEK, 1990] and patterns can be used for VMSs.

The patterns of VMSs may be:

- continuous, when they consist of uniform areas or lines as in permanent signs; this is the case for example of prism signs and internally illuminated signs (fig. 1);

- discrete, when they are made up of separate elements; these elements can be arranged on the front of the sign to reproduce the patterns of permanent signs, either in a predetermined manner (fig. 2), in which case the number of messages the sign can display is limited, or in matrix form (fig. 3), in which case there is no limit to the number of messages that can be displayed.
Figure 1. Prism-type variable-message sign

Figure 2. Variable-message sign with predetermined discrete patterns
Discrete-pattern signs can be subdivided into three categories:

**Luminous discrete-pattern signs** in which each element emits its own light.

The technologies in current use are:

- fiberoptic signs in which each point consists of one or several ends of optical fibers illuminated with white light, with coloured filters used to obtain the desired colour; in the case of matrix patterns, electromechanical shutters control the lighting and extinction of each point;

- light-emitting diode signs in which each element consists of one or more diodes; the diodes emit a quasi monochromatic light - red, yellow, or green - and each point may consist of a mixture of diodes of different colours to produce an intermediate colour.

**Nonluminous discrete-pattern signs** in which each element reflects part of the external light illuminating it.

In daylight, the effectiveness of devices of this type depends on ambient illumination. At night, they require external artificial illumination. Currently, the reflecting elements consist of fluorescent surfaces.

**Hybrid (luminous and nonluminous) discrete-pattern signs** in which each element consists of fluorescent reflecting elements and of luminous points constituted by the ends of fiberoptic strands.

In daylight, the light from the elements is a mixture of the light reflected by the fluorescent surfaces and the light emitted by the optical fibers. At night, there is practically no reflection and only the optical fibers are perceived.
3. LEGIBILITY OF ALPHANUMERIC INFORMATION SIGNS

The legibility of a sign, whatever its technology, depends first of all on the message character size (geometrical criterion), then on the luminance of the characters and their contrast with the sign background (photometric criteria).

3.1. Geometrical criteria of legibility

If we consider the legibility of a sign in daylight, one bearing a message of satisfactory luminance in strong contrast with the sign background, then only geometrical criteria are relevant. The distance at which a message can be read can be calculated from the height of its characters and the position of the sign with respect to the road user. It must then be checked that this distance is compatible with the time needed to read the message, which depends on the prevailing speed on the road.

3.1.1. Influence of visual acuity

It should be recalled that the distance at which a message of a given size can be read depends on the driver's visual acuity. Visual acuity is the capacity to see the details of an object clearly. It is defined as the reciprocal of the smallest angle \( \alpha \) (in minutes) at which the eye can see a detail, \( e \), or separate two points or two lines: \( V = 1/\alpha \). Converting \( \alpha \) to radians gives:

\[
V = \frac{d}{3438 \ e}
\]

For the reading of an alphanumeric message, the detail to be perceived, \( e \), is the thickness of the line making up the characters and, \( d \), is the reading distance.

In the case of signs having characters formed by 5x7-point matrices, this width \( e \) may be taken to be 1/7th of character height \( H \).

Visually acuity is commonly stated in 1/10ths, where the perception of an angle of 1' corresponds to 10/10, the usual reference value. This acuity ranges from 1/10 to 20/10 in daylight [Bry, Colomb, 1988]. It varies with ambient illumination and with contrast.

Assuming that the sign is observed under optimum conditions, a reading distance can be calculated versus letter height for different visual acuities. This is what is shown in figure 4.

For example, for an individual having a visual acuity of 10/10, the letters of a message must be more than about 200 mm high to be read at 100 m.

The reading distance for a motorist having a visual acuity of only 5/10 would be half this distance.
3.1.2. Influence of reading time

VMS specifications [1990] stipulate three different character sizes for different approach speeds:

<table>
<thead>
<tr>
<th>Approach speed (kph)</th>
<th>Recommended character height (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>110 - 130</td>
<td>400</td>
</tr>
<tr>
<td>90</td>
<td>250</td>
</tr>
<tr>
<td>60</td>
<td>160</td>
</tr>
</tbody>
</table>

The variation of recommended height with approach speed makes allowance for the driver's reaction time, and more particularly his reading time.

The time needed to read a message can be estimated from the number of units to be read, according to an English study [Odescalchi, Rutley, Christie, 1962], by the formula \( t = 0.31 N + 1.94 \) (seconds), where \( N \) is the number of units to be read (words, numbers, symbols, etc.). This formula gives an order of magnitude, and may be expressed more simply as \( t = N/3 + 2 \). More recent work [R. HALL, MCDONALD, RUTLEY, 1991] leads to an estimate of reading time that is only half as great. Nevertheless, for this evaluation, we shall retain the first method, which gives the user, in a real-life situation, a margin of safety by allowing him time to read the message twice, if necessary. From this time required to read the message, it is interesting to calculate, for a given character height and thus a given reading distance, the maximum reading time and the number of units that should not be exceeded.

In the diagram of figure 5, the distance necessary for reading is shown by \( CA \).

\[ CA = \sqrt{\text{v.t}} \]

where \( C \) is the point at which reading starts as determined by the visual acuity;
A is the point at which reading ends because the sign leaves the cone of clear vision defined by a half angle \( \theta = 10^\circ \) with respect to the direction of fixation [King, 1971];

and \( v \) is the speed.

\[
\begin{align*}
A & \text{ is the point at which reading ends because the sign leaves the cone of clear vision} \\
& \text{defined by a half angle } \theta = 10^\circ \text{ with respect to the direction of fixation [King, 1971];} \\
& \text{and } v \text{ is the speed.}
\end{align*}
\]

\[
\begin{align*}
\text{Figure 5. Angular conditions determining start of reading CP'.} \\
& \text{This diagram is for the driver of a private car.}
\end{align*}
\]

In other words, the message must have been read by a distance \( AP' \) from the sign.

Assuming a sign at a height of 7.50 m from the ground, and the eyes of the driver of a private car at a height of 1.20 m, the 10° limiting cone means that distance \( AP' \) is

\[
AP' = \frac{PP'}{\tan (10^\circ)} = 36 \text{ m}
\]

Suppose that the sign is on a motorway where the recommended speed is 130 kph and the character height is 400 mm. According to figure 4, the reading distance for the sign for a person with 10/10 acuity is about 200 m. The distance remaining in which to read it is distance \( CA \), equal to 164 m in this example.

The corresponding reading time is \( t = \frac{CA}{v} \), equal to 4.5 seconds in this example.

It can be deduced that the number \( N \) of units that should not be exceeded for a driver having 10/10 visual acuity to have time enough to read them, which must be less than or equal to \( 3(t-2) \), is equal to 7 for this example.

This means that under the conditions of the example described, a motorist having 10/10 visual acuity will not have time to read all of a message more than 7 words long.

The messages used on roads and motorways are generally shorter than this [J. Durr, 1990], and so easier for motorists to read.

Over-long messages might be misunderstood and induce dangerous behaviour, such as braking as the sign is approached so as to have more time to read it.
This calculation method can be used to determine reading distances or times. A calculation program applies this same procedure and makes it possible to vary the diverse parameters and so assess the influence of speed, visual acuity, the number of words, and so on, on reading distance.

3.2. Photometric criteria of legibility

When the luminance of the characters or the contrast with the background decreases, the subject's visual acuity declines and the reading distance becomes shorter (cf. figure 1). To limit the loss of acuity and thus the reduction of the reading distance under conditions of degraded visibility, it is necessary to establish contrast and luminance criteria so as to keep the day and night legibility of a sign adequate.

This is the objective of the study described below.

It was noted that some VMSs were hard to read in daylight because of too little contrast between the characters and the background. The matrix structure of most messages contributes to this difficulty according to the size and spacing of the points of the matrix and, most important of all, the luminance of the characters.

A Dutch study [Van Meeteren et al, 1968] has shown that a luminance ratio of the order of 10 between the letters and the background leads to optimum legibility of the messages of internally illuminated signs.

It may be wondered whether this result applies to VMSs and whether it is possible to determine not only a reading optimum but also a reading threshold on the basis of photometric criteria.

A study of the day and night visibility of VMSs has been conducted at the LCPC, working with the INRETS, in an attempt to answer this question.

Daytime legibility is treated as a matter of luminance contrast. The night results could also be treated in terms of contrast, but, under the conditions investigated, the background luminance of the sign is generally negligible. And so these results are stated solely in terms of the luminance of the characters.

3.2.1. Experiment

The study was carried out on a discrete-pattern sign, a diode prototype, designed by the optronics laboratory at Poitiers. This sign exhibited a single character from among the 26 letters of the alphabet, formed by 5x7 points and 320 mm high. Each point could consist of 1, 4, 9, 16, 25, or 36 diodes. The luminous intensity per point ranged between 0.02 and 1.2 cd at night and between 0.2 and 8 cd in daylight.

This sign was presented in turn to 27 observers placed 200 m away inside a stopped vehicle. For the experimental procedure, to assess the influence of contrast on the observers' performance, it was simpler to operate at constant distance and determine variations in the percentage of accurate identification than to determine, for each individual, a variable reading distance for constant performance.
3.2.2. Day results

The results are given in figure 6.

We give the percentage of correct identification by 27 observers versus luminance contrast.

This contrast is defined as the ratio \( C = \frac{L}{L_F} \)

L is the luminance of the character, \( L_F \) the background luminance.

In the course of this test, the background luminance varied between 100 and 500 cd/m². For the calculation we used the value \( L_F = 200 \text{ cd/m}^2 \).

What then is the luminance \( L \) of the character?

In daylight, this luminance is the sum of the intrinsic luminance \( L_I \) furnished by the light-emitting points and the luminance resulting from the diffusion of ambient light from the front of the sign, i.e. the background luminance \( L_F \).

\( L = L_I + L_F \)

The intrinsic luminance \( L_I \) can be calculated from the luminous intensity per point of the matrix, \( I_p \), and the area \( S \) of the character.

\( L_I = \frac{I_p \times 35}{S} \)

To determine \( L_F \), a standard measure has been defined in photometric laboratory. The background luminance, \( L_F \), is measured on a character that is off, in the...
reference axis (normal to the front surface), with illumination from an angle 20°
above this reference axis, with the luminance obtained referred to an illumination
of 80,000 lux in the plane of the front surface of the character.

Figure 6 thus shows the contrast \( C = \frac{L}{L_F} = \frac{L_I + L_F}{L_F} \) on the x-axis.

It can be seen that the percentage of characters correctly identified increases
rapidly from 10 to 50 %, then reaches 85 %, as the contrast increases from 1.5 to
about 3, then to 8. Performance then stabilizes at about 85 % for contrast values
between 8 and 20.

The various symbols represent different point sizes. This experiment did not find
any influence of point size on performance.

To illustrate the effect of contrast on legibility, we have reproduced the word
"PARIS" (fig. 7), in matrix characters, on three different backgrounds ranging
from dark to light, with the luminance of the letters unchanged. The contrasts,
from top to bottom, are approximately \( C = 20 \), \( C = 3.3 \), and \( C = 1.5 \).

![Image of the word PARIS with different contrasts](image)

Figure 7. Illustration of effect of contrast on reading of message

This study of the influence of contrast on legibility was taken into account when the
specifications of variable-message signs were revised [1990]. For day visibility,
the photometric characteristics of variable-message information signs are stated in
contrast form, as defined above.

3.2.3: Night results

At night, the background luminance is negligible and legibility depends only on the
luminance of the characters.
The results of the night experiment show a percentage of correct identification, of the order of 60%, that is stable for character luminances between about 10 and 700 cd/m² [Colomb, Hubert, 1990]. These values agree with those given in the literature [Allen, 1967]. On the basis of a study carried out on internally illuminated signs, under both rural and urban night conditions, the author recommends, for comfortable reading:

- in rural zones where there is little or no illumination, a luminance between 30 and 300 cd/m²;
- and in highly illuminated urban areas, a luminance between 300 and 1500 cd/m².

These values were used in preparing the specifications.

4. LEGIBILITY AND RECOGNITION OF PICTOGRAMS

4.1. Legibility

Permanent warning, prohibition, and indication signs use symbols. This representation is taken over by variable signs used for the same purpose.

To be legible, they must, like alphanumeric signs, satisfy geometrical criteria (minimum symbol size) and photometric criteria (satisfactory luminance and contrast).

Colorimetric requirements are stated in the specifications but not presented here.

**Remark:**

Colour affects the legibility and understanding of messages. It contributes to the contrast and to the meaning of the message (e.g. red = danger). Regulation colour ranges are proposed in the specifications. Some differ from the International Commission of Illumination, (C.I.E.) recommendations to allow for drivers' possible deficiencies of colour vision and so permit the use of the diode technology which red colour point is out the CIE range. Some colour-deficient individuals might perceive the red from diodes too poorly [Corno, Viénot, 1990]. The practical consequences should be investigated and taken into account in the specifications.

- As regards the geometrical criteria, the dimensions of VMSs (triangle or circle) are stated in the specifications. The size of the symbol itself is not specified. A "reading" distance can be estimated for the sign, as a function of visual acuity, after the "detail to be perceived" has been determined for the symbol. For a first approximation, "the smallest thickness of a part of the symbol" may be used as the definition.

- For the photometric criteria, the luminances may be measured and the contrast calculated easily on signs with continuous patterns. For signs with discrete patterns - matrix or predetermined patterns -, the luminance can be calculated from the measured luminous intensity and the area of the symbol.

4.2. Recognition

There is currently a difference in specifications between alphanumeric-message signs and pictogram signs.
For the former, the shape of the characters, letters or figures, is clearly stipulated in the specifications and standard alphabets are proposed. But for discrete-pattern pictogram signs, it is merely stated that "The style of the symbol must be as close as possible to the style required for the symbols of permanent signs as specified in the 'list of pattern films and pattern elements of signs'. It must be possible to identify the symbols without ambiguity."

But, with this type of sign, the style of the patterns becomes a luminous pointillism that departs from the traditional shape of the continuous pattern, leading to a loss of information that must be evaluated. This type of sign has an undeniable impact that must not be impaired by a defective representation of the symbols. Our objective is to attempt here to define limits in the manner of representation so as to preserve the legibility and understanding of the symbol displayed.

A study of the perception of the patterns of VMSs was accordingly conducted, using the EDGAR software developed at the LCPC [Carta, 1990] to generate the symbols. This program is primarily a tool for investigation of the perception of matrix symbols on variable-message signs. But it can also be used in designing VMSs.

It can be used to display, on the monitor of a PC or compatible microcomputer, a figure made up of juxtaposed circular or square elements of the same size and any colour. This figure is a matrix, the size of which can vary according to the operator's initial choices. This basic module can be used to create, freely and interactively, any figure.

In the context of a study of the perception of the patterns of VMSs, an algorithm was developed to translate the symbols of traditional signs, entered using a digitizing tablet, into matrix form automatically. An imager is then used to reproduce these matrix signs in the form of slides that can be shown to observers in an attempt to determine the minimum matrix size compatible with good recognition of the symbol.

4.2.1. Description of the experiment

The study of recognition of matrix sign pictograms consisted of presenting, to a group of 30 observers, a series of 26 slides reproducing the following signs:

- slippery pavement (A4)
- left-hand bend (A1a)
- trucks may not overtake (B3a)
- pedestrian crossing (A13b)
- dangerous gradient (A16)
- road work ahead (AK5).

Each sign was presented in three matrix sizes (40x40, 64x64, 80x80) and in three types of matrix translation:

- a "thick" matrix representation of the traditional symbol consisting of all matrix elements that intersect the symbol;
- a "thin" matrix representation of the traditional symbol consisting of only matrix elements strictly contained within the symbol;
- a free representation.

Figure 8 shows the permanent sign and the three types of representation.
Figure 8. The "road work ahead" sign in permanent form (a), in a free representation (b), in a thin 80x80 matrix representation (c), and in a thick 80x80 matrix representation (d).

The presentation distance, given the size of the slide, corresponds to observation from 100 m on a road. Presentation was for a limited time ranging from 100 ms to 1 second.

This experimental procedure was used because presentation for a limited time, which is a sort of degradation of the image, reveals the various stages of the information processing mechanisms. It makes it possible to put forward a judgment concerning the way in which the subjects apprehend the various messages and so select the most effective among the messages.
4.2.2. Results

The first results of the study can be used to classify, in order of importance, the parameters that influence symbol recognition. The order is:

- complexity of pictogram;
- type of matrix translation;
- matrix size;
- presentation time.

More precisely, it was found that:

- signs bearing a complex pictogram (A16) are recognized with difficulty; the level of correct responses does not exceed 50 %, even with an observation time of 1 second and an 80x80 matrix;
- signs bearing a message that is simple but made up of curved lines (A4, A13b, AK5) must be represented in a matrix that is large enough (64x64), but then attain 70 % correct responses with an observation time of 200 ms;
- the signs of which the patterns "hold up" well under transformation (A1a, B3a) score 80 % correct responses with a 40x40 matrix and an observation time of 200 ms.

It was also found in the course of the tests that an image may be rendered ambiguous by a lack of information (e.g. symbol excessively simplified or defined by a contour only), or by an excess of irrelevant information (masking of essential features by a plethora of meaningless details), or also by the existence of several possible interpretations (e.g. confusion of two similar symbols).

When a message is presented, the subject frames, checks, and revises hypotheses concerning what he perceives; an organization will gradually be imposed on the information. During the analysis of a message, this organization may fluctuate. The human system tolerates large shape distortions. It can recognize, as the same message, messages having very different superficial characteristics, but this flexibility has its limits, as we have already noted.

It should be recalled that these results were obtained in simulations using slides representing VMSs, with a constant luminance contrast. They must be validated on actual signs, in particular on VMSs with luminous discrete patterns, because with such technologies as optical fibers or diodes, with a large luminous intensity, the large luminosity of the points produces an apparent enlargement of the symbols represented. This effect may influence symbol recognition.

CONCLUSIONS

Variable-message signs are a user information medium with a fast-changing technology in which there is a large growth of systems using discrete patterns, which may be luminous, reflecting, or both at once. To be effective and credible to the user, they must first of all be legible under the various conditions of observation encountered on roads and motorways. Their legibility depends on various parameters and on how the text or pictogram is represented. Geometrical criteria allowing for the reading time of a message (character height, number of words, speed) make it possible to evaluate the reading distance of a sign.
A study of the particular case of alphanumeric information signs provided information that was useful in setting photometric specifications that ensure adequate visibility under a variety of conditions. Contrast criteria have been incorporated in VMS specifications.

The understanding of VMSs was studied by simulation of the particular case of recognition of matrix symbols. The complexity of the pictogram is the factor that most influences symbol recognition. This study is a first step in the process of optimizing these symbols.

Not all of the parameters relevant to the effectiveness of VMSs have been covered here. Colour, in particular, has been omitted; it is currently the object of some studies of the consequences, to individuals having deficient colour vision, of the chromatic and luminous qualities specific to LED technology.

In addition, the use of new technologies (hybrid luminous and reflecting signs, segment matrix signs, etc.) raises new questions, in particular concerning contrast measurements. Studies are continuing at the international level, notably under the "Visual aspects of VMSs" technical committee of the International Commission on Illumination.

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REFERENCES

M. Bry, M. Colomb
Visibilité de la signalisation : les besoins des usagers et les technologies disponibles
Revue Générale des Routes et des Aérodromes n° 658 - Décembre 1988

Van Meeteren, A. Leebeeck, H.J. and Blokland de Graaf, N.H.
Legibility of internally illuminated highway signs
Report IZF - 1968 - C2 TNO The Netherlands

M. Colomb, R. Hubert
Legibility and contrast requirements of variable message signs
69 th Annual Meeting of T.R.B. - 1990 - To be published

Cahier des charges des panneaux à messages variables
Arrêté du 13 août 1990 relatif à l'homologation des panneaux de signalisation à messages variables

Allen et al
Luminance requirements for illuminated signs.
Highway Research Record Board - 179 pp - 16 - 37 - 1967

Odescalchi, Rutley, Christie
The time taken to read a traffic sign and its effects on the size of lettering necessary
TRRL n° LN/98 - 1962

VTI RAPPORT 372A
Determination of sign letter size requirements for night legibility by computer simulation
Highway Research Record n° 366, p. 48-63 - 1971

J. Durr
Groupe USAP Information des usagers, sous-groupe "lexique"
Rapport provisoire - Juin 1990

V. Carta
Étude du graphisme des symboles matriciels des panneaux à messages variables - Programme EDGAR
TEC n° 103 - Nov-Déc. 1990

F. Corno-Martin, F. Viénot
Conséquences pour les individus présentant des défauts de la vision des couleurs, des spécificités chromatiques et lumineuses de la technologie à diodes utilisée en signalisation.

C. Dudek
Guidelines on the use of changeable message signs
Federal Highway Administration Report n° FHWA . TS. 90-043 - Nov. 1990

R. Hall, M. Mc Donald and K. Rutley
An experiment to assess the reading time of direction signs proceeding of Vision In Vehicles III - p. 333-350 - 1991
Man and His Wheel:
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The man and his wheel: cognitive and perceptual aspects

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Summary

It is commonly agreed that visual perception is the most prominent faculty among the psychological, internal processes involved in the act of driving a car. It is therefore not surprising that 'where to look', 'when to look' and 'how to look' are major issues in the instruction of novice drivers. Despite the fact that visual strategies are being taught, we are still rather limited in the understanding the differences between novice and expert driver in their visual behaviour. It is concluded that 'understanding' visual behavior requires an exhaustive model of the cognitive and perceptual processes. This paper outlines a theory that explores the involvement of the visual system in driving. The theory is discussed on three levels of description: a taxonomy of the visual tasks, an algorithmic account for the tasks and an implementation of the algorithms in a simulation of the driver. The chapter is concluded by recommendations for the instruction of novice drivers.

1 Introduction

In many European countries the training of novice drivers is a time consuming and costly endeavour. While the ultimate goal may be teaching how to drive we sometimes might get the impression that the aspirant drivers are trained to pass a driver's exam, what does not necessarily mean that they learn how to drive. Thus we may identify an intriguing area of research by posing the questions what it is that makes an 'expert' driver so successful and how a novice driver can be instructed such that he will become an expert in the shortest time possible. These two questions form the basis of this chapter. It will turn out that the formulation of a highly effective driving instruction requires a full scale perceptual/cognitive model of the driving task.

Many of the verbal instructions during driving lessons concern the visual search strategies of the novice driver, where and when to look are major issues (De Velde Harsenhorst & Lourens, 1988). Furthermore, it is generally assumed that 90 percent of all information that is picked up during driving is visual. We may conclude that visual strategies and perception perse are major factors in the understanding of the learning process of the novice driver (Wierda, 1990).

In the remainder of this chapter the outline of a theory of visual perception and cognition in driving is given. The full text can be found in Wierda and Aasman (in press).
Research strategy

An important concept in publications on perception in driving is expectancy, see for example Hills (1982). The term indicates that driver behaviour is not only dependent on what the driver actually sees but also what he expects to see. Consequently the driver will scan his environment by body-, head- and eye-movements to 'test' his expectations. Therefore, in building a model that accounts for the visual strategies of drivers, the central cognitive processes that are responsible for 'expectations' must be incorporated. Because this is a huge task, it seemed wise to cut the modelling in three phases as has been suggested by Marr (1982) in his monograph on the theoretical approach of human vision. The first phase deals with the questions what the necessary visual processes are in a particular task and why they are necessary. The result is a computational theory of vision in driving. In the second phase an algorithmic account is given for the computational theory. For each specified visual/cognitive task the necessary internal representations are defined, as well as the primitives (the elementary building blocks in the representations) and the processes that transform an element from one representation into another. In the last phase the algorithmic model is implemented. Implementation can take two forms. Firstly we can search neuro-physiological databases for brainstructures that are capable of the functions as defined by the algorithms. Secondly the algorithms may be implemented in a 'psychological valid' simulation of the cardriver. By comparing the output of both implementations with observed perceptual behaviour of drivers the computational and algorithmic model are tested. In next paragraphs some major issues in the three modelling phases are discussed subsequently. A full elaboration of each phase can be found in Wierda and Aasman (in press).

A computational model of vision in driving

The criteria for the enumeration of the visual tasks in driving are efficiency and safety. The job can be considered as a normative taskanalysis (see Brookhuis, 1989) resulting in a taxonomy of visual tasks such heading angle estimation, 'own' speed and speed of others derivation, obstruction detection, detection, classification and identification of traffic infrastructure and specific traffic situations, etcetera. The taxonomy is a long list, once more indicating the heavy involvement of the visual system in driving.

The 'what has to be done (visually)' question has been extended by examining empirical data of expert drivers. After all, expert drivers normally do the driving task efficiently and safely. One of the major outcomes is that visual behaviour, in terms of body-, head- and eye-movements differ substantially from subject to subject. Take the example of a driver on a straight highway, cruising at 90 km/hr with the only instruction to maintain speed and heading angle. Using a NAC V eye-mark recorder the eyemovements are recorded (Wierda, 1990). In figure 1 a 100 second period is plotted for 18 subjects. Each white spot in the horizontal black line indicates that the driver is looking at the point of expansion in the optical flow, or in other words 'gazing at the end of the road'. In the black sections of the line the driver is looking at the speedometer, inside or outside mirror or any other location than the point of expansion. Subject number twelve is looking for only very short periods of time at the road, while number fourteen is gazing at the end of the road for the major part of the 100 second interval (reanalysed data from Jesserun et al, 1990).

Two conclusions have been drawn from the computational model. Firstly, we can specify the visual tasks to a high degree but individual human drivers carry out
these task rather differently. Secondly the visual tasks are to a large extend spatiotemporal in character.
Both conclusions have major consequences for the algorithmic model and its implementation.

4 An algorithmic model of vision in driving

On this level of the model the necessary internal levels of representations are defined. Each representation has its own primitives, the elementary data structures that are used to built elements in the representation. It is beyond the scope of this chapter to fully describe all levels, only an outline will be given. For basic theoretical considerations see Marr (1982), and Wierda and Aasman (in press) for the entire model of vision in driving.

The first internal representation is a one to one copy of the excitations on the retinas and is called the primal sketch. A number of visual routines are specified that are capable, among others, of extracting closed contours and depth (by stereopsis) which segment the image into surfaces with elementary depth cues (Ullman, 1984, Wierda, 1990). These surfaces and depth cues are stored in a second level of representation that is called the 2 1/2D sketch.
As algorithmic restrictions for the mentioned lower levels of vision count the different Fields of Vision (FOV) for different visual dimensions, such as colour, brightness contrast and features as letters versus numbers. For example equiluminant colours can only be used to discriminate contours from the back-
ground in an area of approximately 15 degrees of visual angle around the fixation point while motion can be detected in an area of 210 degrees horizontally. As complementary restrictions we can mention the Spotlight of Attention or Attention Area (AA), a small area of 1.5 angular degrees in which the image is represented in full detail (Posner, 1980, Parasuraman, this volume). Some theorists have suggested that the spotlight can be smeared out over a region of 15 angular degrees and that the spotlight should be considered as a zoom lens of attention (Erikson and James, 1986). The detailing of the image drops with an increasing Attention Area. The largest possible area (15 degrees) is called Visual Lobe (VL) and is functionally different from the entire field of vision which has major implications for the degree of detailing in the primal and 2.5D sketch (see Drury, in press, and Wierda and Maring, in press).

The existence of the selective filters AA, FOV and VL are of course the primary reason for the driver to move his body, head and eyes toward objects of interest. This enables us to research visual strategies by examining these movements. After all, drivers 'look' at particular spots in the task environments because they expect to 'see' something. However, there are a number of caveats in the relation between seeing and eyemovements (see Groner, 1988). For example the fact that a subject is fixating on a particular object does not necessarily mean the subject is 'seeing' the object. And the reverse is also true: we may not conclude that if a subject does not fixate on an object he will not 'see' it. The lesson to be learned is straightforward: one must be very precautious in interpreting eyemovements and scanpaths while the interpretation is only possible within an existing perceptual/cognitive model.

It is important to notice that the 2.5D sketch does not represent depth but only indicates potential depth by the orientation of surfaces. Furthermore the contents of the representation are viewer dependent: if the eyes are moved, the contents change immediately. It is very implausible that objects are recognized by comparing a remembered image (of for example a car) with the actual contents of the 2.5D sketch since an object has an uncountable number of appearances due to different perspectives. To enable recognition an algorithm has been proposed that calculates a vector from the 2.5D sketch that represents the spatio-orientational orientation of the surfaces that constitute the object. Attached to this vector, also called the main axis, is a vector that defines the potential volume of the object. This set of vectors can be conceived of as a 'skeleton' of an object. While the image of an object changes dramatically if a different perspective is taken, the 'skeleton' remains relatively unchanged. Therefore the skeleton (the vectors) are usable in a pattern matcher: for each prototypical object only one (prototypical) skeleton is stored in a visual memory and is used to compare with the derived skeleton of a newly seen object. Once an object is recognized it is represented internally by its skeleton. In this representation the perceived objects are defined in respect to their own axis (vectors) and therefore the spatio-orientational relations between objects is known independent of the viewing angle. The major property of the skeletons is volume, hence the representation has been called the 3D internal model.

The skeletons for objects are stored as headed hierarchies (see Jackendoff, 1987). A hierarchy is built from levels of descriptions of main and auxiliary axis. Take the example of a car. The top or most abstract level represents the car as no more than a box. The level below the top gives the main axis of the dominant constituent part: the doors, a top and the trunk. Each of the constituent parts has an own main axis. The hierarchy can be unfolded to an appropriate level of detailing. The point to be made here is that a car approaching in the distance will be recognized as an element of the class of cars, without knowing type, make and whether it is a four door or coupe. If necessary the hierarchy may be unfolded. The headedness of the prototypes refers to the property that the loca-
tion and possible movements of the constituent parts are determined by the
next above level: the location of a door and the way it may swing open is deter-
mined by the prototype that captures a car as a box.
Recently we have proposed that the 3D prototypes also encompass the relative
motion and speed of an object. This is realised by attaching a movement vector
aligned with the main vector. Since the 3D model is not dependent on the par-
ticular viewing point it is conceivable that objects may move in the 'minds eye':
even when a driver looks away from a point where he has detected an oncoming
car he still will know after a while where the once seen car will be approximate-
ly. To justify this temporal/spatial capability the level of representation has
been called 31/2D structure. Objects are represented as volumes and they are
spatially located with respect to each other (the human observer is a 31/2D
object too) while their position is updated automatically when time runs by.
It is the same level of representation where we defined prototypes of infrastruc-
ture and typical traffic situations. Infrastructure is stored as headed hierarchies,
the main axis indicate the orientation of the surfaces of roads, intersections et-
cetera. It is furthermore conceivable that the 31/2D prototypes of road users
are linked to the headed hierarchies for infrastructure by attaching them at spe-
cific 3D locations. These locations are derived from the speed vectors of the
prototypes. Thus new prototypes are formed that capture typical infrastructure
with potential (by definition relevant) road users. These new prototypes are
stored as typical traffic situations which might be recognized by expert drivers
in a flash.
Recognizing the fact that the outline of the algorithmic model must be superfi-
cial by the limited space of this chapter we proceed by concluding that the for-
mation of prototypes of objects, infrastructure and traffic situations is depend-
ent on learning. Only by experience in traffic adequately tuned prototypes will
be formed. 'Learning' may explain the huge differences in scanning behaviour
of individual drivers, each subject having a idiosyncratic set of 31/2D proto-
types. In figure 2 a flowchart of information and actions is given in which the
main concepts of the theory are depicted.

Global scanpaths consist of (potentially) large body-, head- and eye-movements
and are initiated by the knowledge already available in the system. When a
prototype of an intersection is matched with a current image, eye- and head-
movements are initiated automatically to the locations where relevant road
users may be. Recognition of specific road users may require a detailed examin-
ation of the image resulting in small eyemovements with short fixations. These
patterns are called local scanpaths (see also Nodine and Kundel, 1987).

5 Implementation of vision in driving

As has been stated in the introduction the computational and algorithmic
model are tested by implementing, in other words by simulating, the perceptual
module in a general, intelligent architecture. This system is called Soar and was
developed on concepts derived from the work of Newell and Simon (1972) on
human problem solving. Aasman (1988) used Soar to test cognitive driver mod-
els. The model as outlined in the remainder of this chapter is an elaboration of
earlier versions and by now the implementation is an autonomous, intelligent
agent that is capable of 'driving' (see also Aasman and Michon, 1991). Soar was
proposed initially by Laird, Newell and Rosenbloom (1987). From a theoretical
point of view it is the embodiment of the Problem Space Hypothesis (PSH).
This hypothesis states that all human intelligent behaviour can be cast as search
in problem spaces. From a practical viewpoint it is an architecture that evolved
from production systems and, as a result, inherited many of its attributes (Newell & Simon, 1972). Its typical properties are that it maintains a goal context in a working (symbolic) memory. Given a current goal, productions will search Working Memory for information that is relevant in the problem space and that might solve the goal. A problem space is in some respects synonymous with what we usually call a task domain. It incorporates all task-specific knowledge that a system has about a particular task. More formally it is defined as a set of states, including an initial and desired state, and operators that will transfer an initial state into a desired state. If a goal turns out to be inachievable in the current state (this situation is called an impasse) then a subgoal is defined in a newly created state. The subgoal is directed at the elimination of the reason for the impasse. Subgoals can be generated recursively. The combination of a goal, problem space, state and operator is called a 'context'. When subgoal is achieved, Soar learns a new production called a "chunk" that summarizes the problem solving in the subgoal. This chunk is applied automat-
ically as soon as Soar runs in the future into the same state that caused the original impasse. The creation of chunks is the major form of 'learning' in Soar. By now we may see how prototypes are formed. When the novice driver is encountering an unknown situation, he/she must 'think' about where to look and what to do. Since the car needs to be controlled simultaneously, several forms of stimuli call upon the attentional mechanism. Highly probably several impasses occur; in solving the impasses the novice driver learns what to do the next time a 'comparable' situation is encountered. Eventually this will lead to the creation of prototypes for traffic situations, and by that time the driver will have become an 'expert'. In figure 3 an overview of the principal components of the Soar implementation is given.

![Diagram of the Soar implementation](figure3)

**Figure 3.** An overview of the major components of the implementation of the driver model in Soar.
The functionality of the implemented model will be shortly discussed by reference to figure 3. Firstly we distinguish specific routines that deal with the 'outer world' (the LISP routines) and the Soar structures (the lower part of the figure). The LISP input routines embody low level visual constraints such as the size of VL and FOV. The Lisp output routines control the movements of head and eyes. Both routines are directly read and or triggered by SOAR input and output. Soar input calls Lisp to transfer 'newly seen objects'. These objects are transformed in Working Memory Elements (WME, commonly called Wim mies) which are used in the pattern matcher that is capable of 'recognizing' objects, infrastructure and typical situations. Soar output will search WMEs that embody motor commands. If it finds one it will trigger LISP output to execute the motor command (to move body, head or eyes). Long term memory production rules search WM for appropriate WMEs. WM may contain hundreds of WMEs at the same time while all production rules are matched in parallel against the WMEs. If a production rule is matched it will 'fire' and will possibly be executed. Its action may be adding a WME to WM. The WME can be a motor command, or a piece of conceptual knowledge which can trigger a next production rule.

An example of a production that fires if two WMEs are present in WM that both represent a moving object is given below. It ensures that an object that is moving faster than an other object will capture 'attention':

```
(sp base-level*prefer*move-attention*moving-better
 (goal <g> ^state <s> ^operator <o1> + ^operator <o2> + )
 (<o1> ^name move-attention ^object <o1> )
 (<ob1> ^moving yes)
 (<o2> ^name move-attention ^object <o2> )
 (<ob2> ^moving no)
 -->
 (goal <g> ^operator <ob1> > <ob2> )
```

The first part of the production (the lines above the arrow) is the conditional part. Soar will try to match this conditional part against elements in WM. The last line is the action part. It states that the relevancy of object ob1 must be higher than ob2.

From the implementation of the visual functions we have concluded that the model actually displays searching behaviour comparable to human visual search. Above that, it turned out to be necessary to give the model a number of parameters which determine the functionality of the model to a large extend. Just as we may distinguish human drivers in terms of experience or risk taking, the Soar implementation apparently may also have many faces.

Recently the initial implementation was completed to a full functional model. By now the model can be tested by comparing observed eye- and head-movements of human subjects in specific situations with behaviour of the Soar model while 'it drives' in exactly the same environment. It is expected that eminent differences will enable 'tuning' of the implementation in Soar. Above that, the empirical data should also have their consequences for the algorithmic level; this model may need to be adjusted as well.
Conclusion

Although the theory as has been outlined on the three levels of description is hardly full grown we may draw some preliminary conclusions. In particular recommendations for the training of novice drivers are of interest since new methods of instruction become available by the introduction of high speed graphical computers. It is expected that in the next few years we will be able to simulate the traffic environment on low cost machines so accurately that these machines can be used as a learning environment for trainees. This gives the opportunity to develop entirely new educational systems.

From the computational model we can draw the conclusion that visual perception in driving may be clustered in three sets of tasks. The first set focuses on detection, for example the detection of obstructions, other road users and signs. The second set captures the tasks that focus on the (visual) interpretation of situations while the third set focuses on the dynamics of the traffic environment. However, from the algorithmic and implementation level we may conclude that the three sets of tasks are strongly related. For example, the recognition of a particular traffic situation will guide the visual search for relevant objects. Hence the detection of obstructions has become an integral part of the visual search.

‘Learning how to drive’ is, with respect to the algorithmic and implementation level, firstly the development of efficient prototypes (enabling efficient recognition) and secondly the ability of spatio-temporal reasoning. An example of this ability is to ‘know’ where a car that approaches on a crossroad will be after a few seconds without looking at it. The development of prototypes may be speeded up by verbal instructions and by guided experience. Here ‘intelligent’ traffic simulators may have their impact. Learning to use the ‘internal 3 dimensional, dynamic world’ to predict an evolving traffic situation is probably highly dependent on experience. And here again simulators can be very valuable: they can provide the trainee over and again with those situations which are most beneficial for the learning process.

Literature


Erikson, C.W., James, J.D. St. (1986) Visual attention within and around the field of focal attention: a zoomlens model. Perception and Psychophysics, 40, 225-240.


Measuring Effects of Variable Message Signing on Route-Choice and Driving Behaviour

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Measuring Effects of Variable Message Signing on Route-Choice and Driving Behaviour

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Abstract

Certain parts of a road network may suffer from congestion, whereas other road sections still have spare capacity. As a part of a dynamic traffic management system that aims at an optimal use of the whole network, Variable Message Signing (VMS) may be a means for diverging traffic flows from an originally intended route towards an alternative one.

The tendency to diverge will depend on the manner the information is presented to the driver. In a driving simulator study different implementations of VMS were evaluated in terms of route-choice and driving behaviour. The VMS elements that were varied included
1) the removal of the critical destination from the main route sign together with adding this destination on the exit sign,
2) the crossing out of the critical destination on the main sign by a red line, and 3) and indication of the reason that diverging is advised by the message "queue" in combination with 2). These three elements were also combined with a yellow flasher after the added destination on the exit sign, resulting in six VMS configurations.

Motivation was controlled by a special pay-off structure with two penalty schemes, viz. a modest one with a one guilder and a severe one with a two guilder penalty for every minute late. Each subject conducted 60 runs, of which 14 were with VMS. 48 male subjects participated in the study.

The proportion of VMS runs in which the advice to diverge was not followed by the subjects, appeared to be dependent of the type of VMS and ranged from 0.9 to 27%. The combination of the indication "queue" and the crossed out destination on the main sign resulted in the highest proportion of persuasiveness of VMS. The flasher was only effective when the crossing out was applied separately.

In this study a decision-making process such as route-choice had an influence on the resulting driving behaviour at and near the decision-point. A high inclination to diverge appeared to be accompanied by early exiting and the maintaining of a relatively high speed, indicating less hesitating behaviour than in conditions with a low propensity.

From a methodical point of view, it is interesting to conclude that apart from perceptual-motor tasks also cognitive and motivational aspects can be studied successfully in a driving simulator.

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MEASURING EFFECTS OF VARIABLE MESSAGE SIGNING ON ROUTE-CHOICE AND DRIVING BEHAVIOR
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1. INTRODUCTION

A dynamic traffic management system aims at an optimal use of a complete road network. As a part of such a system, Variable Message Signing (VMS) may be a means for diverging traffic flows from an originally intended route towards an alternative one. The inclination by motorists to diverge may depend on the manner the information is presented. In the context of the TNO project DARTS (Development of Advanced Road Transport Strategies) and partly commissioned by the Dutch Ministry of Transport, the TNO Institute for Perception conducted a simulator study to evaluate different implementations of VMS in terms of both route-choice and driving behavior at the diversion point.

2. METHOD

2.1 General

In the TNO driving simulator (see Par. 2.3) subjects made runs on a network of freeways that, to a certain degree, was modelled after the ring road configuration around the city of Amsterdam (Fig. 1).

![Fig. 1 Lay-out of the Amsterdam Ring Road as used in the experiment.](image)

After this schematic map was showed, the subject was told to imagine himself driving every morning from the direction of Amersfoort to his work at Zaanstad where he has to arrive at 9.00 hrs at the latest. At 8.30 hrs he finds himself near Diemen at the entrance of the Beltway and has to make the decision to take the Beltway either to the left (in fact straight on) or to
the right. An experimental run in the simulator consisted of the subject driving from the road section near Diemen up to the first exit after having entered the Ring Road at the diversion point, for a total distance of about 4 km. Hence, subjects did not finish the whole trip. According to a given probability distribution of arrival times, an arrival time was determined and presented to the subject directly after each run. Each subject conducted 60 runs, of which 14 were with VMS ('VMS runs'). No other traffic was present on the road.

In order to make it a realistic route-choice problem with consequences with respect to the role of time delay, motivation was controlled by a special pay-off structure with two penalty schemes, viz. a modest one with a one-guilder and a severe one with a two-guilder penalty for every minute late at the destination 'Zaanstad'. The total amount of penalties was settled with the money subjects got paid for their participation in the experiment. For more details on the experimental design the reader is referred to Janssen, Van der Horst, and Hoekstra (1991).

2.2 VMS configurations

In the experiment six different implementations of VMS were evaluated. The choice for these configurations were partly based on the results of a VMS study by Erke and Gottlieb (1980). Relative to the 'normal' signing ('Zaanstad' straight on, see Fig. 2) the VMS elements that were varied, included:

![Fig. 2 'Normal' route signing direction 'Zaanstad' at the diversion point.](image)
1) The removal of the critical destination (Zaanstad) from the main route sign, together with adding this destination on the exit sign (Fig. 3a),

2) the crossing out of 'Zaanstad' on the main sign by a red line, while adding 'Zaanstad' on the exit sign (Fig. 3b), and
3) an indication of the reason why diverging is advised by the message 'queue' ('file' in Dutch) in combination with 2), see Fig. 3c.

These three elements were also combined with a yellow flasher directly next right to the added destination on the exit sign in order to attract attention to the change (Fig. 3d, 3e, and 3f). For all six resulting conditions an advanced exit sign, equal to the actual exit sign, was located at a distance of 600 m from the decision point. Both penalty scheme and VMS configuration were varied between subjects, resulting in $2 \times 6 = 12$ experimental conditions. In total 48 male subjects participated in the study.

2.3 The TNO driving simulator

The experiment was conducted in the TNO driving simulator of the TNO Institute for Perception. Recently, the visual scene has been implemented by Computer Generated Images (CGI). Fig. 4 gives the basic configuration of this fixed-base driving simulator.

Fig. 4 Basic configuration of the TNO driving simulator.

The control system has a modular design with three sub-systems:

- The supervisor computer (COMPAQ 386) with tasks such as communication with both the experimenter and the other sub-systems, the control and monitoring of the experiment, data-storage, etc.,
- the vehicle-model computer (IBM 286) for calculating the momentaneous position (X-, Y-, and FI-coordinates) of the simulated vehicle; this vehicle has the dynamic characteristics of a Volvo 240,
and
the visual scene computer (Megatek 944 CGI-system) that generates real-time images with a update rate of 30 Hz.

The subject is seated in a fixed-base mock-up of a Volvo 240 and has all normal controls (steering-wheel, accelerator, gear-shift, brake, etc.) at his disposal. Based on the status of these controls, the vehicle-model computes the consequences in terms of speed- and heading changes, in a similar way as a real vehicle would react to driver's actions. Feedback of steering forces is given to the driver by means of an electrical torque engine, and of sound by a electronic sound-generator (noise of engine, wind, and tyres). The momentaneous position (X,Y) and heading-angle (F1) are transmitted via the supervisor to the visual-scene computer. The CGI-system computes the corresponding visual scene as seen from the driver with a resolution of 1024 x 1024 pixels in full colour (24 bit RGB). This image is projected on a screen in front of the mock-up by means of a high-resolution BARCO-GRAPHICS 800 projector with a display rate of 60 Hz. For reasons of readability of the route signs, in this experiment a horizontal visual angle of 27.5° has been applied, together with double-sized letters resulting in a readability distance of about 300 m.

3. RESULTS

The pay-off structure did not have main effects on the inclination to diverge or on the driver behavior at the diversion point. Therefore, the results in the following sections are averaged over the two pay-off schemes.

3.1 Route-choice

The proportion of VMS runs in which the advice to diverge was not followed by the subjects, appeared to be dependent of the type of VMS and ranged from 0.9 to 27%. Fig. 5 gives, for each of the six VMS configurations, the percentage of non-obeying VMS runs, averaged over the two penalty schemes for each group of four subjects.

A log-linear analysis showed that the crossing out of the critical destination on the main sign in combination with the indication 'queue' resulted in the lowest percentages of non-obeying the advice to diverge. The removal of the critical destination on the main sign only led to relatively high percentages of non-obeyance (17%). The flasher was only effective when just the critical destination was crossed out on the main sign, the percentage of non-obeying then decreased from 27 to 4%, on an average.
3.2 Driving behavior at the diversion point

Apart from the inclination to diverge, the type of VMS may affect driving behavior at the diversion point as well. To investigate the relationship between both, the following parameters of driving performance were measured:

- the longitudinal position of exiting relative to the beginning of the exit lane when subjects in VMS runs decided to diverge, and
- vehicle speed on the approach to the decision point (mean speed in the area from 200 - 0 m to the sign).

Fig. 6 gives the correlation between the median position of exiting (after averaging the results over 2 x 4 subjects per experimental condition) and the inclination to diverge. VMS configurations with a low propensity (a high percentage of non-obeying VMS) resulted in relatively late exiting.

Compared with non-VMS runs, there was an overall speed increase in VMS runs of 2.6 km/h. Moreover, there was a tendency to drive faster according as more runs had been conducted. To compensate for the latter effect, the speed increase by VMS relative to the previous and next run (both without VMS) was taken for comparison. A high inclination to diverge (a low percentage of non-obeying VMS) was associated with relatively high speeds at the diversion point, see Fig. 7.
4. DISCUSSION AND CONCLUSIONS

The manner Variable Message Signing (VMS) is presenting information to the driver had a considerable influence on the drivers' inclination to diverge. Of the VMS implementations investigated in this study, the VMS configuration where crossing out the critical destination on the main sign is
combined with an indication of the reason why ('queue') (of course in combination with adding the relevant destination on the exit sign), gives the lowest percentages of non-obeying VMS. Apparently, this message is so convincing that adding a flasher to the exit sign is not of much help anymore. Just removing the critical destination on the main sign is not very effective, even not when a flasher is added to the change on the exit sign. Crossing out the critical destination on the main sign helps, but only in combination with a flasher on the sign for the alternative route. Apparently, only the flasher, as an active element, makes it explicit enough to the driver that the crossed out signing does not apply.

The analysis of driving behaviour at the diversion point in relationship with the inclination to diverge, reveals that both are interrelated. The pattern that emerged, is that highly persuasive VMS configurations resulted in less hesitating behavior than in conditions with a lower persuasiveness; a high inclination to diverge appeared to be accompanied by early exiting and by maintaining a relatively high speed. In conclusion, VMS configurations with a high rate of persuasiveness are preferred, not only for efficiency but also for safety reasons, since hesitating behavior generally is considered to have consequences for road safety.

From a methodical point of view, it is interesting to conclude that, apart from perceptual-motor tasks, also more cognitive and motivational aspects of the driving task can be studied successfully in a driving simulator. Moreover, it appears possible to relate the outcome of a decision-making process to parameters of driving behavior.

REFERENCES


Acceptance and Benefits of the Berlin Route Guidance and Information System (LISB)

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ACCEPTANCE AND BENEFITS OF THE BERLIN ROUTE GUIDANCE AND INFORMATION SYSTEM (LISB)

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Since 1988 a full scale dynamic route guidance and driver information system is in operation in the western part of the city of Berlin. Some 600 vehicles are equipped with infrared transceivers, on-board-computers and a display unit. 240 intersections have installations of so-called beacons which are connected to a central computer system. When passing a beacon the equipped vehicles receive navigation information which is presented to the driver visually and audibly. On the other hand these vehicles record their travel times and report them to the central computer system via the beacons. This information is used for updating the route guidance information.

Besides the proof of the feasibility and the performance of the system, the field trial was designed such as to investigate the acceptance of the system by the drivers and to estimate the benefits for both, the drivers as well as the community. Special attention has been devoted to travel time savings and safety effects.

The paper will cover the design of the field trial, the concept of investigating acceptance and benefits of the system and last but not least the results. In general, it can be stated that the LISB-system can help substantially improve the management of the traffic and that its additional features offer a variety of beneficial applications.
1. INTRODUCTION

An advanced route guidance and information system has been introduced and tested in the City of Berlin (West) /1/. Infrared transmitters and receivers (beacons) are located at intersections of the main road network transmitting route recommendations to specially equipped vehicles. These vehicles measure their travel times per road section and transmit them via beacons to a central route guidance computer. Based on actual travel times, the central computer calculates the quickest routes in the network. These routes are indicated visually and audibly to the drivers, guiding them to their destinations, taking into account the actual and short-term predicted traffic situation.

Within a large-scale field experiment the system's performance, acceptance by the drivers, and benefits for the users as well as for the municipality have been investigated /2/. The final results will be presented in the following paper. The project was finished by March 1991 and funded by the Federal Ministry for Research and Technology and by the City of Berlin.

2. SYSTEM DESIGN

The intelligence of the system is partly placed in the vehicles and partly in the central computer system. Communication is performed by means of infrared transmitters and receivers in the vehicles as well as at specially selected intersections with traffic lights. These so-called beacons are interconnected to local controllers. The data are exchanged between the beacon controllers and the central computer using existing cables for traffic light control.

The on-board computer contains the navigation system, the position-finding system and the travel time measuring device (Fig. 1). Whenever a vehicle passes a beacon, it receives road map information for the area around the beacon and traffic-dependent route recommendations. This information is the same for all vehicles. According to the destination coordinates which the driver has to enter before starting the trip, the navigation system can select the proper information for the driver. The position of the vehicle is updated every second using a dead-reckoning system with beacon support and map-matching.

The route guidance information is displayed in a way that can easily be understood by the driver. Unambiguous signs and as little information as necessary are a prerequisite in order not to distract drivers' attention (Fig. 2). For this reason, information is only provided whenever a change in direction has to be made, either turning right or left or changing lanes. Every new information is announced by a gong sound. In critical situations and when driving in unknown areas, additional support can be provided by audible information.
The coordinates of the destinations can be taken from a special map covered by a grid of 200 m length. The coordinates of frequently used destinations can be stored in a special memory and recalled using the name under which it had been stored. In addition, the coordinates of 250 well-known locations in the city of Berlin (West) are provided in a read-only-memory.

After activating the destination code, direct-line information and distance appear on the display. During this autarkic navigation the driver has to decide which road to take. After passing the first beacon, the system turns to the route guidance mode, during which the driver is guided from one beacon to the next on the quickest route. At each following beacon updated route guidance information is transmitted if the traffic pattern has changed, and the driver will be directed along the quickest route again. Close to the destination the vehicle is released from the guidance mode, and the driver has to reach his destination by following the direct line information again. As the changes in direction have to be indicated to the driver early enough to choose the correct lane safely, e.g. 300 m upstream, an orientation bar appears at that moment and disappears step by step when approaching the intersection.
Knowing the city map around the beacon and the position of the vehicle, it is possible to measure travel times at each road section on-board. Furthermore, the queuing times at traffic lights can also be registered. This information is transmitted back to the central computer whenever a vehicle passes a beacon and is used for detection of traffic congestions and for updating the quickest routes.

Several work station computers share the tasks that have to be performed in the central route guidance system. One computer is dedicated to traffic control measures and is expected to be operated by the traffic police in the future. A service computer is needed for correcting changes in the network and in the attributes. Another computer is involved in updating the travel time patterns and in detecting traffic disturbances by evaluating the incoming travel times. Based on this travel time information, three so-called route computers calculate the quickest routes from all exits of beacon-equipped intersections to all destination areas into which the city had been divided. According to the system characteristics, an update of the route guidance information can be performed every five to ten minutes.

3. BERLIN FIELD TRIAL

The Berlin field experiment is performed on a full scale dimension, which means that the infrastructure covers the entire area of Berlin (West). However, route guidance information is provided in the main road network of about 750 km length, including an additional 23 km of city freeways. This network represents about 1/4 of the city's total road network.

230 out of 1200 intersections with traffic lights, of which 98 % are controlled by a central traffic light computer and 17 regional computers, and 10 locations on the city freeway are equipped with infrared beacons. The distribution of the beacons within the network corresponds to the traffic density and to the amount of data that has to be transmitted by a beacon.

Some 700 vehicles have been equipped and receiving route guidance information since summer 1989. The time before, the system was extensively tested. Participants' vehicles did not receive guidance information during the tests, but transmitted their travel times to perform basic travel time patterns.

During a period of about six months, the guidance information was based on fixed travel time patterns considering different levels of travel time during peak hours and off-peak hours. Full dynamic guidance was started late 1989. The research and demonstration project was completed in spring 1991.

The objectives of the field trial are to provide proof of the technical feasibility of such a complex system, and to test the technical performance during operation. However, much emphasis is placed on the evaluation of the acceptance of the LISB system by the drivers and the benefits that can be achieved for the users and the municipalities. It can be expected that the benefit for the individual driver is predominantly related to a reduction in travel time when following...
the route recommendations as compared to the travel time the driver
would have perceived if he had followed the usual route taken, on
which supposedly traffic congestion had occurred. Savings in operat-
ing costs, increase in travel comfort and safety, and reduction of
environmental pollution are not considered of similar value for the
individual, but more for the general public. In particular, the expect-
ed increase in traffic safety is of primary interest in order to justify
the investment and operating costs for the road-side equipment. Proof
of a significant impact on traffic safety is a prerequisite for introduc-
ing the LISB system on the German freeways and highways.

4. TECHNICAL PERFORMANCE

The prerequisite for the field test was the reliable operation of all
the technical facilities involved. Of central interest was particularly
the reliability of data transfer between vehicles and infrared beacons.
The frequency range of 930—970 nm used for infrared transmission is
affected much less by rain, snow or fog than visible light (frequency
380—780 nm). Problems only occurred with beacons on city freeways,
as these got dirty very quickly due to their low installation height of
less than 2 meters. At the usual installation height of 2.40 meters it
is only necessary to clean them as a part of normal maintenance
work on the traffic lights.

Malfunctions in data transfer were caused by poor alignment of indivi-
dual beacons, by the breakdown and/or obscuring of beaconheads by
roadsigns and trees. Occasionally, data transfer was also interrupted
by faults in the infrared receiver of the vehicle and in isolated cases
as a result of the low-lying sun. It should however be mentioned that
these faults had little effect on practical operation because all inter-
sections are equipped with two beaconheads at the entry or exit
points. Thus it has been established that infrared data transfer satis-
factorily fulfilled requirements.

The field test supplied a wealth of information to be considered when
the system is developed further. In the new concept, the control
center divides up tasks between route calculation and beacon com-
unication. If one of the route computers breaks down, the remaining
route computers take over its tasks. This merely means that the
cycle time is increased; a backup computer layout is then only
necessary for the communication computer.

For future use, in order to be able to differentiate between different
vehicle types (e.g. automobiles and trucks, as far as there are weight
and height restrictions for trucks in the road network) and to be able
to transfer further data, the transferrable data quantity will be
increased from 10 kilobyte to 64 kilobyte by raising the data transfer
rate from 125 kilobit per second to 500 kilobit per second. The data
transfer rate from the vehicles to the beacons will remain at 125
kilobit for cost reasons.

Further development is also required in the vehicle equipment used.
Apart from poor readability of the alphanumeric display, participants
in the test also complained that turning maneuvers following each
other in rapid succession were not satisfactorily displayed. The new
displays will have improved facilities for showing information.
Under certain conditions disruptions of the magnetic field occurred which could lead to a loss of guidance information, e.g. when a subway train was passing through a tunnel running under the road. However, these disrupting factors can to a great extent be eliminated by making the necessary changes in the software.

As was expected, there were also shortcomings in data supply, especially with regard to determining network attributes such as, for example, the number of lanes. It was especially difficult to show complex intersections on the display, due to the limited number of symbols available. Frequently it was only possible to obtain the necessary information (e.g. number of lanes, prohibited turn-offs) by inspecting the locality on foot. Nor was it possible, due to the size of the road network, to systematically test whether the network had been provided with correct and sufficient attributes, and so participants in the test were requested to report mistakes. In this way it proved possible to give a high degree of credibility to the displays in the vehicle.

Due to the fact that only a relatively small number of vehicles were furnished with the necessary equipment, it was not possible to make the system sufficiently dynamic with regard to changing traffic situations. On workdays a total of about 16,000 travel times were registered, each based on one road section, on weekends the total was about half of this. This means that frequency density was only low on individual road sections. Only about 12% of the routes provided more than 100 measuring values per day, which for daily traffic corresponds on average to one measuring value per time interval with an update cycle of 10 minutes. One can conclude from this that at least 1% of the vehicles travelling in this area would have to be furnished with equipment as the lowest limit value for dynamic guidance.

In order to improve the data position, measuring values were added which were obtained from induction loops installed on the city freeway as part of a congestion warning system. A check made of the average travel time measuring values by comparing them with the values measured with the LISB vehicles showed a good match.

5. DRIVER RESPONSE

The prerequisite for the use of individual guidance systems to influence route selection and thereby to ensure the optimal distribution of traffic in the road network is that the recommendations displayed are adequately adhered to. Approx. 700 vehicles were provided with LISB equipment. About 400 participants in the experiment using mainly private vehicles, but also some with commercially used vehicles, were included in three written surveys requesting information on
- attitudes and expectations
- acceptance and functional adequacy and
- familiarisation effects.

The first survey was made before the vehicles were equipped with LISB-instruments, the second after a short period of familiarisation with LISB and the third sixth months later.
Parallel to the initial survey, a comparative group of members of the German Automobile Club (ADAC) were asked in order to check that the group of LISB participants was representative. Apart from socio-demographic features, comparative criteria were openness to innovation, behavior in road traffic, technical knowledge and driving practice. No significant differences were found between the two groups. Participation in the LISB field test therefore does not presuppose a particularly thorough knowledge of technology or openness to innovation.

However, the initial survey did also show that expected time savings were more of a deciding factor in participation than fuel savings or increased safety. Almost 3/4 of participants were confident that their expectations would be fulfilled.

The second survey was carried out after a short period of familiarisation with the LISB system. The result was general approval of functionality, ergonomic design and user-friendliness. Particularly the acoustic support of the route recommendations displayed was felt to be helpful. Critical comments generally relate to wrong input data for the central computer and the resulting incomprehensible route recommendations.

The assessment of the quality of guidance to the destination must be seen against the background of the inadequate dynamics of the guidance system. As participants were more or less aware of this shortcoming, the generally very positive assessment of guidance to the destination must be evaluated very cautiously, inasmuch as it was considered to be dependent on the traffic situation. Orientation at the beginning of a trip until reaching the first beacon and at the end near the destination by means of linear direction and linear distance were considered less acceptable, although there were no noticeable effects on guidance to the destination.

![Fig. 3: Assessed benefit potential of LISB](image)

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Determining and entering destination coordinates was felt to be too complicated, although the inclusion of a destination memory on the other hand was judged positively. The guidance system is of particular assistance for orientation in the road network and in finding one's destination. This is also shown in the dedicated benefit for series production attributed to the system (Fig. 3). These two features are given particularly positive ratings. Assessments of effects on reducing travel time and improving traffic safety were low by comparison, energy savings being rated lowest. However, experience shows that the latter two features are generally speaking of minor importance from the point of view of the individual driver.

In order to assess the use of systems such as LISB for influencing route choice behavior and thereby improving the distribution of traffic in the network, use intensity, i.e. the frequency of use and adherence to route recommendations, can provide useful information. Here it has proved fruitful to distinguish between behavior in the use of routes regularly followed and those origin-destination relations covered less frequently. Both the frequency of destination entry and adherence to route recommendations have been shown to be high. However, adherence is higher on routes with a low level of familiarity with the location than on frequently used routes (Figs. 4 and 5).

![Figure 4: Percentage of using the system](keeing in drivers the destination)

Here it can be seen that readiness to adhere to route recommendations increases in proportion to lack of familiarity with locality. These cases would appear to offer the greatest potential for traffic redistribution. On the familiar routes on the other hand, the use of LISB leads to optimal behavior patterns in route selection, which, apart from isolated disturbances, cannot lead to further time gains by means of LISB.

An additional stress factor resulting from LISB could rarely be observed. On the contrary, due to improved orientation, stress is reduced to a greater or lesser degree, depending on familiarity with the road network.

In the third survey, some of the questions were repeated in order to determine changes in behavior over time. No significant differences
were recorded compared to the previous survey. Nearly all those asked stated that they had frequently been given alternative route recommendations to their regular ways, which most of them followed and thus accepted as genuine alternatives. This once again shows that individual guidance systems can make a contribution towards improved traffic distribution.

Fig. 5: Percentage of drivers following the route guidance

The positive response to route recommendations on the part of participants is connected with the fact that in many cases travel time was felt to have been saved (Fig. 6).

Fig. 6: Perceived travel time savings

However, comparable investigations have shown that travel time gains are generally overestimated, at least on familiar routes. As gains in travel time often involve higher mileage, a higher average driving speed and/or the fact that the trip is interrupted by fewer traffic hold-ups, lead to an above-average positive assessment of travel time. From the point of view of acceptance of route recommendations, it is of secondary importance whether travel time savings are real or only perceived, as long as the routes selected contribute to the general improvement of traffic distribution.
The positive overall impression of LISB is also illustrated by the fact that the overwhelming majority of participants said that they were in favour of continued operation of LISB and would recommend the system if it were also introduced on highways and in other cities. It is worth noting that 26% of LISB users are prepared to spend between 800 and 1,000 deutschmarks for vehicle equipment and 4% even more.

6. BENEFITS OF LISB

The investigations into the benefits of the system concentrate on traffic safety, travel time savings, possibilities for traffic control and other criteria, some of which are less easy to quantify.

6.1 Traffic safety

Alone by virtue of the possibilities they offer for warning car drivers about traffic jams, ice on the road and fog, etc., as well as for reducing traffic congestion by improving traffic distribution at peak hour traffic, dynamic individual guidance systems which are operated on the basis of on-going traffic situations make an important contribution to increasing traffic safety. In addition, the car driver is assisted with orientation, which helps alleviate stress and thus also increases traffic safety. However, as it is not possible to measure the gains in traffic safety created by LISB directly, a method of investigation for estimating the safety potential was selected. For this purpose three scenarios were examined. Effects

- in the case of frequently repeated trips
- in the case of trips by LISB participants to unknown destinations and
- trips made by people unfamiliar with the locality.

The examination is based on a comparison of driving errors in relation to a predefined normal behavior pattern and finally compares the error rates of the different experiments. A distinction is made between route characteristics and driving maneuvers. The driving errors are recorded on the basis of observation.

An assessment of the safety potential of LISB in the case of regular identical trips (between home and place of work) was undertaken by means of three comparative investigations with the same people: one before the beginning of the field test without route recommendations, a second after a short period of familiarisation with LISB and a third after a further seven months /3/. The aim of the final examination was above all to estimate the influence of the familiarisation effect. If one considers the results of the series of measurements (Fig. 7), a predominantly V-shaped pattern of error quotas can be observed, i.e. the LISB user was able to reduce the error quotas in nearly all areas, but this effect was largely canceled out again as a result of familiarity with the system. Nevertheless it has been established that safety gains do result from the use of LISB, although it was not possible to prove that these were of a significant nature.
The reduction in the error quota shortly after the introduction of LISB can be interpreted in such a way that the LISB users felt as if they had been put on a leash, because they themselves could neither determine the choice of route nor see in advance at which intersections turn-off recommendations would be displayed. This meant that especially aggressive drivers were restrained in their behavior. With growing familiarity with LISB, however, this effect is lost, especially as, in the case of frequently repeated trips, the total number of all regularly displayed alternative routes gradually becomes known and the car driver very often recognizes from the first route recommendation which further recommendations are to be expected.

This perception led to the hypothesis that the safety potential increases in proportion to lack of familiarity with localities. For this to investigate, participants had to undertake journeys to destinations in districts in the city, with which, on their own admission, they were unfamiliar. As the driving errors made by these people including the familiarisation effect were known from the previous investigations, these could be taken as a basis for comparison /4/. Furthermore, the driving errors were reflected in the error level to be expected, which is known as the so-called outsider risk, and reflects the error quota expected to be made by drivers unfamiliar with the locality, as demonstrated by scientific investigations /5/.

When considering the results (Fig. 8), it becomes evident that the total of all errors made by LISB users during trips to unknown destinations is the same as that of all errors made on frequently used origin-destination relations. It is also evident that the error quota is significantly lower than the value to be expected on the basis of the outsider risk. There are, however, differences when the individual distinguishing criteria are looked at more closely. Whereas fewer mistakes were made on main roads to unknown destinations than on
familiar relations, the error rates increase during lane-changing and when passing intersections. The error rates in speed and in behavior in intersections also reach the level of outsider risk because LISB does not provide any advice on speed adaptation or orientation aids within intersections.

Fig. 8: Error rates of LISB users when travelling to unknown destinations /4/

To summarize, one can say that safety increases with the use of LISB in proportion to the lack of familiarity with a given location, and that individual guidance systems make a considerable contribution to the improvement of traffic safety. The safety level of a car driver who is unfamiliar with a given location can, with the support of LISB, be reduced to the level of a person familiar with the location, i.e. the outsider risk is reduced, although not in all its manifestations.

The third examination was undertaken with people from outside the given location who did not have any experience with LISB /6/. Trips from the same origin to the same destinations were compared with each other, whereby one vehicle was equipped with LISB while the vehicle to be compared was only furnished with a map of the city.

The evaluation of driver behavior shows better values for the use of LISB. Violation of the highway code and traffic conflicts occurred less frequently than in the case of trips on the basis of a map of the city. The orientation aid provided by LISB proved particularly positive for older road users.
Summing up all the results of the investigations, one can report that in the case of routine trips there is only a slight increase in safety from using LISB, an increase which is, however, greater the less familiar a driver is with a particular location. Due to the investigation methods chosen it is not possible to convert and quantify the safety potential determined directly into a safety gain in the form of a decrease in the probability of accidents. The dependencies between the error rates determined and the related frequency of conflicts and accidents has not been adequately researched to date and thus cannot be quantified.

6.2 Travel Times

The assessment of travel time savings by LISB users is positive, but difficult to quantify as there are no possibilities for comparison. On the basis of the data reported back by the vehicles, it is possible to evaluate the travel times actually required when route recommendations were followed. The differences in travel time compared to the familiar way can only be estimated, however, because the travel time which the LISB user would have required for his familiar way without using the guidance system is not known. Only the forecast values of the travel times for the individual route sections can be used as provisional reference values which provide the basis for determining the fastest route for the route recommendations.

Comparative trips made with the aim of examining differences in travel time have shown that with and without LISB the actual travel times depend on stochastic influences, meaning that reliable data can only be given as statistical averages. The comparisons carried out on this basis show slight travel time advantage when using LISB. One can assume that the travel time saving on frequently repeated routes is lower than for trips to less familiar destinations.

Based on the results of surveys, it can be assumed that time savings are considered less important than the certainty that one is being directed along the fastest route and that possible traffic jams have been avoided. This realisation reduces the importance of travel time savings as a prime aim of a guidance system.

In addition to the determination of route recommendations, the travel time data collected in the LISB control center can be used for other applications. For example, if the fluctuations in travel times in the road network over the course of a day are considered, it is possible to offer trip planning for the transport industry. This could lead to the optimisation of transport services with resulting reductions in transport times and thus transport costs. A project with this objective in mind is at present being prepared in Berlin. Energy savings resulting from dynamic trip planning are estimated to amount to at least 10%.

A further application lies in checking the green phase distribution at traffic lights by separately calculating the share of congestion in travel time for each approach in order to then compare these with each other. This imbalance in the distribution of congestion time provides information for the redistribution of green phases. Due to the inadequate data position resulting from the too small number of
vehicles equipped, LISB vehicles were specifically used at selected traffic lights, thereby increasing the number of reports received back from the vehicles. Individual results show that there is in fact an imbalance in congestion times during the morning peak-period based on individual approaches. It therefore seems logical to review the signal programs.

These results show that the travel and congestion times reported back from the vehicles are suitable for maintaining and updating signal programs in order to make it possible to adapt them to changing traffic conditions more quickly. This thus contributes towards making private traffic more compatible with the urban environment. The benefits resulting from this justify at least some of the costs involved in introducing and operating an individual guidance system. In addition to this, travel time fluctuations on individual road sections provide an up-to-the-minute picture of the extent of a traffic disruption. This information can be used to improve radio traffic services, for traffic planning measures and for traffic and/or congestion management. This provides further benefits for the public at large.

6.3 Traffic Distribution

One important objective of the field test was to investigate the possibility of using dynamic individual guidance systems for controlling traffic, thereby making a contribution towards traffic management. Due to the small size of the fleet of LISB vehicles used, it was not possible to prove redistribution effects by measuring the changes of traffic quantities in the road network. However, it turned out in a high degree, as route recommendations were followed, redistribution is possible, although the travel time gains achieved were unspectacular.

On the other hand, it was not possible to investigate to what extent route recommendations would still be followed if, in future, route recommendations are not exclusively determined according to the principle of the most time-saving way, but also on the basis of urban-ecological considerations. Results achieved to date would lead one to expect that users will be prepared to accept a system based on such considerations as long as they can be sure that using the alternative route does not take longer than using the familiar route. If the system is made more dynamic and a greater number of vehicles is equipped with LISB, there are still sufficient possibilities of influencing traffic distribution with a view to creating a system of traffic management in line with the needs of the urban environment.

Future strategies for controlling traffic should therefore include dynamic individual guidance systems, on the one hand as a direct measure to control traffic, but also to take advantage of the possibilities for recording the traffic situation and thereby improving the dynamic nature of collective traffic controlling systems.
6.4 Other Benefits

Apart from the possibility of using route recommendations to influence traffic distribution and of obtaining information on the traffic situation via the travel and congestion times reported from vehicles, further benefits are offered by the communication infrastructure. From the point of view of mass transit companies, the use of the beacon infrastructure for influencing the distribution of green phases at traffic lights is of growing importance for increasing the speed of bus and tram traffic. Precisely the multifunctional possibilities for using the system mean that synergic effects can be achieved which, due to the facilities offered for networking the individual functions and components, make such investments and operating costs economically feasible.

With this aim in mind, a project is at present being prepared in Berlin to look into the possibilities for using the LISB infrastructure to influence the control of traffic light installations. A further development phase is intended to test the extent to which communication facilities can also be used for the exchange of data between buses and trams and a control center. Especially with large vehicle fleets, this would lead to a considerable reduction of the load on the data channel and thereby to more economical use of frequencies.

7. CONCLUSIONS

To sum up, the results of the field test present a promising picture of the future potential and areas of use for LISB. In spite of individual technical restrictions, the operation of LISB proved to be reliable and highly successful. In addition to this, accompanying studies on the acceptance and benefits of the system lead one to expect a high degree of effectiveness in relation to investment and operating costs, although at present a lot of effects cannot yet be quantified.

Effects on traffic safety are positive and open considerable safety potential, especially in the case of trips to unknown areas. This assessment gains in significance above all by virtue of the fact that re-routing recommendations by LISB will find even greater acceptance precisely in long-distance traffic. This can be expected as a result of the psychological effect alone, namely that, thanks to the guidance system, the driver will not feel left alone, especially in poor weather conditions and at night. It is here that the orientation support proves its value, a feature of LISB which was given the highest ratings.

By integrating the individual guidance technology into an overall traffic management system, it is possible, in combination with the collective traffic controlling measures, to influence traffic flow more precisely and with greater spacial and temporal differentiation. In this way the prerequisites are created for achieving a new quality of traffic management. Especially the multifunctional character of this guidance technology leads to an increase in efficiency and ultimately to more economical use of the entire traffic infrastructure. This aspect becomes of particular importance when public means of
transport are included in the consideration of alternative routes, route recommendations to Park & Ride facilities are made and parking space management becomes an integral part of traffic control measures. In all cases, individual traffic control systems give direct or indirect support.

The multiple use of LISB data is a further positive aspect which results in a number of measures to increase effectiveness. The comprehensive control of the traffic situation in the main road network made possible by the system permits the traffic control center to intervene precisely in the traffic situation, whereby traffic disruptions can be observed more closely than previously and often preventive measures taken to resolve them. LISB data is also of great value as a planning aid, even for the optimisation of traffic light control or for recognizing and resolving bottleneck situations.

The possibilities for using the LISB infrastructure for communications between vehicles and the control center have not nearly been exhausted. Its use within the framework of fleet management, whether for public transport or commercial vehicles, has not yet been investigated in sufficient detail to allow a final evaluation. Here too, however, one can expect considerable rationalisation effects, also allowing for the handling of commercial traffic in a manner which is compatible with the urban environment. Although the technical possibilities of individual guidance technology have not been fully exhausted, the results of the Berlin field test obtained to date indicate that the considerable expectations with regard to the effect of the system are justified.

There is a tremendous interest in the Berlin LISB system, nationally and internationally. This might be due to the fact that improved traffic management measures are needed in most cities.

However, the promising support of individual route guidance systems to improve traffic management should not distract the view from other solutions and contributions for solving the city's traffic problems of the future. A more intelligent use of existing road capacity, which is a major objective of the LISB system, has its limits when the increase of motorisation cannot be slowed down or if at least the use of the private car does not coincide with the political objectives to improve the quality of life in our cities. Route guidance and information systems are only a part of the general solution of future traffic problems, but they can contribute substantially towards the easing of traffic flow and flanking the implementation of measures politically desirable.
REFERENCES


Automobile Navigation Safety Issues

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1. INTRODUCTION

Intelligent vehicle-highway systems (IVHS) under development in the United States, Europe, and Japan will improve traffic efficiency, safety, and environmental conditions by applying computer, communications and control technologies to road transportation [Jurgen, 1991]. Automobile navigation and route guidance systems (often called driver information systems) are a central element of IVHS.

The need for IVHS and automobile navigation is confirmed by several Federal Highway Administration (FHWA) studies. One study estimated that 2 billion vehicle-hours of delay occurred on urban expressways in the United States in 1987 [Lindley, 1989]. Without further countermeasures, the delay will increase to 11 billion vehicle-hours in the year 2005. The delay cost $16 billion in 1987 and will cost $88 billion in 2005, in terms of 1987 dollars.

Another FHWA study estimated that almost 7 percent of all distance traveled by non-commercial vehicles and over 12 percent of the time spent in such travel is wasted due to poor navigation and route following skills, thus contributing to further congestion [King, 1986]. The annual cost to individuals and to society of this excess travel was estimated at $45 billion. Results of similar studies in Europe and Japan are generally in agreement with those of the United States.

Over 500,000 highway-related fatalities occur throughout the world each year. In the United States alone, there were 47,000 fatalities in 1988, and the total cost of traffic accidents in the United States has been estimated at $130 billion [Betsold, 1989]. Without further countermeasures, the number of accidents and their costs to society will increase because of growth in traffic and the increasing fraction of older drivers.

Vehicles with navigation systems will travel shorter distances and/or spend less time on the road in performing their missions. In addition to helping reduce congestion by making more roadway capacity available for other vehicles, the accompanying decrease in exposure to traffic will reduce the equipped vehicles' risk of being involved in an accident.

Navigation systems will further enhance traffic safety by enabling drivers to proceed with confidence to their des-
tinations without hesitating at decision points or having to make last-moment lane changes or abrupt maneuvers to stay on the proper route. However, the displays and controls of navigation systems must be designed with safety in mind to avoid offsetting increases in accident risk.

This paper reviews the nature and status of navigation-based driver information systems, consolidates some of the rather limited research results now available to gain insights on their potential safety benefits, and identifies key issues that must be resolved to realize these benefits.

2. SYSTEM CHARACTERISTICS AND STATUS

Navigation-based driver information systems automatically keep the driver informed of vehicle location, deduce the best routes to desired destinations taking into account current traffic and road conditions, and speak or display turn-by-turn instructions as the vehicle travels over the route. These systems will also direct the driver to the nearest service station that is open, closest hospital, retailer of a particular product, etc. When nearing the destination, the driver will be directed to the closest available parking space.

Comprehensive automobile navigation systems require the integration of many functions and technologies:

* Means for automatically determining vehicle location with sufficient accuracy to identify the road traveled and each intersection approached.

* Digital map databases that give the identification, location, classification, traffic regulations, and address ranges for roads in areas where the vehicle operates, and which include locations and descriptions of service stations, garages, parking, public buildings, hotels, restaurants, tourist attractions, and other types of commonly used directory listings.

* Route guidance software and driver interface means to determine the optimum route and give real-time route instructions to a specified destination.

* Mobile communications transceiver for receiving traffic and other variable data (e.g., available parking) for the area being traveled, and for transmitting the travel times experienced over different road segments to traffic management centers for augmenting data on local traffic conditions.

Various combinations of proximity-beacon, dead-reckoning, satellite-positioning and map-matching technologies are used to determine vehicle location [French, 1986]. Proximity beacons are short-range (tens of meters) emitters.
of radio, microwave, or infrared signals that are strategically located at key intersections. Reception of the location-coded signals confirms the location of passing vehicles. Dead reckoning with map matching is typically used for navigating between beacons. The proximity beacon's drawback of requiring extensive roadside equipment is partially offset by its additional usefulness as a communication link for traffic and other local data.

Dead reckoning is the process of calculating a vehicle's location by integrating measured increments of distance and direction of travel away from a known initial location. Since distance and heading measurements invariably contain some error, vehicle location based on dead reckoning alone gradually decreases in accuracy until updated by map matching or other means such as signals received from proximity beacons or Navstar GPS (Global Positioning System) satellites.

Satellite positioning systems provide accurate location information when a vehicle's GPS receiver simultaneously receives signals from four or more different satellites. However, high-frequency radio signals from satellites are often blocked by buildings, bridges, trees, etc. Since dead reckoning is required to fill these gaps, the main use of satellite positioning in driver information systems is to eliminate occasional requirements to manually reinitialize when dead reckoning with map matching fails due to extensive travel off of mapped roads, after ferry crossings, etc.

Map matching is an artificial intelligence process that recognizes a vehicle's location by matching its apparent path (based on dead reckoning or other positioning means) with the patterns of digital road maps stored in a database (typically CD-ROM) also used for map display, route guidance, directory information, etc. [French, 1989]. As an example, when a vehicle makes a turn whose location, direction, etc. closely match those of a mapped turn, the vehicle is presumed to be at the mapped location. Almost all state-of-the-art vehicular navigation systems employ map matching.

Unless the location subsystem employs proximity beacons, future systems must include a receiver or transceiver for an alternate type of data communication between vehicular equipment and traffic data centers. Alternatives to the proximity beacon include broadcast subcarrier, cellular telephone, mobile satellite, and various forms of RF data networks [Weld, 1989].

The broadcast subcarrier approach superimposes inaudible data on the sideband of regular commercial FM radio stations for decoding by an inexpensive attachment to radio receivers, and is thus limited to one-way communication. It is called "RDS" (Radio Data System) in Europe where it is being tested for communicating traffic data. Various
adaptations of cellular telephone are also being tested in Europe and Japan. The appeal of mobile satellites is limited by their large signal "footprints" which are ill-suited for communicating traffic data that is useful only within local areas. Cellular-like trunked two-way radio networks are being considered in the United States.

The development of driver information systems has already progressed to the stage of large-scale pilot demonstrations underway in the United States, Europe and Japan, and to the introduction of first generation autonomous navigation systems (i.e., without supporting infrastructure or communication links) that are now available as factory equipment on top-line automobiles in Japan. The technologies are relatively well established, and the remaining steps required before broad deployment are primarily in the area of standards and the unprecedented institutional arrangements needed for coordinating private and public efforts to provide and support the systems.

Cooperative initiatives for achieving these objectives for IVHS as a whole as well as for navigation and driver information systems include DRIVE (Dedicated Road Infrastructure for Vehicle Safety in Europe) and PROMETHEUS (PRogram for a European Traffic with Highest Efficiency and Unprecedented Safety) in Europe and RACS (Road/Automobile Communication System), AMTICS (Advanced Mobile Traffic Information and Communication System), and VICS (Vehicle Information Communication System) in Japan. In the United States, strategic planning for a national IVHS program is being carried out through IVHS AMERICA (Intelligent Vehicle Highway Society of America) which serves simultaneously as trade association, government-industry interface, and advisory committee to the government.

3. SAFETY IMPLICATIONS

Although a number of potential safety impacts of vehicle navigation and driver information systems have been recognized and described in qualitative terms by a number of expert analysts, very little quantitative information is available. In particular, few research results, statistics or direct measures of expected safety benefits or disbenefits are available.

Lunenfeld [1989] suggests that improper trip planning, poor direction finding, and other errors associated with manual navigation may contribute to slow driving, erratic maneuvers, delays, and lost or confused drivers. Unforeseen events along the way can negate a trip plan and require the driver to make mid-course corrections, often without adequate information. Under such conditions, the driver typically slows down, makes sudden lane changes, stops or travels in reverse on entrance or exit ramps, makes illegal U-turns, etc. Although statistics are not available to show the number of accidents that actually
result from such causes, an evaluation of the potential efficiency of various driving aids based on analysis of police reports of 350 traffic accidents in France deduced that use of a navigation aid would have prevented three percent of the accidents [Fontaine et al., 1989].

Navigation-based driver information systems also have potential for improving safety through reduced exposure to accidents as a result of traveling shorter distances and/or shorter periods of time. Although the relationships between accident frequency and total miles driven are complex and not well understood, King [1986] made a simplified assumption that the probability of having an accident was directly proportional to the number of miles driven in conjunction with the FHWA estimate that non-commercial drivers travel almost 7 percent more miles than necessary as a result of poor navigation skills. An alternate assumption would be that the probability of an accident is proportional to the 12 percent extra time spent on the road due to poor navigation skills. Secondary effects from excess mileage and driving time may contribute to additional accidents as a result of increased congestion.

Consolidation of the above estimates implies that use of navigation systems could conceivably reduce the overall number of accidents by as much as five to ten percent. An earlier synthesis based on the same underlying studies indicated a potential savings of $8.3 billion annually in the United States [French, 1990]. However, regardless of the exact numbers, it appears beyond question that the availability of good navigation and routing information should improve driving safety if properly used.

As for safety disbenefits, the literature is fraught with papers warning of the possible adverse effects of navigation systems. However, most of these cautionary views are largely based on generic human factors considerations because only sparse information is available from safety research actually carried out with vehicular navigation systems.

Concerns that driver information systems could increase the potential for accidents center on the man/machine interface and on the additional mental workload imposed on the driver if the system is not designed with safety in mind. Route-finding while driving an automobile is such a common, familiar, and well-learned activity that it is easy to overlook what a large body of knowledge and information the driver must consider.

Petchenik [1989] claims that drivers must simultaneously assimilate four levels of visual information. These include the static macro-environment (the overall landscape as viewed through the windows), static micro-environment (lane markings, road boundaries, intersections, regulatory and information signs, etc.), dynamic macroenvironment-
ment (traffic flow, weather, etc.), and dynamic microenvironment (the constantly shifting milieu unique to each vehicle such as nearby vehicles, transitory objects, pot holes, etc.).

Drivers must concurrently integrate information from five additional domains. These include place identification (names, numbers, etc. typically read from signposts), regulatory environment (acquired knowledge supplemented by signs and signals), tool environment (knowledge sources such as maps, itineraries, communication devices, etc.), driver knowledge (knowledge acquired from all previous experiences with the other environments described, and the ability to integrate this prior knowledge with new information) and the driver’s affective/sensory makeup (all feelings that bear upon driver functionality such as discomfort, fear, impatience, distraction and confusion). Driving thus includes very demanding cognitive tasks even before adding an in-vehicle navigation system for the driver to operate or monitor.

Smiley [1989] suggests that in order for navigation systems to make driving safer and more efficient, they must be evaluated according to the level of mental workload they create, and be designed to measure and respond to the driver’s mental working as it changes during a trip. Virtually all navigation systems already on the market respond to assumed driver workload by disabling certain controls or by not displaying the greatest level of map detail while the vehicle is in motion. Many of the more advanced systems use simplified graphics and/or synthesized speech to minimize driver distraction when giving route guidance instructions.

The potential for excessive distraction of driver attention from the roadway by electronic map displays is the most common concern regarding possible negative impacts of navigation and driver information systems. French research using 60 test subjects of 20 to 63 years in age found that, in glancing at a map display, the eyes were off the road an average of 1.28 ± 0.5 seconds, and 8 percent of all glances exceeded 2.0 seconds [Labiale, 1989].

Results of a US study by Zwahlen et al. [1988] suggest that single glances of less than 1.2 seconds should be acceptable, that glances of 1.2 to 2.0 seconds are only marginally safe, and that glances exceeding two seconds are unacceptable. This research, which used 20 subjects averaging 22 years of age, measured lateral deviations within a traffic lane while taking the eyes off the road to dial a cellular telephone.

Consolidation of the US and French results suggests that use of map displays may indeed be dangerous. However, a majority of the more advanced navigation and route guidance systems now being developed use simplified graphics and synthesized voice as the main man-machine interface.
4. CONCLUSION

Navigation-based driver information systems, along with other forms of IVHS, will assure more efficient utilization of roadway capacity and, if designed with safety in mind, will reduce accident rates. However, considerable research is required before the safety implications are sufficiently well-understood for navigation systems to be designed to provide maximum safety benefits.

Suitable technologies for navigation-based driver information systems are already available, and major programs for IVHS development and deployment are now underway in Europe, Japan and the United States. Major challenges that must be met in order for these systems to be most effective in alleviating congestion as well as improving safety include establishment of system standards and new types of institutional arrangements necessary for the extensive exchange of information required between the equipped vehicles and the highway infrastructure.

7. REFERENCES


Economic Appraisal and Ranking of Road Safety Measures

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ABSTRACT

Economic Appraisal and Ranking of Road Safety Measures

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In Sweden the Road Safety Office (RSO) is responsible for the coordination of the safety work. The Road Safety Council, linked to the RSO, provides advice and assistance. Every year since 1986, the RSO prepares, and the council adopts, a co-ordinated 3-year road safety programme, which is submitted to the Government.

In late 1989, a special working group, consisting mainly of researchers, was formed to assist the RSO and the Council. The main tasks of the group were to:

- develop a method for economic appraisal and ranking of safety actions,
- propose necessary safety actions to attain the safety goals at the lowest possible socio-economic cost,
- identify deficiencies in knowledge and methods.

The group proposes that cost-effectiveness analysis should be used as this method is particularly suitable when there is a defined target value.

Cost-effectiveness calculations have been carried out for some 35 safety actions for which there is sufficient knowledge of costs and effects.

The group suggests, in order to attain the target at the lowest possible cost, that the following actions should be taken:

- lower speed limits on rural roads, combined with increased speed enforcement and reduced tolerance limits at speed checks,
- a large number of minor road and traffic engineering measures (e.g., improved junctions, tunnels and bridges for pedestrians and cyclists and speed reduction devices in urban streets),
- improved protection at railway crossings,
- construction of new motorways.
The group estimates that these actions will lead to reductions in fatalities by about 400 and in police reported injuries by about 5750 per year in year 2000. The socio-economic cost of attaining this is estimated at about US$ 300 per car and year for the ten-year period.

In order to attain the target, the group proposes that monetary accident values used in cost-benefit analysis be increased, for example, for a fatality from about US$ 1.1 million to about US$ 2.4 million.

The group also suggests several other actions, for instance, extended ex-post evaluation and further research and development.
ECONOMIC APPRAISAL AND RANKING OF ROAD SAFETY MEASURES

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Background

In Sweden, the Road Safety Office (RSO) is responsible for coordinating road safety work. Assisting the RSO in this important task is a special council, the Council for Road Safety, consisting of members from nine authorities and organizations occupied in various ways with questions of road safety. The RSO submits to the government each year a road safety programme adopted by the Council for the next three fiscal years.

In 1989, the RSO and the Swedish Transport Research Board commissioned a group of experts, which included members of several research institutes and authorities, to compile basic data for the 1990 programme. The assignment has been implemented in a project called "Socio-economic appraisal and ranking of road safety measures". The project and its results are described in this paper.

Purpose

The purpose of the project was to:

- present a method for economic appraisal and ranking of road safety measures,
- use this method to draw up a proposal for road safety measures that are needed to achieve the road safety goals at the lowest possible socio-economic cost, and
- identify deficiencies in knowledge and methods in making future road safety work more effective.

Safety goals and forecasts

According to a 1982 Riksdag (Parliament) resolution, road safety goals in Sweden are as follows:

1. The total number of persons killed and injured on the roads must be successively reduced.

2. The risk if being killed or injured on the roads must be successively reduced for all road user categories.

3. The risk of being killed or injured on the roads must be reduced to a greater extent for unprotected than for protected road users. Particular attention must be paid to the safety of children.
The 1989 safety programme contained the following quantification of the first goal: "...the goal for the year 2000 ought to be about 200 fewer fatalities and about 5,000 fewer injured persons than in 1988". This has been interpreted as meaning that the number of persons killed and injured (as reported by the police) annually must be reduced to about 600 and 17,800 respectively from 1990 to the year 2000.

To judge what reduction would be required in order to achieve these target values, a forecast was made of the number of persons who would be killed and injured in the year 2000 if no special measures were adopted, that is to say if the risk remained at about the same level as in the mid-1980s. The forecast indicates that if no radical and long-term changes in the development of road traffic occur, then in all probability about 1,000 persons will be killed and about 26,000 will be injured. This means that measures are required which will reduce the number of persons killed and injured on the roads in the year 2000 by about 400 and 8,200 respectively in order to attain the quantified goal, see Figure 1.

**Figure 1.** Number of road traffic accident fatalities in Sweden.

**Economic appraisal methods**

There are two principal methods of determining socio-economic priorities:

- cost-benefit analysis (CBA)
- cost-effectiveness analysis (CEA)
The group proposes the use of cost-effectiveness analysis because this method is particularly suitable when the goal is precisely defined. Furthermore, it does not require the reductions in risks and accidents to be assigned a monetary value.

When using this method, the different road safety measures have to be ranked in ascending order of cost-effectiveness ratio. Cost is here understood to be the net cost to the community (costs less the savings - such as capital investment, travelling time and vehicle costs - which accrue as a result of implementing the measures) and effectiveness, or effect, the expected reduction in casualties. The numbers of killed, seriously injured and slightly injured persons have been weighted by giving "killed" a weighting of 1, "seriously injured" a weighting of 0.166 and "slightly injured" a weighting of 0.004. The total number of persons killed and injured is then expressed as the number of "fatality equivalents". The weightings are based on studies carried out by medical experts.

Safety measures and calculations

To identify conceivable road safety measures, a large number of measures in different Swedish and foreign road safety programmes was studied. From these, the measures which were judged to have a proven effect on road safety, far-reaching potential and other known effects and costs - "calculable measures" - were then selected. A list of other measures was afterwards compiled. The effect of the calculable measures on road safety, as well as their other effects and costs, were then assessed, following which cost-effectiveness calculations were performed.

In this way, a cost-effectiveness analysis was performed for about 35 road safety measures. This resulted in estimates of the cost-effectiveness ratio for each measure, as well as the reduction in fatality equivalents and persons killed and injured.

Proposed safety actions

On the basis of these calculations, and in order to achieve the road safety goal at the lowest socio-economic cost, the group of experts proposes implementation of the following "calculable" measures over the 10-year period up to and including the year 2000.

System of speed limits:

<table>
<thead>
<tr>
<th>Present speed limits</th>
<th>Proposed speed limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motorway 110 km/h</td>
<td>Motorway 100 km/h</td>
</tr>
<tr>
<td>Expressway 110 km/h</td>
<td>Expressway 90 km/h</td>
</tr>
<tr>
<td>Rural road 110 km/h</td>
<td>Rural road 90 km/h</td>
</tr>
<tr>
<td>Rural road 90 km/h</td>
<td>Rural road 80 km/h</td>
</tr>
<tr>
<td>Rural road 70 km/h</td>
<td>Rural road 70 km/h</td>
</tr>
<tr>
<td>Street 70 km/h</td>
<td>Street 70 km/h</td>
</tr>
<tr>
<td>Street 50 km/h</td>
<td>Street 50 km/h</td>
</tr>
</tbody>
</table>

VTI RAPPORT 372A
Also proposed for all types of road:
- increased surveillance and enforcement (up to five times as much)
- reduced tolerance limits (down to 10%).

**Road, traffic and automotive engineering measures:**

<table>
<thead>
<tr>
<th>Present/Object</th>
<th>Proposed measure</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intersection, rural</td>
<td>Grade separation</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Pedestrian/cyclist underpasses/bridges</td>
<td>300</td>
</tr>
<tr>
<td>4-way intersection, rural</td>
<td>Two staggered 3-way intersections</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Concrete barrier, 2-lane and 3-lane roads, rural*</td>
<td>1,250 km</td>
</tr>
<tr>
<td>Intersection, rural</td>
<td>Roundabout</td>
<td>50</td>
</tr>
<tr>
<td>Intersection, 90 km/h, rural</td>
<td>Local speed limit 70 km/h</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Wildlife fence</td>
<td>170 km</td>
</tr>
<tr>
<td>Road and street intersections, fringe development</td>
<td>Roundabout</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Twice as frequent snow clearing operations on pedestrian/bicycle paths</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td>Speed control obstacles in through roads</td>
<td>500 streets</td>
</tr>
<tr>
<td></td>
<td>Speed control obstacles in residential streets</td>
<td>1000 streets</td>
</tr>
<tr>
<td>Road and street intersections, urban</td>
<td>Mini-roundabout</td>
<td>500</td>
</tr>
<tr>
<td>2-lane road, rural</td>
<td>Motorway</td>
<td>750 km</td>
</tr>
<tr>
<td></td>
<td>Wildlife fence</td>
<td>870 km</td>
</tr>
<tr>
<td>Railway crossing, with lights and audible warning</td>
<td>Half-barrier installation</td>
<td>1,000</td>
</tr>
</tbody>
</table>

1. Additional studies necessary before implementation.

VTI RAPPORT 372A
Estimated effects and proposals

It is judged that the proposal would result in 400 fewer persons killed and about 5,700 fewer injured (as reported by the police) in the year 2000. The system of speed limits would then account for about three-quarters of the total reduction. The goal in respect of fatalities would accordingly be achieved, but the reduction in persons injured is too small by about 2,500 for the goal to be reached.

Net costs to the community for the proposal amount to about SEK 6,300 million a year over the 10-year period. This corresponds to slightly more than SEK 1,600 per motor vehicle each year, most of which is attributable to higher time costs. In socio-economic terms, the costs of the measures amount to about SEK 2,300 million annually. All these costs are in 1990 price levels.

The proposal calls for the implementation of measures which show cost-effectiveness ratios of up to SEK 15-20 million per reduced fatality equivalent. Against this background, the group proposes that the traffic administrations (e.g., the Swedish National Road Administration) uprate their accident valuations to higher amounts than are applied at present. Fatalities ought to be uprated to about SEK 15 million, which is more than twice the present figure.

The group also proposes that a large number of "non-scheduled measures" be examined, tested and evaluated, including improved statistical information systems, regional and local road safety programmes, better road safety education in schools and a number of other road, traffic and automotive engineering measures.

The group further proposes that the compulsory periodic vehicle testing programme for cars be revised with a view to introducing a lower level of ambition and that redundant resources could be used for implementing effective safety measures.

Finally, the group proposes that follow-up measures and R&D work in the field of road safety be intensified to provide additional data and a broader basis for safety work in the future.

Conclusion

The group considers that the proposed method is suitable in principle for appraising and prioritizing road safety measures. However, it is necessary to refine the method still further and above all to develop and improve the basis of calculation so that increasingly effective road safety programmes can be drawn up in future years.
Traffic Safety on Two Continents
A Ten-Year Analysis of Human and Vehicular Involvements

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ABSTRACT

Nationally and internationally, it can be said that deaths and injuries from accidents on the highway have now reached epidemic proportions. In the whole world, it is estimated that over 200,000 deaths and over 10 million injuries occur as a result of road accidents every year.

This study, which focuses on fatalities from traffic accidents in Europe and the United States, was undertaken to compare certain demographic and accident characteristics between the two continents. The Western European countries included in the study are: Austria, Belgium, Denmark, the Federal Republic of Germany, France, Great Britain, Italy, the Netherlands, Norway, Sweden, and Switzerland.

The objectives of the study were to: (1) Identify changes in fatalities and fatality rates for different age groups and road user groups as experienced by each of the eleven Western European countries, by Western Europe as a whole, and by the United States from 1978 to 1987; (2) Determine whether there were statistically significant changes in the fatal traffic accident characteristics between 1978 and 1987; (3) Show how people died; (4) Show where people died; (5) Show the number of persons killed in alcohol-related accidents.

The specific conclusions of the study include the following: (1) With the exception of Denmark, Norway and Sweden, the remaining Western European countries and Western Europe as a whole experienced, for the most part, marginal or significant improvement in safety for the entire time period observed, for all age and road user groups. In contrast, the United States experienced marginal or significant deterioration in safety for several of the investigated age and road user groups. (2) During the 1978-1987 time period, (a) the percentage share of fatalities for the age group "15-24" in the United States was on average about 1.2 times that of Western Europe; (b) the percentage share of fatalities for the age group "Over 64" in Western Europe was on average about 1.7 times that of the United States; (c) the percentage share of fatalities for the road user group "Pedestrians" in Western Europe was on average about 1.4 times that of the United States; (d) the percentage share of fatalities for the road user group "Bicyclists" in Western Europe was on average about 3.9 times that of the United States; and (e) the percentage share of fatalities for the road user group "Motorcyclists" in Western Europe was on average about 1.7 times that of the United States. (3) Single vehicle crashes, including those with pedestrians, represent on average about 58% of fatalities in the United States, and about 48% of fatalities in Western Europe. While 44% of fatal single vehicle crashes, excluding those with pedestrians, in the United States are caused by collisions with or without rigid obstacles, this type of crashes in Western Europe represents 30% only. This is probably the result of better road maintenance in Western Europe (presence of guard rails and other roadside appurtenances on many roads). (4) For both Western Europe and the United States about 40% of the fatalities occur in urban areas, compared to about 60% in rural areas. (5) The percentage of persons killed in traffic accidents involving alcohol in Western Europe was decisively lower than the 50% value of the United States. In Western Europe, Denmark had the highest percentage (more than 30%) of persons killed in traffic accidents involving alcohol.

Overall, it can be stated that over the investigated time period Western Europe had experienced a better development in traffic safety than the United States for different age and road user groups. But, if one looks at the ratio of the percentage share of fatalities for different age and road user groups, then the situation in Western Europe is clearly worse than that in the United States. This is clearly supported by the fatality rate (fatalities per 10^6 vehicle kilometers) which indicates that the risk of being involved in a fatal accident in the United States is much lower than that in Western Europe.
1. INTRODUCTION

The tragic but real consequence of traffic accidents continues as one of the world’s most current examples of irresponsible social behavior. People need to be made aware of, and assume responsibility for, the possible effects of their driving behavior on themselves and on others. This lack of awareness and responsibility may be an important reason why more than 200,000 people are killed in vehicle accidents each year. Of the millions who are injured, tens of thousands are maimed for life. The financial cost is many thousands of millions of dollars annually [1-3].

The above numbers seldom appear in a newspaper or in a TV bulletin, but they actually summarize what happens in one year worldwide. A single airline crash, or maritime disaster, is front page news and prompts a federal investigation. But, death in a traffic accident remains, for the most part, an invisible slaughter.

It would be a great task to analyze traffic accident statistics from different geographical regions of the world. Unfortunately, detailed accident statistics are made available by only a handful of countries. Because of these limitations, coupled with financial reasons, this study was confined to traffic accidents in countries of the continents of Europe and North America, for which detailed and complete traffic accident data are readily available.

2. DATABASE AND METHODOLOGY

A single reliable source of demographic and accident data is by far "Statistics of Road Traffic Accidents in Europe," published by the United Nations [4]. Based on this publication, and various national statistics, such as [5], only the accident data of the following countries were considered for analysis in this study: Austria (A), Belgium (B), Denmark (DK), the Federal Republic of Germany (FRG), France (F), Great Britain (GB), Italy (I), the Netherlands (NL), Norway (N), Sweden (S) and Switzerland (CH), and the United States. Hereafter, the eleven European countries will be referred to as Western Europe (WE). It should be noted that southern European countries like Greece, Portugal, and Spain were not included in the study due to lack of data.

The objectives of the study were to: (1) Identify changes in fatalities and fatality rates for different age groups and road user groups, as experienced by each of the eleven Western European countries, by Western Europe as a whole, and by the United States from 1978 to 1987; (2) Determine whether there were statistically significant changes in the fatal traffic accident characteristics between 1978 and 1987; (3) Show how people died; (4) Show where people died; (5) Show the number of persons killed in alcohol-related crashes.

To achieve objective 2 of the study, the investigated time period from 1978 to 1987 was divided into three time periods: Time Period I (1978-1980), Time Period II (1981-1983), and Time Period III (1984-1987). The statistical analysis t-test concerning the difference between means was then conducted for testing the significance of the difference between mean number of fatalities/fatality rates of the three time periods in each of the subject countries.

Readers who are interested in a detailed discussion of the t-test results, and of the comparability of the fatality data, as related to the investigated countries, should consult [6-14].

3. TRENDS OF FATALITIES AND FATALITY RATES

3.1 Demographic Characteristics

Before delving into the analysis of the fatality data for the subject countries, let us briefly talk about important demographic characteristics for these countries (see Table 1).

Column 1 of Table 1 indicates that besides the northern European countries, Sweden and Norway, the Federal Republic of Germany, France, Great Britain and Italy belong to the group of large countries, while Austria, Belgium, Denmark, Switzerland and the Netherlands belong to the group of small countries.

Column 2 indicates that the population density ranges between 13.0 inhabitants per square kilometer in Norway and 403.6 inhabitants per square kilometer in the Netherlands. As can be seen, Belgium is relatively densely populated with about 325 inhabitants per square kilometer, followed by the Federal Republic of Germany, Great Britain, Italy and Switzerland with 160 to 250 inhabitants per square kilometer. Denmark, France and Austria have population densities of about 100 inhabitants per square kilometer, while Sweden and Norway have less than 20 inhabitants per square kilometer. Western Europe as a whole has
122 inhabitants per square kilometer, which is about five times that of the United States.

Note that the area and the population density do not appear to have a significant effect on the increase in the number of registered motor vehicles (see column 3), and on vehicles per capita (see column 4). For instance, the Netherlands which is densely populated had an increase of 14.5% in registered motor vehicles, while Norway which is sparsely populated had an increase of 35.7% in registered motor vehicles. Furthermore, it is interesting to note that the Central European countries, including the Federal Republic of Germany, Switzerland, and France, as well as Italy, have the highest number of vehicles per capita, while the northern European countries, including Great Britain, have the lowest.

Column 5 indicates that the vehicle kilometers of travel may not be directly affected by the increase in registered motor vehicles. For instance, Great Britain, which had an increase of 27.7% in registered motor vehicles, had an increase of only 15.5% in vehicle kilometers of travel, while Norway, with a 35.7% increase in registered motor vehicles, experienced an increase of 52.0% in vehicle kilometers of travel.

Overall, Western Europe experienced an increase of about 24% in both registered motor vehicles and vehicle kilometers of travel. The corresponding US numbers were about 20% and 25%, respectively, despite the significant differences in population density and vehicles per capita that do exist between Western Europe and the United States.

3.2 Traffic Accident Characteristics

Percent changes of fatalities and fatality rates for the countries under study are shown in Table 2. Despite the increase in registered motor vehicles, and vehicle kilometers of travel (see Table 1), the investigated European countries experienced decreases in fatalities. The decreases ranged between 8.3% and 45.7%. The decreases in descending order belonged to the Federal Republic of Germany (-45.7%), the Netherlands (-35.3%), Austria (-30.4%), Belgium (-25.8%), Switzerland (-24.9%), Sweden (-23.9%), Great Britain (-21.8%), Denmark (-17.8%), France (-17.6%), Italy (-14.8%), and Norway (-8.3%). The overall decrease in Western Europe was 27.3%, which was 3.5 times that of the United States (-27.3% vs. -7.8%).

It can also be seen from Table 2 that the Western European countries experienced decreases in both fatalities per 10^9 vehicle kilometers and fatalities per 10^5 inhabitants. Again, the largest reductions of 57% in fatalities per 10^9 vehicle kilometers and 45.6% in fatalities per 10^5 inhabitants were achieved by the Federal Republic of Germany. Note that the decreases in fatalities per 10^9 vehicle kilometers were more pronounced than those for fatalities per 10^5 inhabitants for all countries under study. For both fatality rates, the percent decreases in Western Europe as a whole were between 1.5 and 1.8 times those of the United States (-39.9% vs. -26.1%, and -28.9% vs. -15.9%, respectively).

The fatality rate (fatalities per 10^9 vehicle kilometers of travel) is widely considered to be the most reliable source for an objective comparison. As can be seen from Table 2, the absolute number of this rate for Western Europe (22.6) is significantly higher than that of the United States (15.0). Generally, it can be stated that the risk of being killed in a traffic accident in Western Europe was by 1987 still 1.5 times higher than that of the USA. Furthermore, it is interesting to note that the fatality rate of 22.6 fatalities per 10^9 vehicle kilometers in Western Europe in 1987 was reached by the United States already in 1974.

On the other hand, in terms of fatalities per 10^5 inhabitants, Table 2 indicates that more people die in the United States than in Western Europe.

3.3 Fatalities by Age Groups

Figure 1 shows the distribution (%) of fatalities by age for Western Europe and the United States for 1987. This figure shows that for persons in their late teens and early twenties (ages 15-24 years), traffic accidents accounted for nearly 30% of all fatalities in both continents. Based on Statistics of Road Traffic Accidents in Europe [4] and references [13,14], youths aged 15-24 years make up between 15 and 16 percent of the populations of Western Europe and the United States. Figure 1 indicates then that the percentage share of fatalities for this age group is roughly twice this figure. This result emphasizes the serious need for action to effectively tackle the problem facing this age group in both continents. Especially high among the European countries is the percentage share of fatalities that this age group makes up in Norway, Austria, and the Federal Republic of Germany.

On the other hand, Figure 1 indicates that the percentage share of fatalities for persons aged 65 years and over in the United States is substantially lower than the corresponding one for
Western Europe. One explanation for this finding may be related to different lifestyle patterns and village structures, i.e., more pedestrians on the streets, etc. In Western Europe, persons in this age group represent a high proportion of pedestrian and bicyclist fatalities.

Again, reference to [4,13,14] indicates that the percentage share of fatalities for persons aged 65 years and over in Western Europe is roughly 1.3 times the percentage that this age group makes up of the total population. This result emphasizes the need for action to effectively tackle the problem facing this age group in Western Europe. Especially high among the European countries is the percentage share of fatalities that this age group makes up in Sweden, Denmark, Switzerland, Great Britain, and the Federal Republic of Germany.

The age distributions of persons killed in traffic accidents (Figure 1) may become more meaningful if they were compared with the age distributions of the general population [4,13,14]. A glance at Table 1, which gives fatalities per 10^5 inhabitants by age, clearly indicates that death rates vary tremendously by age, with peaks in the late teenage years and early twenties (ages 15-24 years). After that, death rates decline (ages 25-64 years), then increase again beginning at age 65.

Furthermore, and as we have already noted in Table 2, Table 3 reveals that the population death rates for the different age groups in the United States are higher than those of Western Europe.

Generally speaking, the authors do not wish to speculate on the reasons behind these differences, but merely would like to pinpoint the most endangered age groups, which are shown in this study to be the age groups 15-24 and over 64.

3.4 Fatalities by Road User Groups

Figure 2 shows the percentage share of fatalities for different road user groups for Western Europe and the United States. This figure indicates that (1) the percentage share of fatalities for pedestrians in Western Europe is 1.35 times that of the United States. Pedestrian deaths represent more or less the second largest category of motor vehicle deaths in Western Europe; (2) the percentage share of fatalities for bicyclists in Western Europe is 3.6 times that of the United States. As Figure 2 reveals, bicyclist fatalities in the United States represent a very low percentage of the total number of fatalities; (3) the percentage share of fatalities for motorcyclists in Western Europe is 1.7 times that of the United States; (4) the percentage share of fatalities for passenger car occupants is fairly comparable between Western Europe and the United States. Passenger car occupant deaths represent, with nearly 55%, the largest category of motor vehicle deaths in Western Europe and the United States, with nearly 55%; and (5) the percentage share of fatalities for truck and bus occupants in the United States is 5.7 times that of Western Europe. Truck and bus occupant deaths represent the lowest category of motor vehicle deaths in Western Europe and the second largest in the United States. The difference in truck and bus occupant fatalities between Western Europe and the United States may be explained by the fact that, contrary to Western Europe where speed limits of 60 to 80 km/h do exist for trucks, truckers in the United States drive at speeds similar to or even higher than those of passenger cars. Compared to European drivers, passenger car drivers in the United States normally drive in a more defensive and polite way, while truckers normally drive in a more aggressive way, probably because of longer travel distances and financial constraints. Thus, a European driving for the first time in the United States would feel like a rabbit being chased by truckers. What is needed is that truckers in the United States be required to follow certain speed limits that are lower than those for passenger cars, as is the case in Europe. Until such speed limits could be put in effect, an enforcement of existing general speed limits by the police is deemed necessary.

It can be possible that the lower percentage of pedestrian, bicyclist, and motorcyclist fatalities in the United States is due to the fact that, contrary to Western Europe, in the United States the majority of pedestrians, bicyclists, and motorcyclists also are car drivers. It is assumable that pedestrians, bicyclists, and motorcyclists with driving experience have a better surviving chance in a traffic world reigned by cars [15]. Furthermore, as we have seen in Table 1, vehicles per capita in the United States are higher than those in Western Europe. Thus, it can be expected that Americans spend more time in passenger cars than the Europeans, who are mostly pedestrians, bicyclists, and motorcyclists, and are thus exposed to more traffic safety risks.

4. TEST OF SIGNIFICANCE

Fatalities and fatality rates for different time periods were compared by t statistic to determine if there was a statistically significant difference between the periods. The formula used in calculating the t statistic is provided in [6-8, 11]. Readers may wish to consult these
The following time periods were considered as being suitable for describing the safety impacts of the last decade in each of the subject countries:

- Time period I contains the years 1978-1980 to enable us to describe the fatality development at the end of the 1970's.
- Time period II contains the years 1981-1983 to enable us to describe the fatality development at the beginning of the 1980's.
- Time period III contains the years 1984-1987 to enable us to describe the fatality development in the 1980's.

(At the time the manuscript was completed the data were as up to date as possible).

Especially time periods II and III may be of special interest for the United States, since they represent a crucial turning point in traffic safety, following the introduction of mandatory seat belt laws and stringent drunk driving laws in many states of the USA at that time.

The results of t-tests are presented in Table 4 for the following fatality categories: "Total number of fatalities", "Fatalities per 10^5 vehicle kilometers", "Fatalities per 10^5 inhabitants", the age groups "0-14", "15-24", "25-64" and "Over 64", and the road user groups "Pedestrians", "Bicyclists", "Motorcyclists", "Passenger Car Occupants" and "Truck and Bus Occupants.

Examination of Table 4 reveals the following:

(1) Between time periods I and II, the majority of the Western European countries, Western Europe as a whole, and the United States experienced marginal or even significant safety improvements for different fatality categories at the 95 percent level of confidence. Marginal safety deteriorations were observed for the age group "15-24" (Italy, Norway, Switzerland), and for the road user groups "Bicyclists" (Austria, Great Britain, Norway), "Motorcyclists" (Austria, Italy, Sweden, Switzerland) and "Truck and Bus Occupants" (Denmark, Sweden, Switzerland). Note that between the periods I and II not one significant safety deterioration was experienced by the investigated countries.

(2) Between time periods II and III, worsening of traffic safety record could be noticed for the Nordic countries Denmark, Norway and Sweden, which have experienced marginal safety deteriorations for "Total number of fatalities", "Fatalities per 10^5 inhabitants," the age groups "15-24", "25-64" and "Over 64", and significant safety deterioration for the road user group "Passenger Car Occupants". It is interesting to note that the Federal Republic of Germany experienced, for all age and road user groups, safety improvements which were significant at the 95 percent level of confidence. Countries like Austria, Belgium, France, Italy, the Netherlands and Switzerland experienced for the most part significant safety improvements. Great Britain experienced for the most part marginal safety improvements, which were not significant at the 95 percent level of confidence. For Western Europe as a whole, all age and road user groups revealed significant safety improvements. In contrast, the United States experienced marginal improvements in safety for several fatality categories, but also marginal or even significant deterioration in safety for the age groups "25-64" and "Over 64", and the road user groups "Bicyclists" and "Truck and Bus Occupants".

(3) In general, the results of Table 4 indicate that Western Europe as a whole experienced safety improvements which were more pronounced that those of the United States. For instance, between time periods II and III Western Europe experienced significant safety improvements for all of the investigated fatality categories. In contrast, the United States experienced only marginal safety improvements, marginal safety deteriorations, and even significant safety deterioration development in the United States between time periods I and II to that between time periods II and III, one clearly notes that an unfavorable turning point in traffic safety had taken place in the United States, despite the introduction of mandatory seat belt laws and stringent drunk driving laws in many of its states.

The importance of the results of Table 4 is that they provide traffic safety authorities in the investigated countries with a tool to (a) study the development of different fatality categories; (b) compare their results to other countries; and (c) come up with recommendations for improving traffic safety, especially for those age and/or road user groups which have experienced significant safety deteriorations. For instance, as a result of this study, Denmark and Sweden should pay attention to the road user group "Passenger Car Occupants", which had experienced a significant safety deterioration, while the United States should concentrate on improving safety for the age group "Over 64", which had also experienced a significant
safety deterioration.
In other words, this research study could assist the authorities in the identification of endangered human and vehicular involvements, in terms of their fatality developments.

Generally speaking, it is not the intention of the authors to go deeper in evaluating the previous results because of significant differences that exist among the investigated countries, such as demographic, legislative, etc. The results of the tables, such as Table 4, should be viewed by traffic safety authorities in the investigated countries as indicative of where their respective country stands in terms of fatality development over different time periods. The results are important in that they could pinpoint the problem areas in traffic safety, and thus direct the authorities to concentrate more on those troubled areas.

5. FATALITIES BY TYPE, LOCATION, AND CAUSES OF ACCIDENTS

It would be very much a misleading oversimplification to talk about motor vehicle crashes as if all were similar events. There are pedestrians, passenger car occupants, truck and bus occupants, etc. who fall victims to motor vehicle crashes, such as between car-car, car-pedestrian, etc. Of importance here are also fatalities by location and causes of accidents. In this section, we will address the questions of "How Do People Die?", "Where Do People Die?", and "Influence of Alcohol".

5.1 How Do People Die?

Figure 3 shows fatalities by first harmful event for single and multiple vehicle crashes. Single vehicle crashes (SVA), including those with pedestrians (CWP) and those with or without rigid obstacles (CWO), represent on average about 58% of fatalities in the United States, and about 48% of fatalities in Western Europe.

While 43.9% of fatal single vehicle crashes in the United States are caused by CWO, this type of crashes in Western Europe represents 30.2% only. This is probably the result of better road maintenance and equipment in Western Europe, such as the presence of guard rails and roadside appurtenances on many roads. Thus, compared to Western Europe, Restoration, Rehabilitation, and Resurfacing Strategies of the American road network system are deemed necessary.

For both Western Europe and the United States, it should be noted that one important frequent "first harmful event" in single vehicle accidents was striking a pedestrian (CWP). Note that the situation is worse in Western Europe (18.7% vs. 13.9%). This is especially true for Great Britain where vehicle-pedestrian crashes accounted for 29.9% of the total number of fatalities, while in the Netherlands, pedestrians were involved in only about 11.5% of the total number of fatalities.

In general, the differences in collisions with pedestrians may be explained by the fact that in Western Europe the percentage share of fatalities for persons aged 65 years and over is substantially higher than the corresponding one in the United States (see Chapter 3.3 and Figure 1). Thus, it can be expected that in collisions with pedestrians, especially in Western Europe, elderly people are often killed. The same results were reported in earlier studies [18,19] of traffic safety in the United States and the Federal Republic of Germany, where it was shown that 48% of pedestrian fatalities were persons over 64 years. Today, this is true in many Western European countries [4].

With regard to multiple vehicle collisions (MVA), note from Figure 3 that this type of collisions in Western Europe is higher than that in the United States. In Western Europe, the Netherlands has, with more than 60% of fatalities from this type of collisions, the highest percentage in Western Europe, followed by Denmark, Italy, Sweden, Great Britain, Belgium, Austria, the Federal Republic of Germany, France, Norway and Switzerland.

5.2 Where Do People Die?

The manner of occurrence of traffic accidents varies greatly in urban and rural areas. Approximately one-half of total urban accidents take place at intersections versus about one-quarter for rural accidents. In addition, there is a significantly higher proportion of pedestrian accidents in urban areas. The total number of accidents in urban areas exceeds that in rural areas. These differences are primarily due to greater population density and motor vehicle registrations as well as more restricted regulation of traffic in urban areas as compared to higher speeds associated with rural areas [16].
Figure 4 describes the local distribution (%) of fatalities in road traffic accidents between urban and rural areas for 1987. This figure clearly shows that in both Western Europe and the United States about 40% of fatalities occur in urban areas, compared to about 60% of fatalities in rural areas, even though motor vehicle kilometers driven in most countries is more or less the opposite. The only exception is Great Britain where about 60% of fatalities occur in urban areas, compared to about 40% of fatalities in rural areas. Similar results were reported in 1980/1981 studies [18,19].

Figure 5 describes the location where accidents took place. In terms of road classification, the American "Interstate System" with 8.7% of the total number of fatalities, and the comparable German "Autobahn System" with 6.2% of the total number of fatalities represent the safest road class. Furthermore, note that the other rural roads represent, for example in the United States, (16.5%+32.9%+18.2%) or 68% of the total number of fatalities, and in the Federal Republic of Germany, as an example for Western Europe, (31.9%+28.8%+12.6%) or 73% of the total number of fatalities. While the percentages in Figure 5 are based on studies made at the beginning of the 1980’s, an examination of current fatality data indicates that they are, more or less, still valid today. It follows then that the rural road network system, which consists mainly of two-lane rural roads, represents between 60% and 70% of the total number of fatalities in both continents [18,19]. It is estimated that half of these fatalities (at least 30%) occur on curved sections, primarily in the sense of exceeding the critical speed of a curve and thereby losing control. Based on the percentage of 30%, it can be estimated that, related to the year 1990, about 13,000 persons in the United States, about 3,500 persons in Germany (East and West), and about 13,000 persons in Western Europe lost their lives at curved sites.

From the point of view of highway design and traffic safety engineers, curved sections of two-lane rural roads represent one of the most important targets for reducing accident frequency and severity.

5.3 Influence of Alcohol

Drinking and driving is by far the cause of many serious road traffic accidents worldwide. In Brazil, one person is killed every 21 minutes -- some 25,000 each year -- in alcohol-related accidents. That is about 50 percent of all traffic fatalities there. In Mexico, 80 percent of the 50,000 traffic fatalities are due to 'human error', basically caused by drunk driving. It is estimated that over 25 percent of traffic casualties in South Africa involve alcohol. In the United States in an average year, alcohol-related accidents result in some 650,000 injuries, of which about 40,000 are serious; over 23,000 people are killed -- about half of the total traffic fatalities. Over 30 percent of traffic casualties in Denmark involve alcohol. In England and Germany, about one fifth of all traffic fatalities are said to be alcohol related. In Sweden and Switzerland, about one sixth of all traffic fatalities are due to alcohol-related accidents. In Austria and the Netherlands between 10 and 14 percent of traffic fatalities are said to be due to alcohol [3,4].

Generally speaking, the above statistics clearly indicate that the average value for the Western European countries is decisively lower than the corresponding one for the United States. Recent research findings indicate that the 50 percent figure for the United States may not be correct; it may be even higher [17].

We should point out that (1) data for Belgium, France and Norway were not available in Statistics of Road Traffic Accidents in Europe [4]; and (2) Italian legislation does not require persons involved in road traffic accidents to have their alcohol concentration tested. This may explain why only 0.2% of fatalities is reported as under the influence of alcohol in Italy [4].

6. CONCLUSIONS

Specific conclusions of this study include the following:

(1) Despite the increase in registered motor vehicles, and vehicle kilometers of travel during the period 1978-1987, the investigated Western European countries experienced decreases in fatalities. The decreases ranged between 8.3% (Norway) and 45.7% (Federal Republic of Germany).

(2) The Western European countries experienced decreases in both fatalities per 10⁹ vehicle kilometers and fatalities per 10⁹ inhabitants. Again, the largest reductions of 57% in fatalities per 10⁹ vehicle kilometers and 45.6% in fatalities per 10⁹ inhabitants were achieved by the Federal Republic of Germany. For both fatality rates, the decreases in Western Europe as a whole were between 1.5 and 1.8 times those of the United States (-39.9% vs. -26.1%, and -28.9% vs. -15.9%, respectively).
The fatality rate per 10^9 vehicle kilometers in the United States of 15.0 is still much lower than that of Western Europe. Thus, the risk of being killed in a traffic accident in Western Europe is still 1.5 times higher than that in the United States. Furthermore, it was interesting to note that the fatality rate reached by Western Europe in 1987 (22.6) was reached by the United States already in 1974.

Youths aged 15-24 years make up between 15 and 16 percent of the populations of Western Europe and the United States. The percentage share of fatalities for this age group is roughly twice this figure in both continents.

Fatality rates per 10^4 inhabitants indicate that death rates vary tremendously by age, again with peaks in the late teenage years and early twenties (ages 15-24 years). After that, death rates decline (ages 25-64 years), then increase again beginning at age 65. For the different age groups, these fatality rates in the United States are higher than those of Western Europe.

The percentage share of fatalities for pedestrians in Western Europe (19.5%) is 1.3 times that of the United States. Pedestrian deaths represent the second largest category of motor vehicle deaths in Western Europe.

The percentage share of fatalities for bicyclists in Western Europe (7.2%) is 3.6 times that of the United States. Bicyclist fatalities in the United States represent a very low percentage of the total number of fatalities.

The percentage share of fatalities for motorcyclists in Western Europe (15.8%) is 1.7 times that of the United States.

The percentage share of fatalities for passenger car occupants (about 55%) is fairly comparable between Western Europe and the United States. Passenger car occupant deaths represent the largest category of motor vehicle deaths in Western Europe and the United States.

The percentage share of fatalities for truck and bus occupants in the United States (19.3%) is 5.7 times that of Western Europe. Truck and bus occupant deaths represent the lowest category of motor vehicle deaths in Western Europe and the second largest in the United States.

In terms of statistical significance, the t-tests results indicate that Western Europe as a whole experienced safety improvements which were more pronounced than those of the United States. For the time period II-III (1981-1987), Western Europe experienced significant safety improvements for all of the investigated fatality categories. On the contrary, the United States experienced on the one hand only non-significant safety improvements, and on the other hand non-significant and significant safety deteriorations. The results of t-tests indicate that an unfavorable turning point in traffic safety had taken place in the United States in the 1980's, despite the introduction of mandatory seat belt laws and stringent drunk driving laws in many of its states.

Single vehicle crashes, including those with pedestrians, represent on average about 58% of fatalities in the United States, and about 48% of fatalities in Western Europe. While about 44% of fatal single vehicle crashes in the United States are caused by collisions with or without rigid obstacles, this type of crashes in Western Europe represents about 30% only. This is probably the result of better road maintenance and equipment in Western Europe.

In both Western Europe and the United States about 40% of fatalities occur in urban areas, compared to about 60% of fatalities in rural areas.

The two-lane rural network system is the cause of between 60% and 70% of the total number of fatalities in both continents. At least half of these fatalities (at least 30%) occur on curved sections.

In regard to alcohol related accidents, this study has shown that the percentage of persons killed in alcohol related accidents in Western Europe is decisively lower than the 50 percent value experienced by the United States.
REFERENCES

19. Lamm, R., "What Can We Learn from a Comparison of German and American Accident Statistics?," Proceedings, Thirty-Fifth Annual Ohio Transportation Engineering Conference, Conducted by the Department of Civil Engineering, The Ohio State University, Transplex/OSU, in Cooperation with the Ohio Department of Transportation, pp. 101-121, April 1981.
### Table 1. Demographic characteristics of the countries under study.

<table>
<thead>
<tr>
<th>Country</th>
<th>Area km²</th>
<th>Population Density Inh/km²</th>
<th>Percent Change RMV 1978–87</th>
<th>Vehicles Per Capita 1987</th>
<th>Percent Change Vkm 1978–87</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>83,851</td>
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<td>B</td>
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<td>324.5</td>
<td>10.3%</td>
<td>0.434</td>
<td>9.7%</td>
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<td>GB</td>
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<td>0.388</td>
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<td>NL</td>
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<td>S</td>
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<td>CH</td>
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<td>22.6%</td>
<td>0.576</td>
<td>28.5%</td>
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<td>WE</td>
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<td>122.0</td>
<td>24.0%</td>
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<td>23.6%</td>
</tr>
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<td>USA</td>
<td>9,519,662</td>
<td>25.6</td>
<td>19.6%</td>
<td>0.756</td>
<td>24.8%</td>
</tr>
</tbody>
</table>

Table 1. Demographic characteristics of the countries under study.

Legend: RMV = Registered motor vehicles; Vkm = Vehicle kilometers of travel; Inh = Inhabitants; A = Austria; B = Belgium; DK = Denmark; FRG = Federal Republic of Germany; GB = Great Britain; I = Italy; NL = Netherlands; N = Norway; S = Sweden; CH = Switzerland; and WE = Western Europe.

### Table 2. Percent changes in fatalities and fatality rates of the countries under study, 1978–1987.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>-30.4% (1469)</td>
<td>-44.7% (29.3)</td>
<td>-31.3% (19.3)</td>
</tr>
<tr>
<td>B</td>
<td>-25.8% (1922)</td>
<td>-32.3% (40.5)</td>
<td>-26.2% (19.4)</td>
</tr>
<tr>
<td>DK</td>
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<td>-17.5% (13.7)</td>
</tr>
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<td>FRG</td>
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<td>-45.6% (13.0)</td>
</tr>
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</tr>
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<td>GB</td>
<td>-21.8% (5339)</td>
<td>-32.1% (16.9)</td>
<td>-29.0% (9.4)</td>
</tr>
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<td>I</td>
<td>-14.8% (7259)</td>
<td>-34.6% (23.1)</td>
<td>-16.0% (12.6)</td>
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<tr>
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<td>-35.3% (1485)</td>
<td>-48.0% (16.9)</td>
<td>-38.2% (10.2)</td>
</tr>
<tr>
<td>N</td>
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<td>-39.6% (14.8)</td>
<td>-11.2% (9.5)</td>
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<td>S</td>
<td>-23.9% (787)</td>
<td>-35.7% (14.6)</td>
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<td>-41.4% (20.5)</td>
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<td>WE</td>
<td>-27.3% (38919)</td>
<td>-39.9% (22.6)</td>
<td>-28.9% (13.5)</td>
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<td>USA</td>
<td>-7.8% (46386)</td>
<td>-26.1% (15.0)</td>
<td>-15.9% (19.1)</td>
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Table 2. Percent changes in fatalities and fatality rates of the countries under study, 1978–1987.

Legend: F/Vkm = Fatalities per 10^8 vehicle kilometers of travel; and F/Inh = Fatalities per 10^4 inhabitants.

Note: The numbers in parentheses represent the absolute numbers of fatalities and fatality rates, as related to the year 1987.
### Table 3. Population death rate by age (fatalities per 100,000 inhabitants), 1987.

<table>
<thead>
<tr>
<th>Country</th>
<th>0-14</th>
<th>15-24</th>
<th>25-64</th>
<th>Over 64</th>
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</thead>
<tbody>
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<td>A</td>
<td>4.83</td>
<td>41.71</td>
<td>17.04</td>
<td>20.63</td>
</tr>
<tr>
<td>B</td>
<td>5.23</td>
<td>32.52</td>
<td>18.23</td>
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<tr>
<td>D</td>
<td>4.90</td>
<td>22.75</td>
<td>11.56</td>
<td>21.77</td>
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<tr>
<td>F</td>
<td>5.16</td>
<td>34.64</td>
<td>19.21</td>
<td>22.06</td>
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### Time Period I-II (1978-1983):

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<th>F</th>
<th>GB</th>
<th>I</th>
<th>NL</th>
<th>N</th>
<th>S</th>
<th>CH</th>
<th>WE</th>
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<tr>
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<td>x</td>
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<tr>
<td>F/Inh:</td>
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<td>o</td>
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<td>x</td>
<td>x</td>
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### Time Period II-III (1981-1987):

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<th>GB</th>
<th>I</th>
<th>NL</th>
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</tr>
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<td>x</td>
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<td>+</td>
<td>x</td>
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<td>x</td>
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<td>+</td>
<td>x</td>
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Table 4. Summary of findings (t-tests) for different fatality categories and different time periods.

Legend:  
F/Vkm = Fatalities per 10^6 vehicle kilometers of travel;  
F/Inh = Fatalities per 10^5 inhabitants;  
PED = Pedestrians;  
BIC = Bicyclists;  
MOT = Motorcyclists;  
PCO = Passenger Car Occupants;  
TBO = Truck and Bus Occupants;  
x = Significant improvement in safety (95% level of confidence);  
0 = Marginal improvement in safety;  
- = Marginal deterioration in safety;  
+ = Significant deterioration in safety (95% level of confidence).
### Table

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### Figures

**Figure 1.** Distribution (%) of Fatalities by Age Groups for Western Europe and United States, 1987.
## Distribution (%) of Fatalities by Road User Groups for Western Europe and United States, 1987

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<thead>
<tr>
<th>Country</th>
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</tbody>
</table>

**Legend:**
- PED = Pedestrians
- BIC = Bicyclists
- MOT = Motorcyclists
- PCO = Passenger Car Occupants
- TBO = Truck and Bus Occupants
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<tr>
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</tbody>
</table>

Legend: MVA = Multiple Vehicle Accidents; SVA = Single Vehicle Accidents; CWO = Collisions with or without rigid Obstacles; and CWP = Collisions with Pedestrians.

Figure 3. Distribution (%) of Fatalities for Single and Multiple Vehicle Crashes, 1987.
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</tbody>
</table>

**Figure 4.** Distribution (%) of Fatalities for Urban and Rural Areas, 1987.

**Figure 5.** Distribution (%) of Fatalities for Road Classes.
Description and Testing of a Side Impact Protection System

Jan Ivarsson
Volvo Car Corporation
Sweden
Description and Testing of
a Side Impact Protection System

Jan Ivarsson
Volvo Car Corporation
Göteborg
Sweden

Abstract
This paper will describe the engineering of structural changes to a passenger car in order to improve Side Impact Protection. Test results from tests with various methods will be given. Comparison between an in-house test method and pending American Side Impact Regulation will be made. Conclusions about expected injury reduction when introduced on the market will be made.
Methodology for the Development of
Collision Avoidance Strategies Based on Accident Data

Kenneth L Campbell
University of Michigan
USA

and

Dawn L Massie
University of Michigan
USA
ABSTRACT

METHODOLOGY FOR THE DEVELOPMENT OF COLLISION AVOIDANCE STRATEGIES BASED ON ACCIDENT DATA

Kenneth L. Campbell, Dawn L. Massie
University of Michigan
Transportation Research Institute

This paper presents a proposed approach to the analysis of accident data in support of the development of collision avoidance technology. The preliminary results of an effort to identify and rank collision situations on the basis of a "collision typology" are summarized for four databases. An 18-level collision configuration variable was constructed which included the number of vehicles involved, their relative orientation, intent to turn, relation to intersection, and traffic control at the intersection. "Contributing factors" are defined and identified on the basis of statistical associations between the levels of the factors and the categories of the collision typology. This is a departure from much of the previous work that depends on the assignment of culpability, or cause, in each accident. Instead, the proposed approach would employ special studies to establish typical sequences of events for the most prevalent collision situations. Five of the most prevalent collision types were selected for more detailed review based a probability-based sample of the original police accident reports. Opportunities for intervention, and the nature of the interventions, would be identified on the basis of the typical sequence of events for each collision situation studied.
METHODOLOGY FOR THE DEVELOPMENT OF COLLISION AVOIDANCE STRATEGIES BASED ON ACCIDENT DATA

Kenneth L. Campbell, Dawn L. Massie
University of Michigan
Transportation Research Institute

It is currently argued that most of the readily achievable gains in passenger car occupant protection have been realized and that further progress will be slower and more costly (Viano, 1988). Collision avoidance technologies are rapidly becoming a major focus of highway safety research. In this approach, the objective shifts from protecting occupants in the event of a collision to designing advanced devices that may help avoid a collision in the first place.

However, the safe and effective application of advanced technologies to the problem of collision avoidance first requires an understanding of the traffic situations in which collisions occur. Initially, this understanding must come from the current accident experience. The challenge is to develop methods for analyzing these data to determine priorities in developing collision avoidance countermeasures. This paper presents a preliminary version of a methodology to accomplish this goal. The presentation of this methodology draws heavily on exploratory work recently conducted at UMTRI (Campbell et al., 1990 and Massie et al., 1991).

Previous studies assigned factors contributing to accidents into three categories: human, environment, and vehicle. However, human error is implicated in 88-95% of the collisions in these studies (Sabey and Taylor, 1980; Treat et al., 1979; Perchonok, 1972). In this approach, the physical evidence is relied upon to assign culpability for the accident to the factor or combination of factors identified. Tangible evidence of abnormalities, or defects, in the vehicle, roadway, or environment (such as flat tires or icy pavement) usually linger long enough for investigators to record. The assignment of culpability usually assumes that the traffic system is adequately configured. More to the point, the vehicle and roadway are not likely to be found at fault unless tangible evidence confirms that they did not meet design specifications. Relatively little evidence of the human role remains. In the absence of physical evidence of a vehicle, roadway, or environmental defect, the human is likely to be held responsible. Thus, the underlying assumptions of these studies predetermined that human errors would be most frequent.

While the idea of human culpability may be attractive, it has not led to improved human performance or improved traffic safety. Advanced technologies now offer the promise of a transportation system that is more tolerant of human characteristics. The current challenge is to forget the counter-productive concepts of culpability and cause and develop an objective description of accidents that provides a comprehensive picture of the situations in which collisions occur.

Other experts have proposed that the pre-crash movements and intents of the involved vehicles (driver at fault or not) are of primary importance for the study of collision avoidance (Haight et al., 1976). A brief review of some of these studies is presented by Massie (1991). However, most researchers were only able to study a few hundred accidents. Our objective was to study the pre-crash situation in large accident databases.
The approach presented in this paper is a significant departure from most previous studies in that the initial steps of the methodology seek to identify statistical associations between collision situations and contributing factors. This approach avoids the inherent bias in assessing the role of each factor on a case by case basis. As proposed by Joksch (1983), it is sufficient for the identification of statistical associations that a factor simply be recorded as "present" or "not present." The general approach is to identify the most common collision situations and the contributing factors associated with each. Then, a statistically representative sample of each collision situation is studied in detail to determine the physical sequence of events that links the contributing factors with the resulting collision. The objective is to develop a list of collision situations, ranked according to the potential benefits of collision avoidance, along with a characteristic sequence of events for each. This information will support the identification of opportunities where intervention has the potential to prevent or mitigate the collision and the nature of the required intervention. The steps in the proposed method are summarized below.

1. Define relevant collision situations (types).
2. Rank the collision types by the potential benefits of collision avoidance.
3. Identify contributing factors associated with each collision type.
4. Characterize each collision type in terms of the physical sequence of events leading to the impact.
5. Identify opportunities in the sequence of events where intervention has the potential to prevent or mitigate the impact.

The remainder of the paper will elaborate on each step and provide illustration where possible. A Discussion of future work and Conclusions follow the presentation of the proposed method.

1 DEFINING COLLISION SITUATIONS

Collisions can be classified in innumerable ways, depending on the research problem at hand. The objective here is to classify accidents in ways that will facilitate the evaluation of collision avoidance countermeasures. The resulting classification will be referred to as a "collision typology." The process of developing a typology must start with a hypothesis as to the characteristics of the accident that will best discriminate the opportunities for intervention. This necessarily involves some assumption about the types of intervention, or technologies, under consideration. The focus of the work to date has been on vehicle-based collision avoidance technologies. Consequently, the assumption has been made that the pre-collision relative position of the vehicle to the object, or other vehicle struck, is of primary importance.

2 RANKING THE COLLISION SITUATIONS

The objective here is to rank the collision situations based on the potential benefits of collision avoidance. The issue is the choice of a dependent variable as a measure of benefit. Two obvious candidates are the prevalence and risk of a given type of accident (Campbell, 1984). Prevalence is simply the frequency, or proportion, of collisions involving a particular factor. Countermeasures aimed at a factor associated with a large proportion of accidents have greater
potential benefits than those aimed at something that occurs very infrequently. However, prevalence is not the only measure. Another consideration is the injury severity of different collision types. One would like to take into account the fact that prevention of a collision resulting in serious or fatal injuries is of greater benefit than preventing a collision of less severe consequences. Risk, on the other hand, is the likelihood of experiencing a collision involving a particular factor per unit of exposure to that factor. It seems appropriate that countermeasures for high-risk factors should take priority over those for low-risk factors, particularly if they are equally prevalent.

While data exist for estimating the prevalence of particular collision types, there are no satisfactory sources of exposure data or even a consensus of how best to measure exposure. Vehicle-miles of travel is a common measure of exposure, but total travel is not sufficient because of the different levels of risk associated with particular factors. For example, nighttime travel generally has a higher risk than daytime travel (Williams, 1985, Campbell, 1991). Exposure to many types of collisions increases as a vehicle enters an intersection and performs a certain maneuver (Joksch and Knoop, 1983), thus travel on non-intersection road segments has a different risk than travel through intersections. Defining exposure as "the opportunity to be involved in a accident", Council et al. (1987) argue that exposure types parallel collision types, so individual, specific exposure formulas should be calculated separately for each collision type of interest. However, assuming mileage is the desirable exposure measure, one would ideally wish to have travel data cross-classified by the factors that distinguish the differing risks for different types of travel. Since there are currently no available data that contain all of these factors, collision types in this paper will be ranked according to prevalence and injury severity, but not risk.

3 A PRELIMINARY COLLISION TYPOLOGY

A preliminary collision typology developed by the UMTRI research team is described by Massie (1991) and repeated here. Creating the collision typology was an iterative process. The first step involved reviewing the many variables in the data files and choosing the ones that appeared most useful for the task of developing a typology of the most common collision scenarios. One premise followed in creating the collision typology was that it was more appropriate to look at the intended pre-crash movements of the involved vehicles than whether the resulting collision configuration was angle, head-on, rear-end, etc. After a brief review of the data used, the collision typology is presented.

3.1 Accident Data Sources

The research team used four different files of accident data in attempting to develop a typology of the most common motor vehicle collision situations. Two were state files consisting of all police-reported accidents in Michigan and Washington. The project used the 1989 version of the Michigan accident database, which contained 417,252 accident records and 707,718 traffic unit records (motor vehicles, pedestrians, pedacyclists). Because this file was so large a 50% random sample was conducted at the accident level, pulling all corresponding vehicle records. This resulted in an analysis file with information on 208,399 accidents involving 353,372 traffic units. The full
version of the 1988 Washington file was used. This database contained 125,920 accident records and 237,019 vehicle records.

The third source of accident data was the National Accident Sampling System (NASS) files from 1985 and 1986. These files are produced by the National Highway Traffic Safety Administration (NHTSA), as part of a program begun in 1980 for carrying out special investigations on a nationally representative sample of police-reported accidents in the various states. This is the only nationally representative database covering all types of motor vehicle accidents in the United States. However, it is by necessity rather limited in size. Consequently, two years of data were combined to create a file of 23,371 accidents involving 38,482 vehicles.

The final source of data was the Crash Avoidance Research Data file, commonly known as the CARDfile. This database is the product of a recently established NHTSA project to collect all the police-reported accidents for three years from six states and to put these data together in a common format in order to have available a large accident database. The six states are Indiana, Maryland, Michigan, Pennsylvania, Texas, and Washington, and the three years used were 1984, 1985, and 1986. Since the original CARDfile contained over 4 million accidents and over 7 million vehicles, a special 5% random-sample file was drawn for the actual analysis. This file contained 211,943 accident records and 370,151 vehicle records.

3.2 The Collision Typology

The collision typology generated has 18 levels and incorporates the number of vehicles involved in the accident, the relative pre-crash orientation of the vehicles, their intent to turn, the relation of the accident to an intersection or driveway, and the traffic control in the case of accidents taking place at an intersection. Certain restrictions were made in the collision data for this project. The main focus was the accident experience of "ordinary" drivers. Consequently, accidents involving drivers who had been drinking, drivers who were indicated to have been driving recklessly or carelessly, and drivers under the age of 16 were excluded from the analyses. The exception was that reckless drivers cannot be identified in the Washington or CARDfile data, so accidents involving reckless drivers were not excluded from these two files. Since the focus of the project was on the accident experience of motor vehicles, collisions involving pedestrians or pedacyclists were excluded as well. All of the analyses were conducted at the vehicle level, so the single-vehicle percentages in the distributions are much smaller than they would be as percentages of all accidents.

A comparison of the 18-level collision typology among the four accident datafiles is shown in Table 1 and Figure 1. For this table and figure, the data have been restricted to passenger cars only where driver age was known. The 18 categories of collision types have been abbreviated here and elsewhere. "S.V." stands for single-vehicle and "M.V." stands for multi-vehicle. Three categories of single-vehicle accidents have been defined, the first two taking place at an intersection and the third occurring away from an intersection. "Signal" and "sign" refer to the traffic control at intersection accidents. Signal-ized intersections have an automated three-color traffic light, while signed intersections are controlled by a stop or yield sign or a flashing light. Among the 15 multi-vehicle collision categories, all but three describe accidents taking
place at an intersection. The intersection accidents were split into three broad
categories of vehicles approaching on crossing paths ("cross"); vehicles
proceeding from the same direction ("same dir."); and vehicles approaching
from opposite directions ("opp. dir."). Each of these three general categories is
split according to the traffic control and whether both vehicles were moving
straight ahead ("straight") or one or both was attempting a turn ("turning").
Finally, the last three multi-vehicle categories describe collisions occurring
away from intersections. The "driveway" group represents accidents where one
or both vehicles was entering or leaving a driveway or parking space. The
other two categories are for vehicles approaching in the same direction or from
opposite directions, not at an intersection.

Table 1 - Collision Type Distributions for Four Datafiles

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<td>1.05</td>
<td>0.60</td>
<td>1.13</td>
</tr>
<tr>
<td>M.V. Same Dir/Turning/Sign</td>
<td>2.02</td>
<td>2.43</td>
<td>0.92</td>
<td>3.24</td>
</tr>
<tr>
<td>M.V. Opp Dir/Straight/Signal</td>
<td>0.13</td>
<td>0.17</td>
<td>0.34</td>
<td>0.25</td>
</tr>
<tr>
<td>M.V. Opp Dir/Straight/Sign</td>
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<td>0.67</td>
<td>0.71</td>
<td>0.95</td>
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<tr>
<td>M.V. Opp Dir/Turning/Signal</td>
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<td>4.24</td>
<td>4.93</td>
<td>5.18</td>
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<td>2.22</td>
<td>2.16</td>
<td>3.59</td>
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<tr>
<td>M.V. Non-Inter/Driveway</td>
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</tr>
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<td>M.V. Non-Inter/Same Dir.</td>
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<td>M.V. Non-Inter/Opp. Dir.</td>
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<td>2.53</td>
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</tr>
</tbody>
</table>

TOTAL 100.00 100.00 100.00 100.00
Sample Size 118,908 227,128 17,419 164,375
Sample Fraction 100% 50% -- 5%

NOTE: The figures in this table are column percentages for each datafile at the
vehicle level. They represent passenger cars only and exclude cases where driver
age was unknown. Only non-pedestrian/pedalcyclist crashes with "ordinary" drivers
were considered.

As Table 1 and Figure 1 indicate, the collision typology distributions are quite
stable across the four datasets. Considering the somewhat disparate data
collection and coding methods in the four data sources, the consistency between
files is encouraging. The results indicate that some of the more common
collision categories are single-vehicle non-intersection accidents; multi-vehicle
driveway/parking accidents; multi-vehicle, non-intersection, same direction
Fig. 1 - Collision Type Distribution, Comparison of Four Datafiles
collisions; and the group of multi-vehicle, crossing paths at intersection accidents.

Since the characteristics of potential collision avoidance devices are not well known, it was difficult to select independent variables that would classify accidents in ways that would facilitate the assessment of potential benefits of collision avoidance technologies. Consequently, the procedure discussed here was exploratory, and the resulting typology should be considered as an initial attempt in an iterative process. In general, one would not expect a single collision typology to be adequate for all classes of technology or countermeasures.

4 IDENTIFYING CONTRIBUTING FACTORS

Having defined and ranked the collision situations, the next step is to identify contributing factors associated with each collision situation. Candidate factors can broadly be grouped as driver, vehicle, environmental, and roadway. The objective here is to find statistical associations between the candidate factors and individual collision types. Factors that are associated with particular collision types are described as "contributing factors," in that they characterize the conditions in which the collisions occur. Beyond describing the collision environment, contributing factors also are used to formulate hypotheses as to the physical sequence of events that will be developed in the next step. Examples of contributing factors from previous work (Massie, 1991) are presented in the remainder of this section.

Given the similarity of the overall collision typology distribution among the four datafiles, it was decided to use just one file to explore contributing factors. The CARDfile was rejected because it contains no road class variable and has an unacceptably high missing data rate on its rural/urban variable. Concerns with sample size prevented use of the NASS files. This left the two state files of Michigan and Washington. Since the 50% Michigan sample file contains more cases than the entire Washington file, it was decided to use the 1989 Michigan file for the series of two-ways distributions. The Michigan file contains all of the variables required for this series of distributions.

In Figure 2, the collision type distribution is compared for passenger cars; light trucks and vans; and medium and heavy trucks in the 50% Michigan 1989 file. One main difference between the three vehicle types is that while 25% of the light trucks were involved in single-vehicle, non-intersection accidents, this was true of only about 15% of the passenger car and large truck involvements. Large trucks had a higher proportion of multi-vehicle, non-intersection, same direction involvements (29%) compared to cars (20%) and light trucks (18%). More minor differences include the relatively low incidence of driveway/parking accidents for large trucks and the higher incidence of multi-vehicle, same direction, turning collisions among large trucks. On the other hand, passenger cars were over-represented in the multi-vehicle, opposite direction, turning accidents.

One factor that is certainly involved in the differences between the distributions is the travel patterns of the different vehicle types. For example, large trucks typically have a higher share of travel on limited access roads and in rural areas than do other classes of vehicles. This affects the likelihood of
Fig. 2 - Collision Type by Vehicle Type, Michigan 1989
large trucks experiencing particular types of collisions and is probably responsible for their lower incidence of driveway/parking accidents and higher incidence of non-intersection, same direction collisions. These comparisons across vehicle type illustrate the need for exposure data. While differences in collision experience between different types of vehicles should be considered in the application of collision avoidance technology, it is beyond the scope of this paper to explore the issue further. The remaining distributions in this section will be restricted to passenger cars.

Figure 3 presents the collision typology for passenger cars in the Michigan 1989 file according to the road surface condition at the time of the accident. Over 24% of the accidents occurring on snowy/icy roads were single-vehicle, non-intersection collisions, compared to 14% of the collisions on dry roads and 10% on wet roads. Snowy/icy roads were also over-represented in the non-intersection, opposite direction group. There was a high incidence of wet roads among non-intersection, same direction collisions and among same direction intersection collisions where both vehicles were going straight.

Accident severity should be considered in addition to prevalence when evaluating the potential of collision avoidance technology. The passenger car cases in the Michigan file are split in Figure 4 into fatal, injury, and property-damage-only (PDO) involvements. Over 28% of the fatal accidents were multi-vehicle, non-intersection, opposite direction collisions, compared to just 3% of the injury involvements and 2% of the PDOs. Fatal involvements were also over-represented in the crossing paths, both straight, at signed intersections group. On the other hand, fatal involvements were under-represented among driveway/parking collisions, same direction, non-intersection collisions, and all four categories of same direction, intersection collisions. Another interesting difference is the lower percentage of single-vehicle, non-intersection collisions among injury-producing collisions (8.7%) compared to both fatals (17.1%) and PDOs (17.4%). In general, these findings are a reflection of a higher probability of fatality in rural accidents where travel speeds are higher as compared to urban areas with relatively lower travel speeds.

Driver age is another important factor since the perceptions and reaction times of drivers vary with age, as do the exposure patterns. The Michigan cases were divided into three groups of drivers, those age 16 to 25; 26 to 55; and 56 and older. Underage drivers had previously been excluded from the analysis file. In Figure 5 the collision distribution is compared among these three age groups and among alcohol-involved drivers of all ages. The alcohol-involved drivers are the primary group excluded from the previous analyses. The main differences in the collision distributions in terms of age are between the older drivers compared to the two younger age groups. Drivers 56 and older were found to have higher percentages of driveway/parking involvements and crossing paths, both vehicles moving straight collisions, both at signed and signalized intersections. The older drivers had lower percentages of single-vehicle non-intersection involvements compared to the other two age groups.

Comparing the impaired and unimpaired drivers, Figure 5 indicates a preponderance of single-vehicle accidents among the alcohol-involved drivers. Nearly 41% of the involvements of alcohol-involved drivers were single-vehicle accidents at non-intersections compared to about 15% for the three unimpaired groups. The great over-involvement of alcohol-involved drivers in single-vehicle accidents makes it difficult to evaluate their distribution of multi-
Fig. 3 - Collision Type by Road Surface Condition, Passenger Cars Only, Michigan 1989
Fig. 4 - Collision Type by Accident Severity, Passenger Cars Only, Michigan 1989
Fig. 5 - Collision Type by Driver Age and for Alcohol-Involved Drivers, Passenger Cars Only, Michigan 1989
vehicle collisions compared to unimpaired drivers by looking at Figure 5. If the three categories of single-vehicle accidents were excluded from consideration, other differences would emerge between impaired and unimpaired drivers. The alcohol-involved drivers experienced more multi-vehicle, non-intersection, opposite direction collisions, same direction, both straight, at signalized intersection involvements, and opposite direction, both straight, at signed intersection collisions compared to the unimpaired drivers.

Simple distributions have been used here to illustrate the association between individual collision types and particular levels of the candidate contributing factors that were examined. This association can be quantified by the odds ratio, or cross product ratio, through the application of log-linear models. The resulting tests of significance serve to identify significant associations.

5 CHARACTERIZING THE PHYSICAL SEQUENCE OF EVENTS

The objective of the analytic work described in the first three steps is to provide a comprehensive statistical description of factors and combinations of factors associated with each collision situation. These statistical associations often suggest hypotheses as to the physical sequence of events. The remaining steps require the additional information and insight gained from review of individual accidents. The goal of this step is to identify the actual sequence of events that is typical of each collision situation. This step is essential because it confirms the hypotheses of the previous steps and is the basis for the development of countermeasure hypotheses in the next step.

It would be preferable to characterize the physical sequence of events on the basis of detailed investigations of a statistically representative sample of accidents from selected collision types. A comprehensive evaluation of the potential benefits of advanced collision avoidance technology will almost certainly require information that goes well beyond the scope of existing accident data files. Furthermore, the cost and complexity of obtaining the additional data is likely to limit the scope of such studies. Depending on the collision situation and the nature of the countermeasure(s) under consideration, the data needs may be different. In the context of the proposed method, these supplemental data collection activities will be referred to as "special studies."

Essential requirements for such a special study are: (1) to have a procedure for identifying accident subsets for such studies, and (2) to be able to relate the subset studied to the larger, statistically representative, database. Within the context of the proposed method, the collision typology would provide the framework for identifying accidents subsets appropriate for additional study. It is assumed that the variables used to define the typology characterize essential elements of the collision situation to the extent possible within the limits of existing data. The ranking of the collision types identifies those with the greatest potential benefits. Consequently, the top ranked collision types are the likely candidates for special studies. The variables used to define the typology would be used to define a sampling procedure to select a random sample of accidents falling into the selected collision types. The sampling would be tailored to produce the desired number of accidents over a specified period. Thus, a random sample that is statistically representative of the selected collision types is specified for the special study. The typology also
relates the selected collision types to the overall accident database. If the projected benefits can be related to the variables defining the typology, an extrapolation can be made from the subset(s) studied to the entire accident population.

Such data collection was not within the scope of the current work. As an alternative, copies of the original police accident reports were reviewed. State computerized collision files do not contain all of the information represented on police reports, especially that described in the narrative and scene diagram. The five most prevalent collision types were selected for this review, and a sample of Michigan police reports was drawn to examine these collision situations in greater detail. The objectives of the review were (1) to assess whether the collision types developed from the computerized data accurately characterized the salient features of the pre-collision situation, and (2) to discover additional factors that might be associated with certain types of collisions. The collision types selected were driveway/parking collisions; single-vehicle, non-intersection collisions; same direction, non-intersection collisions; and two crossing paths collision types, those at signalized intersections and those at non-signalized intersections. In addition to the intrinsic interest of each of these collision types, the five selected subsets account for about two-thirds of all involvements in the typology for each of the four datafiles analyzed (Michigan, Washington, NASS, and CARDfile).

A total of 209 cases in the five categories was obtained from the Michigan State Police records, sampling randomly within a total of 32 strata. The strata, which were defined by driver age, land use, light condition, and the collision type scenarios, were used in order to ensure that there would be adequate representation of various factors of interest in the case study sample. A total of 40 cases of single-vehicle, non-intersection collisions were reviewed; 18 of crossing paths collision types, those at signalized intersections and those at non-signalized intersections; 59 in the driveway/parking category; and 37 cases of non-intersection, vehicles moving in the same direction. While the scope of the results summarized here (Massie, 1991) did not specifically include identification of the sequence of events, some of the information recorded suggests salient events.

5.1 Single Vehicle, Non-Intersection

Fifteen of the 40 cases examined involved hitting an animal—12 times it was a deer. An additional computer run on the Michigan file showed that animals are involved in 10% of all police reported accidents in Michigan, and that 44% of non-pedestrian, non-intersection, single-vehicle accidents involved striking an animal. Three-quarters of these collisions were in rural areas after dark. Other major categories involved striking a fixed object (32.5%), overturning (7.7%), and striking a parked vehicle (12.1%). Snowy/icy roadways and younger drivers were over-represented in each of these latter three categories.

Further statistical analysis was carried out for the single-vehicle accidents. As would be expected, nearly all pedestrian, pedicycle, and animal collision occur on the roadway, plus about half of the collisions with parked vehicles. Focusing on the single-vehicle collisions occurring off the roadway, the associated driver factors are alcohol impairment and younger male drivers. With regard to vehicles, light trucks are associated with these collisions. With regard to the roadway, slippery road surfaces, skidding, and curves are associated.
5.2 Crossing Paths at a Signalized Intersection

In 18 cases where the vehicles were crossing paths at intersections with functioning 3-color traffic signals, the most common problem was one vehicle simply proceeding into the intersection when the signal was red. Only two of these involved a legal right turn on red. In 12 of the remaining 16 cases the at-fault driver was clear, while in four cases both of the colliding drivers claimed to have a green light. Older drivers were slightly over-represented among the at-fault drivers.

5.3 Crossing Paths at a Non-Signalized Intersection

Fifty of the 55 cases of vehicles crossing paths at a non-signalized intersection involved one vehicle failing to yield at a stop sign, yield sign, or flashing red light. Two of the collisions involved a right-turning vehicle striking a vehicle waiting at a stop sign, and three of the collisions were at uncontrolled intersections (one because the traffic signals were inoperative). The failure-to-yield collisions tended to fall into two major categories—cases where the driver told the police that he or she had stopped but then pulled out and collided with an oncoming vehicle and cases where no claim of having stopped was reported in the police narrative. Older drivers were substantially over-represented in the former group, while younger drivers were over-represented in the latter group.

5.4 Driveway/Parking

Only one of the 59 cases which involved entering or leaving a driveway or parking place happened to take place at a parking spot. Of the 23 cases leaving a driveway, 12 involved turning left, 7 involved turning right, and 4 involved backing out. Of the 35 cases entering a driveway, 25 involved turning left, 9 involved turning right, and one involved backing in. Clearly, left turns are a particular problem in these collisions. Many of the accidents took place in driveways located adjacent to intersections, which may have contributed to the confusion leading to the collision. Almost 17% of the cases involved rear-ends of a car stopped or slowing to turn into a driveway. Another 15% involved an attempt to pass a vehicle turning into a driveway. Only 6 of the 59 cases were of the form that might be the most commonly expected: a vehicle backing from a driveway or parking spot into traffic.

5.5 Same Direction, Non-Intersection

Finally, of the 37 cases of vehicles colliding while traveling in the same direction away from intersections, 24 involved striking in the rear a vehicle in the same lane—usually one that was slowing down or stopped for a traffic light or to make a turn or due to general congestion. The remaining 13 cases involved sideswipe collisions of vehicles passing, changing lanes, etc. Eight of the 24 rear-end collisions involved chains of three or four vehicles. Wet or snowy pavements were far more common among the freeway rear-ends than among those occurring on other roads. For the same direction, non-intersection cases in general, both younger and older drivers were over-represented among the at-fault drivers in the sample.

The study of individual accidents is an essential element of the proposed method. However, the objective of these case studies is not to assign fault, but
to determine the physical sequence of events leading to the collision. Although the difference may be subtle in some situations, this approach may be both more realistic and more relevant. Of course, the results summarized here were obtained through a simple review of police accident reports from the State of Michigan, not actual investigations, and identification of the physical sequence of events was outside the scope of our work to date. The results are included here, in part, to evaluate the preliminary typology, and to suggest the nature of information that would be addressed by the proposed special studies. Individual police accident reports were not reviewed for 13 of the 18 categories that correspond to about 1/3 of all involvements.

From the summaries presented, it is fairly clear that each of the collision types reviewed is essentially different in character from the others, with two exceptions that will be briefly mentioned. Most obvious, of course, is that the subsets describing two vehicles on crossing paths at an intersection are quite similar for the signed as compared to signalized intersections. The significant difference here seemed to be the behavior of older drivers at signed intersections. Here, the older drivers often stop and then pull out inappropriately, while the younger drivers more often fail to stop altogether. Older drivers did not appear to be over-represented similarly at signalized intersections. Further study is necessary to verify this pattern. If it is consistent, it has important implications for the types of collision avoidance devices that would be effective.

However, the group identified as entering/leaving a driveway/parking space was rather mixed. Overall, most of the "driveways" were entrances to commercial establishment such as shopping malls, many of which were equipped with signals. Others were driveways in close proximity to an intersection. Only 6 out of 59 cases reviewed fit the expected situation of a vehicle entering or leaving a driveway or parking space. Consequently, the case review suggests that the typology should be revised to allocate most of this group to the respective intersection situations that they most resemble.

6 IDENTIFYING OPPORTUNITIES FOR INTERVENTION

Characterization of the physical sequence of events was not within the scope of our work to date. For the purpose of describing the proposed methodology, the statistical information will be used to form a hypothesized sequence of events. Under the proposed method, the hypothesized sequence of events would be verified, or replaced, on the basis of the special studies to establish actual sequences of events characteristic of each collision type. However, for this discussion, the hypothesized sequence will be used.

Also as an illustration, "obstacle detection technology" will be used as a proposed countermeasure for these single-vehicle collisions. The preliminary analysis presented here suggests the complexity of the actual accident experience. Impacts on the roadway with pedestrians, pedacyclists, and animals frequently occur at night. Time is the critical element to any collision avoidance strategy. In general, interventions taken earlier have a better chance of success. Nighttime suggests that attention/perception may have been a factor in these collisions, perhaps due to limited visibility or fatigue. For animal impacts, reaction time may have been the critical factor. For the most part, the impacts on the roadway tended to involve unimpaired drivers.
The situation for single-vehicle impacts occurring off the roadway is quite different. Here, it is more likely that a young, male, impaired driver is involved in a situation where the demands are increased by the nighttime environment, slippery roads and a curve. These circumstances suggest loss of control prior to leaving the roadway. Detection of a roadside obstacle at this point would appear to be of little benefit. To be effective, it would seem that a countermeasure must intervene prior to the loss of control.

7 DISCUSSION

The process of creating the most useful typology of collision situations to assist in the development of collision avoidance technologies is far from complete. The research team selected variables for the collision typology because it was expected that they would characterize those elements of the pre-collision situation that were pertinent to the identification of possible collision avoidance countermeasures. Accidents within a particular collision type are expected to be more similar in terms of potential collision avoidance countermeasures than accidents in a different category of the typology. Different assumptions as to the pertinent collision characteristics, perhaps to address a different class of technologies, would produce a different typology.

The review of individual police accident reports from the selected collision types showed that similar vehicle movements and relationships were involved in different collision types. For example, rear-ends of vehicles slowing in traffic occurred in both driveway-related and same direction, non-intersection collisions. Many of the accidents included in the driveway/parking group could be redistributed to the intersection categories in future iterations of the collision typology. From the point of view of technological interventions, a typology based on pre-collision vehicle movements and spatial relationships promises to be more directly applicable to research on collision avoidance through vehicle-based sensors.

Cases involving opposite direction collisions both at and away from intersections are less frequent but generally more serious collision situations. Crash avoidance devices or techniques that prevent these would potentially have a larger payoff than those which address less serious accidents. In general, collision severity should be included along with frequency, or prevalence, in ranking collision situations.

Analyses of a two-vehicle datafile would yield more detail about collision types. In such a file, the data from both vehicles in an accident, such as the ages of the two drivers or the movements of the two vehicles, would be brought together in one record per collision. This would permit analysis of the interaction of drivers of different age groups in various collision situations and of the specific intended pre-crash movements of each vehicle involved in an accident.

Finally, not only should new versions of the collision typology be developed, but they should be tested on additional datafiles and vehicle subsets. Most of the results presented were for passenger cars, although the most prevalent collision situations were shown to be somewhat different for heavy trucks. Also, the European accident experience may not be the same as in the United States. The same applies to the review of police reports. Most of the data used for this paper came from Michigan's collision files. Special studies need to be
conducted on other states, or countries, which differ from Michigan in terms of climate, topography, population density, and other factors.

The work presented was based on existing accident data. However, improvements are needed in data collection in order to better support collision avoidance work. Current coding of collision data emphasizes crashworthiness, not collision avoidance. Collision type, for example, is coded on accident reports for the first, or most, harmful event, which is not necessarily indicative of the pre-crash paths of the vehicles. Viable coding systems must be developed for reliably recording pre-collision information as part of the original accident report. This information is essential if the developing advanced technologies are to address real, as opposed to perceived, problems.

As discussed earlier, another data collection need concerns exposure estimates. Accurate information on vehicle mileage cross-cut by such factors as traffic density, road class, land use, and light condition is needed to gauge the risk of involvement in particular types of collision. Performing risk assessments would help in establishing priorities for competing countermeasures.

8 CONCLUSIONS

The design of collision avoidance technology and estimates of the potential effectiveness can be enhanced by a more accurate and detailed description of the actual collision experience. Expected benefits may not be realized if technology is implemented on the basis of an insufficient analysis.

Existing accident data can support a much more comprehensive analysis than has been conducted to date. Advanced technology offers the promise of collision avoidance countermeasures that were not previously feasible. These new opportunities require a new perspective on the accident experience. Problems that were viewed as "human errors" in the past are now opportunities to change the nature of the driving task to make it more compatible with the range of human performance. In order to develop such countermeasures, the accident experience must be analyzed to identify the most common situations that are amenable to the new countermeasures. Then these situations must be described in sufficient detail to identify the performance requirements of potential countermeasures.

This paper has described one possible approach to this analysis in the hope of stimulating discussion of these issues. The results presented are preliminary, and are only intended to illustrate the method. The method is iterative, and the results of any iteration are only as good as the initial assumptions and the available data.

While it is asserted here that there is much that can be accomplished with existing accident data, it is also clear that existing data will not provide all the information that will be needed to make informed choices among alternative countermeasures. In order to support a renewed interest in collision avoidance, changes are needed in the broad-based, statistically representative databases to better identify the essential characteristics of the pre-collision situation. In addition, an essential feature of the proposed method is that it provides a framework for the identification of specific subsets that can be targeted for special studies to collect additional information that cannot be collected in the
mass data. As described here, the typology provides a method for identifying specific collision situations of interests and for relating the special studies to the larger, statistically representative, database.

In closing, it must be emphasized that this is work that should be addressed immediately, before further countermeasure development occurs and before choices among countermeasures are made. The methodology needs discussion and refinement, and new priorities for data collection need to be developed. This work addresses the definition of the problem. If the problem is not sufficiently defined, the risk is greater that countermeasures may be developed, and even implemented, for problems that do not exist.

9 REFERENCES


Critical View of Traffic Safety Management
in a Developing Country; A Case Study of Jordan

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A CRITICAL VIEW OF TRAFFIC SAFETY MANAGEMENT IN A DEVELOPING COUNTRY; A CASE STUDY OF JORDAN.

ABSTRACT

In Jordan, according to 10 years of road accident statistics, there is a continuous fluctuation in the number of accidents, fatalities and injuries. However, this is despite the fact that there has been a great input into the reduction of the frequency and severity of road accidents. This problem is considered to have direct impact on the economy as it causes loss of valuable resources to the country.

This paper critically evaluates the existing situation by searching into 10 years of Police road accidents records and correlating such statistics to all responsible road organizations in the country through conducting a comprehensive survey by means of a questionnaire. The paper also describes the existing problems and the levels of ignorance which are practiced on a daily basis in dealing with road accidents all over the country.

This paper presents a new approach which can be used to specifically define the road accident situation in a typical third world country. A specific definition of the problem highlights the scale of the problem together with the need for developing a constructive program for the prevention and reduction of the frequency and severity of road accidents in developing countries.
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A CRITICAL VIEW OF TRAFFIC SAFETY MANAGEMENT IN A DEVELOPING COUNTRY; A CASE STUDY OF JORDAN.

ABSTRACT

In Jordan, according to approximately 10 years of road accident statistics, there is still a serious problem. However, this is despite the fact that there has been certain efforts directed towards the reduction of the frequency and severity of road accidents. This problem is considered to have direct impact on the economy as it causes loss of valuable resources to the country.

This paper critically evaluates the existing engineering for safety situation by considering 10 years of police road accident records and correlates such statistics to all responsible road organisations in the country through conducting a comprehensive survey by means of a questionnaire. The paper also describes the existing engineering for safety measures which are practiced on a daily basis to reduce road accidents all over the country.

This paper suggests a new approach which can be used to specifically define the road accident situation in a typical Third World Country. A specific definition of the problem highlights the scale of the problem together with the need for developing a constructive programme for the reduction and prevention of the frequency and severity of road accidents in developing countries.

INTRODUCTION

Many developing countries have a serious road accident problem. Recently, interest in road accidents in developing countries has begun and therefore, certain efforts in certain countries on many levels are being directed to reduce this worsening situation. However, it appears that the road accident problem is inevitable (in developing countries) despite an increasing awareness from the various governmental bodies who are responsible for reducing the frequency and severity of road accidents. It is also believed that the problem itself is underestimated by the developing countries and minimal progress would be achieved unless the country has adequate facilities to identify the problem, analyse it and solve it.

The work of the TRRL (1)[cited in 2], has clearly indicated the interaction of the vehicle, road user and the road environment factors which are involved in any one accident. However,
discussions through private communications (3) with some of the responsible personnel for road accidents from various third world countries, has indicated that the work of the TRRL (1) has indeed been misinterpreted.

This is the case in Jordan where almost all personnel who are responsible for the reduction and prevention of road accidents in the country, believe that at least 95% of all road accidents are a result of human error. Therefore, Such personnel who include politicians, engineers and local governmental officials are convinced that the best way to combat road accidents is by punishing the road user following any conviction. However, the road user is not educated sufficiently to realise what a conviction incurs.

The authors are aware of the work which was carried out by the TRRL (1), who assigned certain percentages to the three factors mentioned above. The above researchers concluded that road users have a predominant percentage contributing to any road accident and the road users' percentage alone which contributes to an accident amounts to approximately 65%. They also indicated that over 25% of road accidents are due to human error and the road environment together.

As a result of the above work, it can be concluded that the human factor exist (not as a single cause) in approximately 95% of road accidents. Similarly, the road environment exist (not as a single cause) in approximately 28% of road accidents. The above researchers emphasised the fact that the most effective remedial measures are not necessarily directly related to the main causes of accidents. As it is possible that for any particular accident, the road user fails to cope with a certain black spot in the road environment.

The misinterpretation of the assigned percentages on accident causes (in developing countries) is considered a myth when it has hindered the need for the investigation into other various equally important elements (the road environment and the vehicle) which when they are ignored, would ultimately encourage the road accident problem to mount to a chronic situation. Sabey and Staughton (1)[cited in 2], indicated that in the United Kingdom, the potential savings in reducing accidents and injuries might be of the order of 20% for the road environment, 25% for the vehicle and 33% for the road user and usage.

Typical of the above situation is Jordan, where the road user is assigned all the blame for the occurrence of almost all road accidents in the country. On the other hand absolutely no road safety education is incorporated in the education curriculum from the ministry of education at schools. However, there are numerous campaigns that are directed to the public through radio, television and newspapers almost on a daily basis. It is unfortunate to note that such campaigns are carried out with questionable significance in relation to the real road safety problems that the road user needs to be aware of. Moreover, such campaigns and slogans are never evaluated statistically or otherwise to investigate their effectiveness.

Therefore, it appears from the above that despite the fact that
the road user is assigned all the blame and the media continuously requests the public to drive with care, no systematic educational programmes have been implemented and geared towards educating the road user, and more importantly, no blame has ever been assigned to the road environment nor to the vehicle. This paper highlights the role played by the highway and traffic engineers in Jordan and evaluates their expertise, attempts and attitudes towards reducing the epidemic of road accidents.

THE EXISTING ROAD ACCIDENT SITUATION IN JORDAN

As a result of much emphasis placed on providing a road network to accommodate the considerable rate of traffic growth and to satisfy the needs of transporting goods and merchandise within Jordan, Jordan has experienced rapid road construction over a relatively short period of time. Consequently, this did not allow for careful and adequate planning of engineering for safety to take place on both the short and long term basis. The engineering for safety in Amman in particular and in Jordan in general leaves much to be desired when considering the road accident situation in the country. Where owing to high accident rates, the economic cost of accidents for the year 1987 was estimated at 196 million dollars.

In order to describe the accident situation in Jordan it must be pointed out that the population of Jordan is 3.4 million, mainly distributed over 97,000 square kilometer with 1.3 million living in densely populated Amman (the capital) followed by distributions in seven secondary cities within Jordan. There is a total of 5865 Km of paved roads which provides the basic road network. The seriousness of the road accident situation in Jordan may be described by comparing the fatality rate in Jordan with other corresponding rates of a number of countries. Smeed (4) have shown that for a group of countries a relationship between fatality per 10,000 vehicles and the vehicle ownership levels exist and can be represented on a log - log graph. Therefore, the following equations (statistically significant at one percent level) were derived for the fatality and casualty rates against the vehicle ownership levels for 30 developing and developed countries for 1986:

\[
F/V = 0.1339 \left( \frac{V}{P} \right) - 0.711
\]

\[
C/V = 0.1585 \left( \frac{C}{P} \right) - 0.324
\]

As shown in figure 1, the fatality rate in Jordan for 1986 was 41.4% greater than that suggested by the regression equation (A). Similarly, from figure 2 the casualty rate for Jordan was 119.4% greater than that suggested in equation (B).
Figure (1)

Figure (2)
Furthermore, figure 3 shows comparisons of persons killed per 100 million vehicles/kilometers against time for Jordan and Denmark. It can be seen from this figure that while the above rate for Denmark is steadily reducing, the rate for Jordan appears to be fluctuating with no indication of improvement. Figure 4 shows typical types of various accidents occurring throughout the country. It is interesting to note that the average percentage of pedestrian accidents over 10 years is 24%. It was also found that 65% of the pedestrian casualties are under the age of 15 years.

Comparisons of persons killed per 100 million veh./kms. Vs time for Jordan and Denmark.


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Moreover, the authors believe that in Jordan there is an underestimation of the road accident figures. The underestimation of the existing situation can mainly be due to the following:

1. Many accidents are not reported to the Police, the unreported accidents in Jordan for example were estimated to form 43% (5), and therefore if this percentage is ignored in the analysis it could almost certainly underestimate the scale of the problem and therefore serve, to obscure the way for searching for the genuine causes of the problem.

2. It can be clearly seen that near misses in Jordan are far greater than those occurring in the developed world. No statistics are available as yet to show this situation however, driving in Jordan could cause numerous near misses due to several reasons, which are not taken into consideration when comparisons are made with the developed countries.

It therefore seems likely, that conflict techniques could serve better to highlight the underestimation in such comparisons.

Finally, with respect to the above accident situation, it can be concluded that in Jordan there is a serious road accident problem.

METHODOLOGY

For the purpose of this paper, it was considered that the most accurate means of obtaining data regarding the role of the highway and traffic engineers was by using a questionnaire. The objectives of the questionnaire were to assess, evaluate and investigate the following:

1. The education and experience of the engineers who are responsible for the identification, classification and diagnosis of road accidents which occur within the vicinity for which they are responsible.

2. The essential road accident data and tools that they have available to them for identifying, classifying and diagnosing hazardous road locations within their responsibility of work.

3. The engineers' general attitude towards their role in reducing the frequency and severity of road accidents.

To ensure a comprehensive and a representative sample, the questionnaire covered the three main governmental bodies which encompass all the highway and traffic engineers that are responsible for all road networks in the country as follows:

1. Greater Amman Council (GAC) which is responsible for all road networks in the capital city (Amman). Figure 5 shows that approximately 54% of all accidents in Jordan (averaged over 10 years) take place on the GAC road network, while figure 6 shows that approximately 49% of pedestrian accidents take place on the GAC road network.

2. The Ministry of Public Works (MPW) which is responsible for all rural road networks which connect the various cities and...
villages together. This ministry is responsible for eight local councils distributed in Jordan. Approximately, 18% of the total accidents in Jordan take place on the MPW road network (figure 5).

(3) The Ministry of the Municipalities and Environment (MME) which is responsible for all the urban road networks within the various cities in Jordan through 173 municipalities distributed throughout the country. Approximately, 28% of road accidents take place on their road network (figure 5).

The above governmental bodies are solely responsible for all highway and traffic related development within their localities as shown above. Such responsibilities include the setting up of traffic signals, traffic lights, preparing traffic studies (traffic forecasts for specifications, controls and improvements), designing intersections, car parks, numbering roads and
streets, manufacturing, mounting and maintaining street furniture and various other related duties.

It can therefore be concluded that the above governmental bodies are the only bodies in Jordan which are responsible for engineering for safety.

**DATA COLLECTION**

The data obtained for the analysis of this paper was mainly based on the results obtained from the questionnaire and the police accident reports which have covered 10 years of accidents data that took place throughout the Jordanian road network. Prior to the submission of the questionnaire, various contacts were made to the above bodies to ensure that the distribution of the questionnaire covered all those who are working in the field of road accidents or any related road engineering fields encompassing road accidents.

In addition to the careful selection of the engineers, only 2% engineers (sample subjects) were considered for this study and all of which according to the questionnaire stated that they are responsible for promoting traffic safety through their jobs, consider road safety in their analysis and/or responsible for traffic engineering and planning in their departments.

It must be emphasised here that the 24 sample subjects constitute almost all of those who are responsible for engineering for safety in the country. Six of the sample subjects are employed by the GAC, 9 of the sample subjects are employed by the HPW and 9 are employed by MME.

For the purpose of analysing the results, the SPSS package was used to enable cross tabulations and analysis of the various questions asked together with an overall summation of results to be carried out.

**DATA ANALYSIS**

**EDUCATION AND EXPERIENCE.**

The questionnaire has shown that 100% of the responsible engineers possess a bachelors degree in civil engineering, 17% possess a masters' degree in traffic engineering and planning and one doctorate in civil engineering. Therefore, all engineers are at an adequate level of road accident skill development. This general engineering qualification (with respect to the field of road accidents) is further supported with a number of years of experience obtained in traffic engineering and planning with a mean of 3.5 years and a highway design and road construction with a mean of 4.5 years. However, no experience was obtained whatsoever in the field of road accident analysis as stated by the sample subjects.

It was hoped that certain training courses in the field of road accidents had been attended due to the nature of their employment and their inherent responsibilities. However, the questionnaire has revealed that no training courses had been attended
in the field of road accidents by any member of the sample subjects. It is very important to note that owing to the multi-disciplinary nature of the field of road accidents and the relatively modern academic development in this field, particularly in developing countries, it can be suggested that during the academic life of the mentioned engineers, they have barely touched upon the field of road accidents. Therefore, comprehensive training courses geared towards effective low cost remedial measures in relation to engineering for safety is an absolute necessity to initiate the application of the appropriate knowledge which without, the problem will not be solved. It appears that the sample subjects require greater experience and expertise to deal adequately with engineering for safety in Jordan.

AVAILABILITY OF ESSENTIAL DATA.

It cannot be over emphasised that the accident data collection and analysis are the absolute basis in any attempt made for appropriate accident reduction and prevention. The number of accidents (occurring throughout the road network), number of casualties, accident severity and other related data are necessary to be held by the road engineering bodies for the identification of hazardous road locations. Such information should form the road accident data bank (ADB). On the other hand, information on traffic volumes, road curvatures, type and magnitude of junctions, road surface type and texture, road furniture and other related parameters should also be available to the governmental engineering bodies and ultimately stored in their road data banks (RDB's).

Both the road ADB and the RDB would enable the road accident analyst to produce accident rates in terms of million of vehicle kilometers travelled along road sections, million of vehicles entering intersections and various other related important accident rates that would involve highway geometrics in order to be able to provide measures of exposure and rank sites according to a list of priority for remedial measures. Jacobs (2) have claimed that road accident data collection and analysis in developing countries are carried out predominantly by the police force. Somnemitr (6) has pointed out that in Thailand due to the existence of too many kinds of accident report forms, the data collection systems cause repetition, confusion and complexity. In Jordan the collection and analysis of road accident reports are carried out totally by the police force, which agrees with the findings of Jacobs. The fact that the Jordanian police is the only body in Jordan to collect accident reports, makes it easier for those who are concerned with the road accident analysis to obtain such reports (unlike the situation observed by Somnemitr). The analysis of such reports by the highway and traffic engineers for example, could be carried out successfully, provided that the police reports are accurate and adequately
An investigation (7) into the Jordanian road accident police reports revealed that almost 70% - 75% of these reports could give a very good description and information related to the reported accidents and can adequately be used along with information obtained from the RDB's to detect black spots, black sites and black areas in urban and rural areas in the whole of the Kingdom.

From the above, it is evident that no progress can be made in the field of engineering for safety, unless the accident reports are in existence and can be considered the main tools for the highway and traffic engineers provided that they have the expertise in using such invaluable data.

The results of the questionnaire are shown in table 1. It is apparent that the percentage of the police reports received by the engineering governmental bodies is clearly inadequate. (i.e.

Table 1 also shows that 5 out of 24 sample subjects (21%), claimed to have ADB’s in their departments. This indicates that alternative means of data collection may be in existence. However, a further consultation to the above bodies confirmed that no alternative means such as conflict techniques, or any other source of obtaining road accident data used to form such ADB’s. Consequently, one may infer that the sample subjects who believe that their bodies had ADB are in fact unaware of the capacity, function and requirements that indeed constitute the accident data bank.

Table 1 also shows the results concerning the existence of the RDB’s. It was found that, 29% of the sample subjects indicated that they have RDB’s, however, 30% of the sample subjects stated that their RDB’s are stored on computers. Further, 38% of the sample subjects indicated that they have road data banks for some roads only. Although the RDB’s appear to be in existence, private communication has indicated that the RDB’s are unlikely to contain a viable road inventory. This is due to the necessity and complexity of the amount of the data which is required, in order for it to be stored and related to the various components of road characteristics, traffic counts and volumes and the previously mentioned ADB’s.

It was also found that of all the sample subjects, 65% have influence over decisions that are made in their departments concerning road accidents, 70% have in their departments existing plans to improve road safety and 71% are committed to their prepared plans and allocated budgets to carry out engineering for safety successfully.

To be able to have influence over decisions and commitment to prepared plans for engineering for safety, can be considered a useful tool to the highway and traffic engineers that can be utilised productively to ensure the development of engineering for safety. However, a cross tabulation of the results have counted those engineers who have influence over decisions and yet have answered no for the existence of ADB and who also do
not receive any police accident reports. The total number of such engineers was 11 out of 24 (46%). A further cross tabulation of the eleven engineers revealed that 7 of the engineers (64%), also have influence over budgets in their departments. It is unfortunate however, that engineering for safety measures are directly related to the availability of data (ADB’s and RDB’s) to any highway and traffic engineers concerned with engineering for safety. Therefore, the accuracy and quality of the decisions that are made can be described as good as the insufficient data that they receive.

ATTITUDES TOWARDS RESPONSIBILITY FOR ENGINEERING FOR SAFETY.

Attitude as a concept is very difficult to define and evaluate and has in the past been ignored as a definite problem in the improvement of the road accident situation, particularly in developing countries.

For the purpose of this paper the authors have defined attitude as the sample subjects’ commitment towards their responsibility, role and requirements for promoting engineering for safety in their governmental bodies. Undoubtedly, attitude is of extreme importance, especially when predominant sample subjects are vague or even evasive of their ultimate responsibilities. This is evident from the fact that success or the lack of it, in determining the problem, was attributed to the lack of funds and qualified personnel to deal with road accidents in their departments.

The majority of the sample subjects (73%), believe that their departments are not doing a good job in contributing to the reduction and prevention of road accidents. Furthermore, 23 out of 24 sample subjects (96%), have indicated the lack of funds. All of the sample subjects indicated the lack of qualified personnel to deal with road accidents in their departments.

In the authors’ opinion, these results imply that the sample subjects have a positive attitude at least in acknowledging that their departments have a greater role to play in engineering for safety. They also acknowledge that engineering for safety requires a greater budget owing to the extent of the problem and sufficient experienced staff to deal with it. However, it can also be argued that since the sample subjects have inadequate ADB’s and RDB’s together with a considerable lack of experience in the field of road accidents, their answers to requiring a larger budget and additional experienced employees to deal with engineering for safety can only be regarded as an excuse for evading responsibility.

This is particularly true since accident reduction and prevention are not the only justification for the highway and traffic management measures. Other justifications, such as, dealing with peak hours and congestions, savings in journey time, operating and locating traffic signals and signs and the convenience of a particular road users group, which may result in a valid measure being implemented by the highway and traffic engineers. This could increase the number of road accidents. Therefore, the
consequence of such measures should be known and considered before deciding on them by the highway and traffic engineers. In their answers to the question concerning whom they believe to be responsible for engineering for safety in Jordan, 12 out of 24 sample subjects (50%), indicated that the police department should be the only body responsible for the road accident situation in the country. Two out of the 24 sample subjects (8%), assigned the sole responsibility to the Universities in Jordan. Two out of 24 sample subjects (8%), indicated that the ministry of transport should have the sole responsibility. None of the GAC sample subjects (approximately 54% of road accidents take place on their road network) admitted any responsibility. Six out of the 24 sample subjects (25%), claimed that the MEF and the MME should be responsible for the road accident situation in the country.

It is interesting to note that one sample subject who claimed to be receiving 50% of the police accident reports stated that no one should be responsible for road accidents in Jordan. The attitude regarding who should be responsible for engineering for safety presented by the sample subjects indicates that the majority are unaware of the fact that it is themselves (sample subjects) who should be responsible for engineering for safety. The authors acknowledge the efforts of the sample subjects and the heavy burden placed upon them due to the rapid urban and rural development, which gives rise to the need for road accident analysts to work in conjunction with the sample subjects. The authors are also in agreement with the idea of creating a national committee with a qualified personnel to deal with the road accident problems as is the case in many developed countries. This however, does not alleviate the responsibility in engineering for safety by such sample subjects particularly as they are the ones who are responsible for safe traffic flow and they are mostly traffic engineers, planners and decision makers in these areas.

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

It is obvious that the road accident situation in Jordan requires immediate attention. This paper has highlighted that the absence of experience and appropriate knowledge of road accidents by the sample subjects is an indication that engineering for safety is largely ignored. The insignificant percentages of received police accident reports by the sample subjects and the inadequacy of the ADB’s and RDB’s in the departments of all sample subjects together with the absence of qualified personnel employed solely for the purpose of road accidents analysis, is yet a further indication that engineering for safety is largely ignored. Huhlrad (8) through field studies has indicated that there is a great need for knowledge and know-how in developing countries in order to deal with road safety problems.
The need for a greater budget (as called by the sample subjects) due to the limited financial resources should not be considered a valid justification for the do nothing policy adopted in engineering for safety. Jacobs (9), indicated that it is financially difficult for developing countries to deal effectively with road safety problems. However, he also indicated that under such circumstances, any measures that are introduced should be carefully appraised and an assessment made to their relative effectiveness.

The majority of the sample subjects seem to be aware of their departments not doing a good job in reducing road accidents. It also appears that the general attitude of the sample subjects towards their professional role has given rise to unclear boundaries of responsibility. This in turn implies that at management level a systematic approach is required to define the boundaries of responsibility and clarify the role of the sample subjects in reducing the frequency and severity of road accidents.

**RECOMMENDATIONS**

It is recommended that the three principal elements that contribute to the creation of an accident namely the road user, road environment and the vehicle should be given equal importance for the reduction and prevention of road accidents. The role and responsibility played by the corresponding governmental bodies (in developing countries) concerning the above elements must be clearly defined.

The road accident numbers and rates (i.e. number of accidents, injuries, fatalities, etc.) should not be the only way to describe the accident situation in any developing country. The accident situation in developing countries should also be described and evaluated in terms of the various management strategies that are followed in engineering, education, enforcement and evaluation of the overall accident situation. Unless the management of the aforementioned elements are clearly defined, the road accident statistics will only give misleading conclusions regarding the accident situation in developing countries.

This paper suggests a methodology by which the management of engineering for safety can be evaluated in a developing country. The methodology presented by the questionnaire, evaluates the role played by the highway and traffic engineers and the various tools that are available to them in order for their role to be clearly defined to ensure efficiency.

Similar methodologies should be adopted to evaluate the role played by the corresponding governmental bodies for educating the road user, inspection of vehicles, enforcement of the law and the overall evaluation of the road accident situation. Systematic approaches of various management strategies concerning road accidents have been forwarded by several researchers (10,11,12,13,14), which are of extreme importance and value if they are implemented successfully. However, due to the complex nature of the multi-disciplinary field of road accidents, the general attitude towards the importance of this field and the
coordination required of the various related responsible governmental bodies, in addition to the scarce financial resources, makes the implementation of such approaches in developing countries an incredibly difficult task.

Therefore, it can be suggested that in the process of allocating loans and financial aid to developing countries (through various agencies such as the World Bank) to aid their development in their transportation sector, due consideration should be given to the development required in the field of road accidents. Also, consideration should take into account the knowledge and experience that is already in existence in the developed world in several institutions such as INRETS (France), VTI (Sweden) and TRRL (U.K.).

As mentioned above, the complex nature of the field of road accidents and the need for effective low cost remedial measures of all factors contributing to road accidents, call for considerable long term systematic management. It is recommended therefore, that approved native researchers in road accidents should be involved at management level to monitor such efforts and ensure successful development.
<table>
<thead>
<tr>
<th>Information obtained from the sample subjects</th>
<th>Govt. Eng. Bodies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GAC</td>
</tr>
<tr>
<td>1. Responsible for promoting safe traffic flow and / or responsible for traffic engineering and planning.</td>
<td>6</td>
</tr>
<tr>
<td>2. Percentage received of police reports.</td>
<td></td>
</tr>
<tr>
<td>0%</td>
<td>5</td>
</tr>
<tr>
<td>25%</td>
<td>1</td>
</tr>
<tr>
<td>50%</td>
<td>-</td>
</tr>
<tr>
<td>3. Existence of ADB.</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>2</td>
</tr>
<tr>
<td>No</td>
<td>4</td>
</tr>
<tr>
<td>4. Is the ADB stored on computers?</td>
<td></td>
</tr>
<tr>
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<td>1</td>
</tr>
<tr>
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<td>5</td>
</tr>
<tr>
<td>5. Existence of RDB.</td>
<td></td>
</tr>
<tr>
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<td>2</td>
</tr>
<tr>
<td>No</td>
<td>-</td>
</tr>
<tr>
<td>For some roads only</td>
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</tr>
<tr>
<td>6. Is the RDB stored on computers?</td>
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</tr>
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<td>3</td>
</tr>
<tr>
<td>No</td>
<td>3</td>
</tr>
<tr>
<td>7. Influence over decisions in road acc. matters.</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>4</td>
</tr>
<tr>
<td>No</td>
<td>2</td>
</tr>
<tr>
<td>8. Existing plans for road safety.</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>4</td>
</tr>
<tr>
<td>No</td>
<td>2</td>
</tr>
<tr>
<td>9. Commitment to plans and allocated budget.</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>4</td>
</tr>
<tr>
<td>No</td>
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10. Road safety works are dictated by:

<table>
<thead>
<tr>
<th></th>
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</tr>
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<tr>
<td>Urgent needs</td>
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<td>3</td>
</tr>
<tr>
<td>Social pressure</td>
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<td>3</td>
</tr>
<tr>
<td>prepared plans</td>
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<tr>
<td>other reasons</td>
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11. Department influence over budget.

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<td>4</td>
<td>3</td>
<td>8</td>
<td>15</td>
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</table>


<table>
<thead>
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<th>-</th>
<th>-</th>
<th>1</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>5</td>
<td>9</td>
<td>9</td>
<td>23</td>
</tr>
</tbody>
</table>

13. How many staff dealing only with road accidents?

| None | None | None | 0 | 0 |

14. Do you think that your department is doing a good job in reducing road accidents?

<table>
<thead>
<tr>
<th>Yes</th>
<th>1</th>
<th>3</th>
<th>2</th>
<th>6</th>
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<td>4</td>
<td>5</td>
<td>7</td>
<td>16</td>
<td>73</td>
</tr>
</tbody>
</table>

15. Receive 0% acc. reports and have no ADB, BUT have influence over decisions.

| 1   | 5 | 5 | 11 | 46 |

16. Receive 0% acc. reports, have no ADB, BUT have influence over decisions and influence over budget.

| 1   | 1 | 5 | 7  | 29 |

17. Receive 0% acc. reports, have no ADB, answered yes for the existence of RDB and/or yes for RDB for some roads only, BUT have influence over decisions.

| 1   | 3 | 7 | 11 | 46 |

18. Receive 0% acc. reports, have no ADB, answered yes for the existence of RDB and/or yes for RDB for some roads only, BUT have influence over decisions.

| 1   | 3 | - | 4  | 17 |
REFERENCES


2. G.D.Jacobs, "Road accident investigation in developing countries". Transport & research laboratory, Crowthorne.


14. F.O.Kemp and B. Soesilo,"Managing Human Resources of Road Organisations In Developing Countries". 13th ARRB / 5th REAAA, 1986
Comprehensive Safety Management

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Senior Partner
Ergotrans
United Kingdom
The aim of traffic safety science is to reduce the total community costs of road traffic accidents. The objective in the U.K. is to reduce casualties by one third by the end of this century (based on the average levels of casualties between 1981 and 1985) (1). However, as MacKay has pointed out (2), taking account of current traffic growth forecasts, it will be necessary to achieve personal safety and traffic safety indices of less than half those currently operating in countries which already have levels of vehicle ownership matching projections for the U.K. in 2000 AD. Hence, the purpose of this paper is to explore the possibilities of a more fundamental, comprehensive and integrated approach to traffic safety management than hitherto.

The paper opens by outlining a hierarchy of four goals relating to the number, severity, effects and consequences of road traffic accidents. Practical organisational and operational factors are discussed from the standpoint of the Local Authority having statutory responsibility for road safety. The other "actors" are identified (e.g. road users and vehicle designers) and their differing perspectives and aspirations are outlined, leading to a discussion of the possible courses of action open to these other actors. This is followed by an examination of the goals previously identified, seen from the viewpoint of the Local Authority. This in turn suggests a review of a variety of policies currently available to a U.K. Local Authority, ranging from land use decisions at the strategic level to the selection of "repairable" street furniture at the tactical.
The problems of analysing and evaluating widely different policies are examined and the paper concludes by outlining the concept of Comprehensive Safety Management as a basis for the development of the Road Safety Plans recommended in the Road Safety Code of Good Practice (3). This proposal can be regarded as a development of Urban Safety Management (4), and reflects the view expressed by the Trinca Group that as "many nations are approaching the end of the conventional agenda ... improvement in traffic safety might tend to come from measures outside the traditional safety field"(5).

References
   Transport Studies Unit. Oxford University. January 1990
   London 1989
1. INTRODUCTION - CHAPTER 1

The current road traffic safety objective in the U.K. is to reduce casualties by one third by the end of this century (based on the average level of casualties between 1981 and 1985(1). However, as MacKay has observed (2), taking account of current traffic growth forecasts, it will be necessary to achieve personal safety and traffic safety indices of less than half those currently operating in countries which already have levels of vehicle ownership matching projections for the U.K. in 2000 AD (e.g. Sweden and the Netherlands). Clearly, this represents a considerable challenge. At present, we have available a wide range of safety techniques, however they are not always employed in a planned, co-ordinated manner.

In 1988 the Trinca Group noted that "traffic safety is a very young science. As a discipline it is still evolving at the confluence of the more traditional disciplines of medicine, engineering, law, psychology, economics and mathematics" (3). Thus it may possibly lack the more rigorous methodology of the established sciences. Hence the purpose of this paper is to explore the possibilities of a more fundamental, comprehensive and integrated approach than hitherto. While this paper attempts a broad treatment of the subject, the perspective is essentially that of the local authority having statutory responsibility for road traffic safety.

Understandably, traffic safety has evolved as a remedial, rather than a preventive activity. However, "an accident is a rare, random, multifactor event" (4). Thus "ex post facto" measures will inevitably have only a limited effect. For instance, "Three-quarters of the reported casualties in road accidents in Great Britain occur in towns and cities. Accidents that cluster at particular sites can often be reduced or prevented by treating these sites individually, but more than half the accidents in towns and cities are too widely scattered to be reduced by such treatments" (5). The recently published "Guidelines for Urban Safety Management" were produced in order to deal with this situation, but even the measures proposed in this publication are only likely to produce "Reductions of 10% beyond those achieved by traditional accident reduction and prevention programmes"(6). Thus we may need to examine more radical proposals if the current safety objective is to be achieved.
One possible method is to adopt and adapt the military technique of the Appreciation. An appreciation is an orderly review of a problem, based on the available information, culminating in a statement of the measures recommended to meet it. The accepted sequence is to define the aim, describe the factors which might affect the attainment of the aim, examine the possible courses open, leading to a recommended course of action. The remainder of this paper endeavours to follow this sequence of reasoning.

2. THE PROBLEM - CHAPTER 2

It is possible to regard society as a system of activities linked by communications. These communications can be provided by a variety of methods, ranging from satellite broadcasting to walking. Thus, highway communications should be seen as one part of the total communications system. Road traffic safety is concerned with one adverse consequence of highway communications and its function is to ensure the safe passage of persons, goods and vehicles through the highway environment (defined as that part of the total environment which is within the sensory range of the highway user). The highway environment can be divided into two elements - static (natural and built) and moving (other road users). Thus our problem relates to the unintentional contacts of road users with the static and moving environments. The road user has to operate as part of a competitive, largely uncontrolled system which has an unregulated input, with divided, unclear responsibilities and inadequate communications, carrying a changeable but seemingly increasing load, working in a variable environment together with a multitude of other users of varying abilities and behaviour, many controlling over-powered vehicles. Hence, errors, and consequently, accidents are only to be expected. The Trinca Group noted that "When measured in terms of years of life lost, traffic accidents rank with cancer and heart disease as one of the most frequent causes of death in industrialised countries"(7). Hence, it is an issue which impinges upon the whole of society. However, in order to improve our understanding of the problem, it is necessary to attempt to identify and classify the actors concerned and the following section suggests a possible approach.

3. THE ACTORS - CHAPTER 3

The actors involved in traffic safety can be broadly classified as follows:

(a) Pre-impact  
   (i) Providers
   (ii) Users
   (iii) Regulators

(b) Post-impact  
   (i) Rescuers
   (ii) Repairers

                      Fire and Ambulance Services
                      Personal
                      Medical Services
                      Social Services
                      Property
                      Vehicle Engineering
                      Highway Engineering
Considering in more detail the Pre-impact actors, the providers create the service, the users consume it and the regulators control it. Our concern relates to the planning and operation of this public service, land use/communications system. Friend and Jessop described the public planning process as a "continuing dialogue between a government system and a community system" (8). Employing this distinction, it will be seen that each fulfills the following roles:

**Governmental System**
1. Provider of the highway system
2. Regulator of non-highway communications
3. Regulator of land use and highway communications

**Community System**
4. Provider of non-highway communications
5. Provider of highway vehicles
6. User of the highway

Within both the Governmental and Community systems "safety" is never the paramount consideration, otherwise nobody would ever move anywhere as any movement always involves some risk of impact. Safety may be important, but it is always subordinate to other aims. For example, vehicle manufacturers are primarily concerned with commercial motives while the road user is usually concerned with minimising the perceived cost of travel. While both these actors obviously have a concern for safety, it is inevitably but one of a number of considerations.

Adopting the stance of the local authority with responsibility for road safety (i.e. the County Council), it is next necessary to identify the various factors which will affect any traffic safety programme. Obviously these will vary in each case, but some typical factors are as follows:

(a) The area under consideration
(b) Current policies
(c) Current problems
(d) Future problems
(e) Resources available
(f) Organisational structure
(g) Timescale (planning and execution)

Identification of these factors leads on to the next stage of the analysis which concerns the various courses open to the authority. This stage is at the core of Comprehensive Safety Management.

4. COMPREHENSIVE SAFETY MANAGEMENT - CHAPTER 4

The aim of traffic safety science is to reduce the total community costs of road traffic accidents. These costs depend upon the number, severity, adverse effects and adverse consequences of accidents. Hence it is possible to define the following four traffic safety goals:
(1) To reduce the number of accidents
(2) To reduce the severity of accidents (the amount of kinetic energy consumed upon impact)
(3) To reduce the adverse effects of accidents (damage to persons and property)
(4) To reduce the adverse consequences of accidents (post-impact management)

A road traffic accident may be regarded as an incident in a chronological sequence of events, beginning with the decision by one or more persons to make a journey and ending with the completion of the rehabilitation of the victims, together with the repair of the property damaged. It would therefore seem reasonable to order the available counter-measures in a similar manner starting with the event which initiated the causal sequence (the decision to communicate). Hence, the following sequence is offered as a series of logic gates. It can be viewed as a "Safety Menu" or a list of possible actions which can contribute towards the aim of traffic safety. While the list endeavours to be both comprehensive and consecutive, it should only be regarded as an initial, tentative submission at this stage. Hopefully, it is a form of check list that can be employed by any actor with a concern for safety. However, irrespective of the actor concerned, the intention should always be to commence analysis as early in the "menu" as possible.

(1) Measures to reduce the number of accidents
   - (a) Communications systems policy
      (i) Encourage non-mobility (e.g. telecommunications)
      (ii) Encourage non-highway mobility (e.g. rail and LRT)
      (iii) Encourage un-powered mobility (e.g. walk and cycle)
      (iv) Discourage powered mobility by policies relating to the vehicle population (e.g. taxation)
   - (b) Travel mode policy
      (i) Discourage motor cycle and car use (e.g. parking policy)
      (ii) Encourage taxi and bus use (e.g. bus lanes)
      (iii) Consolidate commercial vehicle use (e.g. transit warehouses)
   - (c) Travel time policy
      Encourage peak spreading during daylight and darkness
   - (d) Route policy
      (i) Definition of road hierarchy
      (ii) Diversion of extraneous traffic to minimise exposure
   - (e) Evasion policy
      Designed to minimise conflict between road users and:
      1. The static environment
         The aim of this policy is to prevent a moving unit (defined as a pedestrian, cyclist or vehicle) coming into unintended contact with the static environment by:
         (i) Geometric design (horizontal and vertical alignment and cross section)
         (ii) Lighting
         (iii) Surface water drainage
         (iv) Surfacing
         (v) Traffic regulation (e.g. speed limits)
(vi) Traffic information (e.g. direction signing)
(vii) Alteration of the remainder of the controllable environment (that part of the environment which can be influenced by the action of the local authority) leading to the modification of user behaviour
(viii) Improved user training (e.g. skid training)
(ix) More responsive vehicle design (e.g. steering, braking)

2. The moving environment

The aim of this policy is to segregate moving units from each other in time or space by:

(i) Physical means (e.g. dual carriageways)
(ii) Traffic regulation (e.g. traffic signals)
(iii) Traffic information (e.g. "Trafficmaster")
(iv) Alteration of the remainder of the controllable environment leading to the modification of user behaviour
(v) Improved user training (e.g. motorway driving)
(vi) More responsive vehicle design (e.g. acceleration)

(f) Land Use Policy

To minimise the additional moving units/distance generated by new development

(2) Measures to reduce the severity of accidents

(a) Speed control (vehicle design and regulation)
(b) Weight control (vehicle design and regulation)
(3) Measures to reduce the adverse effects of accidents by:

(a) The design and construction of the accessible static environment (e.g. "frangible" street furniture)
(b) The design and construction of the moving environment (the offensive and defensive characteristics of vehicles)

(4) Measures to reduce the adverse consequences of accidents by:

(a) Improved incident control and first aid treatment
(b) Improved operation of the emergency and recovery services
(c) Improved operation of the hospital and rehabilitation services
(d) Improved vehicle design to reduce the cost of repair
(e) Improved design of the accessible static environment to reduce the cost of repair

Each of the headings listed above are necessarily brief. While some of them need little amplification, others, for example, questions of communications policy and the definition of a hierarchy of roads, require considerable explanation and expansion to do them full justice.

The suggested taxonomy sets out to construct a logic diagram which attempts to identify and classify possible measures in a hierarchy working from the top down in a causal sequence. Deliberately, at this stage, it does not identify the actors involved (e.g. highway authority, vehicle designer, road user) as they will vary in each case, sometimes overlapping, sometimes conflicting. Obviously, some of the measures identified will be more feasible than others. Nevertheless, questions of practicability depend on prevailing attitudes which are transient rather than absolute. The list includes a wide range of measures, some of which may not always be associated with traffic safety (e.g. land use decisions and repairable street furniture). While some are of proven merit, others may bring more dubious benefits. However, it is submitted that unless all of them are presented for examination, it is possible that some novel, and perhaps radical, solutions, could be overlooked. In an ideal world, to obtain the maximum benefit, all
of these policies (and no doubt others besides) would need to operate together in a concerted manner. Unfortunately, we must acknowledge that for each safety policy, there exists a contrary "unsafety" policy. Hence, the real world situation is likely to comprise a mixture of "safety" and "unsafety" policies co-existing together. Therefore, the success of any proposed "safety" policy is likely to depend on its relationship with the two existing groups of "safety" and "unsafety" policies.

It will therefore be apparent that a number of policy conflicts can occur. These can take place at five different levels:

1. Between a safety policy and a national policy. For example, endeavouring to restrain the growth of the vehicle population will have an effect on the national economy.

2. Between a safety policy and another policy of the local authority. For example, minimising trip length could well conflict with other planning policies.

3. Between a safety policy and a transportation policy. For example, the relationship between the operating speed and capacity of a highway.

4. Between safety policies. For example, consolidating commercial vehicle operation could lead to fewer but heavier vehicles with a consequent increase in the amount of Kinetic energy consumed in an impact. Similarly, lighter vehicles could be less crashworthy.

5. Between a safety policy and user behaviour. For example, reducing vehicle density could enable the remaining traffic to travel faster thus possibly increasing the severity of accidents. Obviously, all those possible conflicts need to be borne in mind when considering the feasibility of any safety policy.

The next stage is to divide the range of measures in the "Safety Menu" into two sections:

(1) Policies which we can influence (e.g. land use decisions and traffic regulation orders)

(2) Policies which are under the control of other actors (e.g. vehicle design and manufacture)

As it is likely that this second category will be the biggest, we should next consider the likely actions of these other actors, on the assumption that our existing policies remain unchanged. We can then examine the policies which we can influence in the light of these considerations.

In the U.K. a local authority has powers to prevent, permit, persuade, promote and provide. Nevertheless, these powers have to be exercised within the prevailing legal framework as interpreted by the ruling political thinking which will in turn determine the financial resources which are made available for traffic safety. The guidance given in the Road Safety Code of Good Practice (9) repeated the assumptions contained in the Government's 1987 Review of Road Safety Policy (10), the first
two of which stated that:

(a) There will be no increase in overall resources available for road safety and

(b) There should be a presumption against measures which involve the imposition of legislative controls on road users except where unavoidable.

It could be that these assumptions prove to be too restrictive and hence incompatible with the Government's stated objective. Even so, setting aside this caveat, it should be possible to identify a number of policies which may then be assembled into alternative but internally supporting packages which can then be evaluated. The precise form and content of the analysis outlined above will obviously depend upon the purpose it is to be put to. For example, an analysis which is to form the basis of a Road Safety Plan (11) would be likely to at least touch on all the items mentioned whereas one which is to assist in preparing a Local Area Safety Scheme (12) will be likely to concentrate more on Items (1)(d) to (3)(a). However, no matter what the purpose of the analysis is, it will be apparent that it will prompt a review of a whole range of existing policies which the authority currently operate. This is consistent with the comprehensive corporate approach recommended in the "Road Safety Code of Good Practice" (13).

5. EVALUATION - CHAPTER 5

Evaluation will be likely to involve the comparative assessment of a number of policies together with a number of specific projects. While this paper has attempted to identify, assemble and classify a range of measures which, "a priori" would appear to have some value, it is not so easy to estimate their merit with any certainty. As Haight stated (14) "One sees time and again large sums of money spent (on road safety) in industrialised countries, the effect of which is so difficult to detect that further sums must be spent in highly sophisticated evaluation techniques if one is to obtain even a clue as to the effectiveness of the intervention". While the effectiveness of a number of established, tactical techniques has been established with some degree of confidence, the value of more novel strategical measures remains open to question. Hence any method of evaluation must acknowledge the existence of uncertainty which suggests the need for some form of risk assessment. We therefore need some way of expressing the range and cost of uncertainty attaching to particular policies or projects. On the assumption that the results of the analysis are presented in a numerical form (either as the output of a mathematical model or a scoring system derived from a verbal model), the following three "indices" are offered for consideration:

1. Uncertainty Index
   Relates the range of possible answers to the mean.
   In other words, highest minus lowest divided by the mean.
   A low index indicates little uncertainty.
2. Cost of error Index
   The cost of amending a project divided by the original cost of the scheme. A low figure suggests a relatively cheap error.

3. Risk Index
   Uncertainty Index multiplied by Cost of error Index. A measure of the risk involved in pursuing a particular option. A low figure suggests comparatively little risk.

While the above indices may give some guidance concerning the risk attaching to particular projects, it is less easy to assess the risk related to specific policies as the overall consequences of policy decisions are often more widespread and delayed.

Evaluation should be followed by implementation but, as this paper has indicated, some policies which may emerge could be relatively untested. Hence, as the Trinca Group rightly emphasized "traffic safety programs should, wherever possible, be pilot tested before large-scale implementation is attempted" (15).

6. CONCLUSIONS - CHAPTER 6

The proposals contained in this paper are not intended to be prescriptive but rather to stimulate discussion of a set of general principles which may be of help in the management of traffic safety. While the paper has attempted to identify and classify the range of safety policies, the sequence in which they are considered and applied is of equal importance. Comprehensive Safety Management can be regarded as a logical development of "Urban Safety Management" (16) and the "Safety Audit of Highways" (17) and reflects the view expressed by the Trinca Group that as "many nations are approaching the end of the conventional agenda....improvement in traffic safety might tend to come from measures outside the traditional safety field" (18).
REFERENCES


10. Reference 1 P 2.


12. Reference 5 P 27.


15. Reference 3 P 59.

16. Reference 5 P 17.


18. Reference 3 P 33.
Future of Road Traffic Management
Urgent Global Harmonization Will Affect All Governments

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The Future of Road Traffic Management:
Urgent Global Harmonization will affect all Governments
by Arthur R. Olin

Abstract

In a global sense most national practices, legal and technical, in the field of Road Traffic Regulations, are related to the UN Conventions on Road Traffic. In the process of preparing, or revising, Conventions of this complex nature, it is obvious to all professionals involved that the only possibility to reach a reasonable level of agreement, as to the final shape of the documents, is to make them quite wide in their significance. In addition, the judgment of the Conventions on the national levels are sometimes misinterpreted as a consequence of poor or none existing information on the objects in view during the preparatory work.

This in turn has resulted in remarkable and scarcely noticed differences in applications, also in between nations who ratified the Conventions. Several basic functions in the field of Road Transportation are suffering from the lack of a reasonable harmonization: capacity and general level of service, safety and costs for operation, supervision and the over all transport cost itself.

For instance, Traffic Control Devices, quite different in shape or color, have the same meaning in neighboring nations. In other cases symbols, or even complete traffic signs, identical in shape and color, have different or contradictory meanings. Also some nations use 'home made coded information', completely incomprehensible to foreign drivers.

This paper argues that the need for a permanent service to all Governments as a link in between the quite superficial Conventions, from the practical point of view, and the national legislative processes and Manuals is most urgent. However, this paper is not concerned with the question of left- or right-hand driving.

The necessity of a broad and fast international cooperation to meet actual, and most of all future demands on technical harmonization partly as a result of new technologies, like IVHS, is discussed.

Finally, this paper puts the focus on the need for nations to be free to form their own future; possible ways to raise financial resources and how to administrate the work and how to motivate Governments to take active part.
TRAFFIC SAFETY ON TWO CONTINENTS

THE FUTURE OF ROAD TRAFFIC MANAGEMENT:
URGENT GLOBAL HARMONIZATION WILL AFFECT ALL GOVERNMENTS

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"We can no longer accept the fact that Traffic Control Devices, identical in shape, color and size, have opposing meanings in neighboring nations"

From a Traffic Police Report after a road accident with a foreign driver and two other persons killed.

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1. INTRODUCTION

In a global sense most national practices, legal and technical, in the field of Road Traffic Regulations, are related to the UN Conventions On Road Traffic. In the process of preparing, or revising, Conventions of this nature, it is obvious to all the professionals involved that the only possibility to reach a reasonable level of agreement, as to the final shape of the documents, is to make them quite wide in their significance. In addition, the judgement of the Conventions on the national levels are sometimes misinterpreted as a consequence of poor or none existing information on the objectives in view during the preparatory work in the UN.

In turn, this has resulted in remarkable and scarcely noticed differences in applications, also in between nations who ratified the Conventions. Several basic functions of international Road Transportation, in a most general sense, are suffering from the lack of a reasonable harmonization. Road capacity and the general level of service and convenience of drivers (it seems as road navigation plays a major role here); safety and the costs of operation suffer from the lack of a reasonable harmonization. Training/information to professionals but most of all, a service aiming to support Governments could make things a lot better.

For instance, Traffic Control Devices, quite different in shape or color, have the same meaning in neighboring nations. In other cases symbols, or even complete traffic signs, identical in shape and color, have different or contradictory meanings or are used in different ways in different nations or continents. Also, some nations use 'home made coded information'. This is completely incomprehensible to foreign drivers.

This paper argues that the need for a service to all Governments as a link in between the quite superficial Conventions and the national legislative process is most urgent. Also, this paper underlines the need to combine this service with the aims of related high tech industry (IVHS), practical Traffic Engineering and the developments and experiences from the road.

The necessity of a broad international cooperation to meet actual, and most of all future demands on technical and human factors related harmonization, partly as a result of advancing new technologies, like IVHS, is discussed.

Finally, this paper puts the focus on the need for nations to be free to form their own future - however Governments need a lot of information to avoid the risk of violating practices elsewhere. Also possible ways to raise a needed financial resource, how to administrate this most urgent service and how to motivate concerned Governments and Road Administrations to take active part is discussed.

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2. BACKGROUND AND PROBLEM

2.1 General

International trade was 1990 estimated to increase by almost 5% each year during this decade. The international tourist industry was expected to grow even faster - it is judged to increase by some 7.5% annually until the year 2000. No doubt, road transportation will record an unbeatable share of the total increase of the volumes in global transportation - in particular this will be the case in regions with a fast developing infrastructure.

This in turn will put the situation of the individual drivers in focus as driving in foreign countries, whatever the reason might be, most likely will undergo a rapid growth as well. Globally, enhanced living standard in combination with local multiple car ownership, growing trade and needs for more transportation, will put new and big groups of individuals in the driving seat. In combination with well known results in the accident rates and influence by road transportation on the environment, this will underline the needs of better national management and a deeper international coordination.

A growing international exchange in road transportation will not be the concern of drivers only, in the sense of problems in a particular driving situation. It most certainly will be the concern also of all Governments. The problem here seems to be that the majority of Governments, maybe almost all of them, not yet have recognized the new character of this business: they will more or less be forced to give up some legislative and practical positions - once introduced as national standard - to facilitate driving in foreign countries.

Also, and in the name of the dislike of future mistakes, Governments will have to realize the need, whatsoever, of international consultations before forming new national standards in this field. If this will not be the case, a reasonable conclusion will be that individual national peculiarities are regarded as a most important goal in itself - also if this will be to the disadvantage to the General Public.

2.2 The Main Problem

Governments and national Police and Road Administrations all over the world are continuously confronted by problems related to the level of efficiency in the road transportation sector with reference to capacity, quality, safety, finance etc. To meet urgent problems as far as road traffic is concerned, interference of some kind often is carried out in a fast manner and without a proper coordination with other nations.
The actions probably give the wanted results on the national level and the administrators and the General Public find themselves happy with it - few people ask for the situations to follow. As to international harmonization of traffic regulations, this seems to be a main problem to the global society as a whole.

The general motive behind that statement is simply the fact that professionals in this field have poor or no knowledge-experience-understanding of what people in other nations believe is the best solution. Simply, administrators normally act from a strict national view and seldom ask themselves what will be the best in the long run, also with reference to national interests.

There are, however, some exemptions. In some regions of the world nations form biddies to make agreements aiming to harmonize the national practices on a bilateral but limited base. This kind of cooperation is not necessarily to the benefit in a global perspective: the more groups of nations find internal ways of harmonization, the harder it will be in the next round to harmonize these groups of nations, especially if there is no well functioning link in between. Furthermore, the time factors as well as information to others on the actions are neglected.

The future problems for the car, bus and truck industry on one side and on the other side the Ministries and Road Administrations of the world, are closely related and will include political, administrative, technical and financial demands of quite a new dimension. In the age of IVHS, one of the basics terms will be a total and quite immediate correspondence between messages given by systems carried by the vehicles and the traditional ways of informing drivers, i.e. by traffic signs and other traditional devices of similar nature.

As to IVHS only, there is accordingly a very clear connection between a most sophisticated high tech, national legislation, traffic engineering and human factors that will affect all Governments. Unfortunately, Governments suddenly, and without time for preparations will find themselves in confrontation with a situation with a built in demand for fast actions. This will be troublesome, probably expensive and most certain to the disadvantage to safety as the General Public always is in need of time for adjustments of this type.

To make the listing of problems more complete, the missing link is to be discussed: there is no responsible body on the international level acting to prepare the nations of the world: adequate information on the actual global situation and the expected consequences is missing.
2.3 Two main systems or a third alternative as well?

The formal connections for all nations as to driving rules, traffic control devices etc run through the UN Conventions on Road Traffic. However, this tool is obviously much too weak to meet present and future demands off a reasonable international harmonization in this field. In addition, the Conventions, and related documents, are indeed not functioning, or meant to serve, as icebreakers for national legislation or use in the daily practice - they most of all have a role of explaining, in general terms, what once was agreed and by this reason the rest simply is omitted in the documents.

Mainly as a result of the shape of the world map and different political, financial and industrial development in the world, two main 'systems' - some people call it philosophies - as to traffic regulations are to be found: The so called American and the European Code.

Africa and the main part of Asia adopted the European system; Australia and some parts of South East Asia in general adopted the American system. In some regions, like South America and South East Asia, a mix in between the two systems took place.

Unfortunately, in some nations both systems are practiced in a strange and 'impossible' mix; in others individual systems not known by others are practiced. These groups of nations might be refereed to as 'nations of the third alternative'. There are few nations without some influence by this 'third alternative'. The tendency to allow this alternative to grow is clear. No organized action to minimize this development is known so far.

It is reasonable to assume that Asia and East Europe for years to come will be the most intense regions as to the expansion of the Road Transport sector. The US and West Europe hopefully will not face an other expansion like what happened in the past 50 years.

2.2 National practices

The national practices, as to legal instruments and Manuals related to Traffic Engineering and Regulations, have reached a far from desirable level of harmonization also on the very same continent. Very few people, if anybody, have a pleasing knowledge of the actual situation in terms of heterogeneous or even conflicting interpretations at the national levels, with reference to the UN Conventions and their intended meaning.
In pace with increasing prosperity and infrastructure, the national needs of legislative and technical tools will grow in terms of more or less sophisticated lawmakers and Traffic Engineering practices - often put into force without reference to research, experiences, practices and agreements made by other nations.

Also, it should be noted that until now the incongruities seems to expand as information activities on the matter are week or none existing. This is serious indeed as a late, and in the long run and evidently inescapable correction is generally disturbing, expensive, time consuming and temporarily probably to the disadvantage to safety and general convenience.

2.3 Most of existing differences are unknown

To illustrate the needs of international harmonization, it is favorable to pick examples of differences from the national 'families' of traffic signs as people in general think they now the meaning of signs. Differences in rules and other, sometimes complicated, subjects need a lot of space and time to be explained.

When looking at the listing below, the reader is asked to think on a stressing situation to the driver: rain, night, heavy and fast traffic mixed with pedestrians dressed in dark, slippery and curved unknown road in a country with a most strange language, hungry back seat drivers arguing on the best way to the hotel (they have lost the road map), rented car with a strange gear box, worn wipers and close to a run out of gasoline.

Signs can differ in a lot of ways. Only some uncomplicated categories are listed:

1. Signs, or symbols, look exactly, or almost the same as back home but mean different things.

2. Signs, or symbols, look quite different but mean the same thing as well known signs back home.

4. The color of directional signs are related to different meanings in almost all nations.

2.4 Regional exemptions

In some regions of the world nations get together to try o form agreements on a harmonized practice. One such cooperation is found in West Europe: the (permanent) European Conference of Ministers of Transport, ECMT. The result of the work carried out, in terms of harmonization between the member states, unfortunately is not enough for non West European nations who adopted the European Code.

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The reason is the fact that the member nations of the ECMT have not yet been prepared to create a well harmonized situation.

At the moment the process of harmonization also is a concern for the Commission of the European Community: Not long ago the Council asked for a Report covering the subject, to be finalized before the end of 1991.

The subject was proposed, among other things, in a Report to the Commission by a High Level Expert Group for a European Policy for Road Safety in February 1991.

Also the International Road Federation, Geneva Office, has engaged itself in a harmonizing process aiming to find European Standards. This work is at the moment directed most of all to meet the needs of the concerned industry of traditional traffic control devices.

The European Committee for Standardization, CEN, has set up a Technical Committee to deal with standards related to Road Equipment. (Please, see the main program for this TRB-VTI Conference: Workshop on International Harmonization, pm September 19)

In the US, the Secretary of Transportation last year reported to the Senate and the House of Representatives (DOT-P-37-90-1) on the needs etc in the field of IVHS.

As a comment to this it could be stated that there is a critical need for common message format as well as common communications as high tech systems become available. Without a uniform link between the road and the vehicle across national boundaries, system effectiveness will suffer. Coordination between all nations is absolutely imperative for the development of a useable system of integrated communications as technology advances.

Nations of East Europe have asked for assistance and advise in the up grading preparations for their Road Transport Systems. The assistance available represents the individual West European national practices.

Also, in Asia, a few individual nations and the Gulf Cooperation Council, GCC, and the Road Engineering Association of Asia and Australasia, REAA, have shown interest in this subject. However, also these parties have some problems in the search for the proper sources in Europe. No European body is ready to give the answers needed.
3. POSSIBLE SOLUTION AND THE CLASSIC DILEMMA

To meet the basic needs of information to Governments and others, it has been proposed that a service is set up to inform on the legal and technical content of important international agreements in this field. At least such a service could make sure that no Administration is making decisions in conflict with the basic opinions of other nations, without the possibility of knowing it.

The desirable level of service hopefully will end up in plans for agreements also on the technical practices — this will make Governments realize the need of giving up some of the national traditions in favor of new and quite identical international solutions. Such a process is extremely hard to manage as long as the general knowledge in the subject is poor. Information and discussions on possible solutions, timing, costs etc. are necessary means to start the process of understanding.

The dilemma is quite clear: all nations must be free to form their own future, what so ever. At the same time there is, no doubt, a duty for those professionals who realize the situation, to make sure the national decision makers have all relevant information to carry out their task without unnecessary false steps.

It is estimated that at least one important national decision as to Road Traffic Regulations is made every day world wide. No one could possibly expect these decisions to be in line with opinions of others on the same issue, as there is no active coordination.

4. LORT

To meet the needs of harmonization it has been proposed to the UN that a service will be formed. The project name for the proposed actions is LORT — LIAISON OFFICE FOR ROAD TRAFFIC. LORT is supposed to be financed by fees in due time and by contributions from Governments and Industry in terms of staffing. The work of LORT is expected to serve as a technical correlative to the duties of the UN and in close cooperation with other international bodies concerned. This is most important to make sure there will be clear limits for the responsibilities.

Except for additional Manuals with reference to the Conventions, information, training and proposals for international harmonization will be the main missions of LORT.
5. RECOMMENDATIONS

As all nations are in urgent need of a service to support the global harmonization in the field of Road Traffic Regulations all bodies concerned are recommended to support the set up of LORT. This could be done through contributions as to the staffing or by other means. Taking part in the staffing will give a good possibility to report to the home base.

In case of interest, please get in touch with the Swedish Ministry of Communications, Stockholm, or with the author of this paper.
Implications of Litigation for Safety Research

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1. INTRODUCTION

This paper presents and briefly examines a sample of issues or questions frequently raised in safety litigation that have important implications for improvements to existing data and information bases. The same considerations that call for improvements to the information bases also point to significant limitations in their legitimate application and utility -- at least until those improvements are made. Because motor vehicle accidents are so pervasive, research to realize such improvements to information bases having to do with road user safety has particularly high benefit potential.

In the United States, accidents are often followed by litigation to settle disputes over responsibility and compensation for damages incurred. When there is disagreement over the facts, causes, and equitable consequences, an injured person may bring suit against those whom he holds responsible for the accident to obtain compensation. However, the determination of accident causation can involve highly complex and esoteric subject areas. Therefore, in order to resolve the matter, a court may allow or require the advice of consultants and experts; and, in response, attorneys on both sides of a dispute may turn to one or more of a wide variety of specialists to evaluate the facts and to give opinions regarding causes, consequences, and possible preventatives of the accident.

But even such professionals often find that the data or other informational bases for answers to questions arising from litigation are nonexistent or are deficient in some important respect. Discovery and identification of these voids or deficiencies is potentially beneficial, because it can help define research, the products of which can be applied to attain higher levels of safety for the general public.

However, for a variety of reasons, the discovery and identification of voids or deficiencies in the knowledge or data bases may be difficult and may also be associated with significant delays. As a consequence, for the period of delay, there is a significant risk that the cause of safety will not be served -- or worse, will be misdirected.

One specific, unfortunate result of being unaware of (or ignoring) such "knowledge vacuums" or inadequacies is the use of data or information to reach conclusions which may not be appropriate to or valid for the situations to which they are applied. When this happens in the context of litigation, serious injustices to one of the litigants may be caused. Nevertheless, the unhappy fact is that instances of such misuse or misapplication are not rare.
The twofold purpose of this presentation is:

a. To call attention to some properties of, and insufficiencies in, existing data or information bases which limit the conclusions that they can legitimately support, and

b. To suggest some remedies, directed at both the information bases, themselves, and their application in litigation.

Examples chosen to illustrate some key problems will include: (a) exposure indices, (b) data base limitations, (c) "surrogacy issues," and (d) "consensual standards."

As a final introductory note: much, if not all, of this paper's substantial content is known to many safety professionals. Nevertheless, because of the importance of the problems addressed here, as well as the frequency with which such problems appear in the courtroom, there is a need to identify them and to suggest some ways to solve or alleviate them. It is hoped that this paper will be a step in that direction.

2. ORIENTATION

No one should disagree that the number and seriousness of injuries are both the essential and the primary criteria of efforts related to safety. In short, they are the "Bottom Line." Indeed, this presentation might be sub-titled: "The Bottom Line Revisited," because each of the principal topics covered, although of central importance to the advancement of safety, is related either to improving:

a. The quality of existing "bottom line" or "bottom-line-related measures," or

b. Our understanding that some data and information which are often thought to be, or are represented as, "bottom-line" or its equivalent, actually are not -- and, accordingly, must be used with great care.

3. EXPOSURE INDICES

One of the most important informational products of safety analysis is an index of risk. Basically, a risk index provides information on the likelihood and seriousness of injury from a particular source. However, the utility of a risk index
is increased if additional information is provided, including some specification of the injury, user, product, usage, and environmental conditions.

Although "raw" accident and injury numbers are important in and of themselves, a risk index brings additional information to safety analyses because it is expressed as a rate -- in which the denominator is exposure. This properly allows, for example, the comparison of the likelihood of being injured while using one product as opposed to another; or if a vehicle operator is 18 years old as opposed to 35; or if the road is wet as opposed to dry; or if the vehicle operator has a BAC of 0.25 as opposed to 0.05; etc. Raw numbers are not sufficient to make such comparative assessments because they lack the normalizing adjustment of exposure, which enables such comparisons to be made fairly.

Thus, in the first example above, a fair comparison of injury rates in different products can be made only to the extent that we can approximate the magnitude and nature of the exposure to each of the products being compared. A first step in this process is to determine how many such products are in use; a second step might be to find out how frequently each product is used; a third could be the duration of each use; and so on. The goal is, of course to be able to compare "apples to apples."

It is also important to realize that, as successive adjustments are made to arrive at an exposure index, the risk picture can change dramatically. A simple example can serve to illustrate this. If 200 fatal accidents in one year are associated with car "A" and only 100 with car "B", a naive person might assume that car "A" is more dangerous. But if it is found that 300,000 "A" cars were in use during that year, and only 100,000 "B" cars, that picture would have to reverse. However, to go a step further, if it is then determined that "A" cars are driven an average of 1,000 miles per month and "B" cars 2,000 miles per month, the picture would reverse again. In this simple example, the above process should be reiterated until all the significant "non-car-connected influencers" of fatal accident occurrence have been accounted for.

The key point of the foregoing is that the fairness and accuracy of evaluations or comparisons of risk levels of products depends on the extent to which exposure adjustments are properly selected and applied.

The unfortunate reality is that sound exposure numbers have been lacking in many safety-related areas. In particular, their absence has been the stimulus for much heated debate and valid criticism in important issues involving both on-road vehicles (e.g., motorcycles) and off-road vehicles (e.g., all-terrain vehicles).
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Obvious initial steps to remedy this problem include reviews by safety agencies to determine and place in priority order the various kinds of exposure data needed to support policy and other safety-related determinations and decisions required of them. This work could benefit from participation by qualified, interested organizations and individuals in the public and private sector. An important next step would be the allocation of sufficient resources to allow useful and valid exposure indices to be generated. A complementary, constructive move would be to publicize that undertaking and also to discourage evaluative pronouncements about the safety of a product (or a product sub-set) prior to the acquisition of valid exposure data on that product.

It is gratifying to note that, relatively recently, some important progress appears to have been made in obtaining improved exposure indices for all-terrain vehicles. Furthermore, the presence of the updated and improved exposure data, not surprisingly, has been associated with significant changes in the federal regulatory plan connected with these vehicles.

4. DATA- AND INFORMATION-BASE LIMITATIONS

Everyone knows that no database or information base is perfect. But it is not clear that everyone is aware of the nature and size of the problems in some existing data- and information bases.

The standard of excellence in the United States for large-scale, highway accident investigation and data gathering was most probably set initially by the National Highway Traffic Safety Administration (NHTSA), beginning with its "Tri-Level Accident Investigation Study" (Treat, Tumbas, McDonald, Shinar, Hume, Mayer, Stansifer, and Castellan, 1979). The top level of that study involved the work products of a Multi-Disciplinary Accident Investigation (MDAI) team of highly trained specialists in a number of different areas, including accident reconstruction, as well as the engineering, physical, medical, and behavioral sciences. Under NHTSA's guidance and support, accident investigation and data collection and analysis has evolved to activities that support such important data and information bases as the Fatal Accident Reporting System (FARS) and the National Accident Sampling System (NASS), as well as the activities in NHTSA which seek to determine -- by engineering analyses, supplemented, when needed by other specialty areas -- whether certain vehicles, their systems, or their components can be judged defective from a safety standpoint.

But other data and information stores give the appearance, at least to some, of completely credible accident data sources. To provide some perspective on the problem, a hierarchy of database information sources can be examined.
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Starting at the top and descending by arbitrarily defined levels of expected comprehensiveness and accuracy, information generated by a:

MDAI team, or substantial equivalent

Trained team of police accident investigation specialists

Single, trained police accident investigation specialist

Single police officer, some training or experience in accident investigation

Single police officer, little training or experience in accident investigation

Lay person, disinterested party, uninvolved witness

Lay person, disinterested party, involved witness

Lay person, interested party, involved witness

Medical service provider or associated person, non-witness, who provides his/her own version of the description given by one (rarely more) of the 3 lowest levels above this one.

It is sad to note the frequency with which "evidence" is presented in courtrooms that comes from database information gathered from the lowest two levels of the above list. Such data bases as the CPSC's National Electronic Injury Surveillance System (NEISS) data base and the NHTSA "Complaint File" contain information of this kind.

To the credit of the CPSC and NHTSA, however, these agencies ordinarily convey some caveats about the sources and the nature of these data so that a user may be sensitized to the limitations of such information.

The CPSC provides a description of the NEISS data base in a booklet (U. S. Consumer Product Safety Commission, 1990); and attaches written cautions concerning the use of data from this system to printouts or reports that are issued in response to user requests. This attachment reads:
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cautions

NEISS data and estimates are based on injuries treated in hospital emergency rooms that patients say are related to products. Therefore it is incorrect, when using NEISS data, to say the injuries were caused by the product.

Another caution that has been advised by CPSC to users of NEISS is that estimates of numbers of injuries associated with a product over a given period may change for that period because of updates. For example, NEISS estimates for 1990 exceeded those of previous years by 18 percent because of an updated sample of the number and the caseloads of hospital emergency rooms in the United States. CPSC points out that trend analysis of NEISS data therefore must take continual updating into account. It may be added that when a researcher or an expert witness cites a NEISS estimate, he should specify the date the estimate was reported.

CPSC also has provided users of NEISS with specific information on such matters as sampling, sources of sampling errors, estimation characteristics, relative sampling errors, and even a few elementary instructions regarding the use of a table of generalized sampling errors for NEISS data.

NHTSA's Office of Defects Investigation has a data base of complaints reported to them through their "Auto Safety Hot Line." NHTSA staff cautions users of this information to be aware that those complaints have not been verified and that persons who report complaints regarding vehicular malfunctions, mishaps, or accidents may not be technically qualified to determine the cause of those incidents. As a consequence, an incident may be erroneously reported as attributable to a particular vehicle system or component when, in fact, it was caused by a different system or component. In some cases, reported malfunctions and accidents which were described in the complaint as vehicle-caused safety problems were found, after extensive, careful investigation by highly qualified professionals, to have been caused by operator error. Furthermore, duplication may occur because an incident may be reported by more than one person, thus spuriously inflating the count of reported problems.

The conclusion that must be drawn from the above is that, in such data bases, the presence of complaints alone does not necessarily demonstrate the existence of a safety problem with the product that is associated with those complaints. That determination must rest on the outcome of a properly-conducted investigation by qualified individuals. Thus, the unqualified recitation in the courtroom of unverified reports constitutes an improper use of that data and information.
The minimum remedy for this problem of limitations in data base information appears to be a requirement that the "parent" agencies provide details regarding the sources and nature of the information in their data bases, describe the limitations of their content, and list and warn against specific misuses of the data and information they contain. The CPSC caveats and descriptive material mentioned above are examples of initial steps in developing such a remedy.

5. "SURROGACY" ISSUES

Researchers face numerous problems generally, but safety researchers must deal with certain special additional problems. The foremost problem that usually confronts researchers relates to resources. Restrictions on the availability of money, materials, and manpower obviously constrain research in one or more important areas such as scope, complexity, precision, number of tests, number of measurements, and so on.

The safety researchers' additional problems stem from their primary focus, which is to reduce the probability (and seriousness) of an injury-producing accident. But it is generally considered unethical to expose test subjects (hereinafter "Subjects") to real hazards. Thus, except for those studies which only chronicle and analyze "real-world" accidents, the researcher is normally forced to introduce a "surrogate hazard" in experiments which aim to determine effective means of reducing the probability of unsafe behavior.

In so doing, the researcher, in effect, assumes that the substitution of the "surrogate hazard" will have substantially the same effect on the subject's motivation and behavior as the real hazard. But, absent some demonstration of equivalence, the soundness of that assumption is questionable. Therefore, The introduction of a surrogate hazard in a study may raise understandable concern over the validity of the results, especially over the legitimacy of generalizing to real-world issues in litigation.

The preceding paragraph exemplifies the concept of surrogacy as it is used in this paper, where generally it refers to the substitution of an artificial condition or characteristic for its real-world counterpart in an experiment. But the more important problems of surrogacy are not so simple as described in the above example. Unfortunately, there are more surrogacy problems than just substituting for the hazard.

The validity of the results of research can be adversely affected by two dimensions of surrogacy. The first is the extent to which some relevant aspect of the surrogate (research) situation differs from the real-world situation. The term
"relevant aspect" is used here to mean a characteristic that would be expected to influence the equivalence of the research results and what happens in the real world. For example, for most studies of driver performance, hair color of the subjects is probably not a relevant aspect; on the other hand, for many studies, age of the subject probably is.

The second dimension is the number of relevant aspects in which the research situation differs from that of the real world. Obviously, the greater the number of those differences, the less likely it will be that the results of the study will accurately agree with or predict what happens in the real world. Each of these two dimensions of surrogacy merits attention because each has the potential to compromise the projected validity and the generalizability of the results of a study. Although precise quantification is not warranted at this point, it is nevertheless useful to use a term like "high-surrogacy level" to describe a study which has a large number of relevant aspects which differ significantly from the real-world situation to which it is applied.

Vivid instances of surrogacy problems occur in the area of warnings research. To give a simplified example, assume that, in the real world, a specific type of vehicle, when operated in a certain way, was likely to have a particular type of injury-producing accident. Suppose some researchers at a university wanted to investigate and determine the effectiveness of on-vehicle warnings in preventing those dangerous operations. To do this, they used their students as test subjects; showed the subjects slides or videotapes of the vehicle in operation; showed them slides of several different of on-vehicle warnings, each of which was aimed to deter the vehicle driver from operating the vehicle in the way that caused the accidents; and then asked the subjects to rate each of the warnings by filling in a form they were given before seeing the slides. The ratings would be in terms of the subjects' estimates of the probability that: (a) operators of that vehicle would heed the warning, and (b) the subjects, themselves, would heed the warning.

There are a number of differences between the research study and the real-world situation, each of which has the potential to reduce the projected validity of the study. These include:

1. The term "validity," as used in this paper, means the closeness with which the findings of a research study agree with or predict what actually happens in the real world.

2. The example in this paragraph is fictitious but accurately characterizes subject selection, as well as procedural and environmental aspects of a number of warnings research studies.
The physical/social setting: Typically, an environmentally controlled, relatively static classroom or auditorium, with a number of other persons present -- including some with more senior academic status, possibly also having authority to grade the [subject’s] academic performance in the classroom or laboratory versus actual operation of the vehicle, usually alone [but, if not, frequently with others operating similar vehicles], dynamically traversing a particular outdoor environment, having the possibility of many different topographical and meteorological characteristics and variations.

The persons involved, Product-related: Research subjects’ interest in, and enjoyment of operating the vehicle, knowledge about and experience in operating the vehicle, knowledge about and experience in operating similar products; self-perceived skill or competency level in operating the product; etc. versus the corresponding characteristics of those who actually would be operating that type of vehicle.

The persons involved, Non-product related: Research subjects’ age, education, peer groups, risk-taking propensities, personality characteristics, physical characteristics and capabilities, etc. versus the corresponding characteristics of those who actually would be operating that type of vehicle in the real world, as well as the same characteristics of other vehicle operators and others at the site with whom the vehicle operator might interact.

Initial focus of attention: On whether the subject believes he or others would comply with the warning [at some unspecified time and place, and under some unspecified circumstances and conditions] versus on operating and controlling the vehicle in a particular environment.

The required behavior: Imagining operating the vehicle, imagining what his [the subject’s] or others’ response would be, and then filling in a form accordingly versus actually operating the vehicle and actually making, or not making, a response which avoids the type of accident being considered.

Memory factors: Remembering a warning immediately after reading it versus remembering a warning read some time previously.

Reaction time "window": Wide -- not time-stressed [to fill in form] versus possibly narrow -- possibly time stressed [e.g., recognizing and avoiding an impending dangerous operational situation] -- assuming the warning is recalled or kept in mind.
Other factors influencing response: Imagining the consequences of encountering the hazard, being observed by others, giving the perceived "correct" response, giving an "acceptable" response, the presence of the teacher, other students, other social influences, etc. versus some combination of: operating the vehicle so as to go from point "A" to point "B" with dispatch, comfort, and safety; operating the vehicle so as to provide excitement and/or pleasure; operating the vehicle so as to avoid an injury producing event.

The time frame: Response now versus response in the future.

Durability of response: This time versus every time.

As voluminous as it appears to be, the foregoing example is nevertheless highly simplified and incomplete. Its primary purpose is to illustrate, albeit only partially, that there is a surprisingly large number of ways -- that can adversely affect the validity of research results -- in which an experimental situation can be different from the real world.

Secondly, the example given is not to represent or imply that all warnings research is burdened by this number of possible, validity-compromising differences between the test subjects and circumstances and their real-world counterparts. It does, however, present a realistic picture of the problems with much of the "research evidence" that is offered in courtrooms to support the contention that, had a warning been given, an injured party's behavior would have changed so as to avoid the accident in which he or she was involved.

To recapitulate, critical problems are created in certain research areas, where various pressures on researchers -- principally from resource constraints -- interact to force the use of surrogates. Prime examples occur with research addressed to identify factors influencing the effectiveness of on-product warnings in eliciting warning-compliant behavior. The fundamental problem is not with the research studies, but with the unwarranted inferences drawn from them.

Thus, in litigation, an "expert witness" may be asked to give an opinion on why an accident occurred. In situations where the behavior of the injured party clearly contributed to the cause of the accident, the "expert" may contend that the manufacturer failed to provide an adequate warning; and that, if only an effective warning had been provided, the accident would have been avoided. When asked to state in what way the warning was inadequate, the "expert" may assert that the "signal word," the content, the size, the location, the conspicuity, or some combination of the foregoing was absent or deficient. When asked to provide the basis for that opinion, the "expert" might cite one or more studies, each of which
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had a high-surrogacy level, in the context of the facts and circumstances of the case being litigated.

Hence, for issues involving volitional human behavior -- such as exemplified by compliance with on-product warnings -- it must be concluded that no significant weight can be given legitimately to assertions that high-surrogacy-level studies accurately predict what would happen in the real world -- except when that predictive capability actually can be demonstrated in the real world -- for that particular warning, and for members of the "target" population.

Given the potential injustices and inequities that could easily be caused in litigation -- as well as misjudgments in the formulation of safety standards -- by the acceptance of assertions based on studies with high-surrogacy levels, what can be done to reduce the frequency with which such information is submitted, as well as the likelihood that it is accepted by a lay audience?

A constructive first step would be for the authors of such research to provide reasonably precise information on the characteristics of the sample of subjects, as well as on the applicable areas where important differences could exist between the experimental study conditions and the real world -- such as those briefly noted earlier in this paper (beginning with "The physical/social setting"). This would enable, or at least help, others to judge the extent to which the studies results were applicable to a particular case being considered in litigation, as well as to standards development or revision.

An extension of this step would be to create a committee or other body within a professional society to explore and define, more precisely than in this presentation, the most relevant aspects of research design, subject selection, methodology, conditions, and other relevant considerations that affect generalizability, i.e., those that would be expected to cause differences between the study results and those of the real world. The membership of such a group would be those principally involved in conducting, reviewing, or analyzing research or applying its data and other results. The product of this initial phase would be the creation and issuance of "guidelines" or a "recommended practice" for such descriptive information to be included in scientific papers and articles reporting research conducted, where one of the purposes of the research is to influence volitional behavior.

A complementary, constructive activity would be for attorneys, as a matter of course in pre-trial depositions, to try to obtain more specific, detailed, and precise descriptions of each of any alleged deficiencies from those who assert that deficiencies existed. Thus, if the contention is that "an adequate 'X' was not provided, and that the deficiency caused the accident," then it would be reasonable, proper, and useful to request that the opinion-giver provide some
specific details which precisely described what, in his or her opinion, was inadequate; and, more important, what would constitute an adequate 'X'. Further, once that description had been obtained, it would be helpful that attorneys request the complete basis for the opinion that what was described as adequate would indeed be effective in averting the accident.

6. "CONSENSUAL STANDARDS"

In the United States, as in other countries, regulatory organizations at the federal, state, and local government level are empowered by law to create and enforce standards. Similarly, technical and professional organizations may also create standards and, sometimes, enforce them (but usually in different ways from those of the government).

Definitions of the word "standard" include "a level or degree of excellence considered as a goal or as adequate;" and "a rule, test, or requirement." As a consequence, it is not unreasonable to expect that the average person, upon being informed that a product does not conform to a standard which purportedly or nominally is addressed to improving safety, will View that product as being deficient and unsafe -- at least to some degree. (Obviously, and almost everywhere, products which do not conform to certain safety standards are in violation of the law.)

Further, if that product was involved in an injury-producing accident, and if it is argued convincingly that the subject matter of the standard is related to the probability of that accident occurring, then it is also not unreasonable to expect that a normal, average person might easily conclude that the failure to conform to the standard was a substantial causal contributor to the accident, and therefore that the product's manufacturer was negligent because of that failure.

This might not be a significant problem if in fact conformance with a safety standard were always related to the probability of an accident occurring. Unfortunately, however, some "standards" have not been demonstrated to have the aforementioned relationship to accidents. The most noteworthy of this latter group are "consensual standards." Although most standards require a consensus of the issuing body, the term "consensual standards," as used here, refers to those that are established by some level of agreement within a committee or other group, but that are not clearly supported by real-world, bottom-line data.

Standards directed to maintain or improve safety may be created or evolve in a number of ways. Almost always, such standards are formulated or refined by individuals, most of whom are highly interested and experienced in the theoretical and/or practical subject matter of the standard. As noted above, most issued
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standards also require a consensus of the group responsible for their creation or revision. Irrespective of the foregoing, neither a unanimous agreement by the standards-setting group, nor the most elegant theoretical reasoning, nor the most dramatic cases, nor the strongest conviction, nor the most compelling intuition -- even taken all together -- are sufficient to assure that conformance to a standard based on those conditions alone will provide some overall improved level of safety, or that failure to conform to such a standard will result in an overall decrease in safety.

The sine qua non for such assurance is provided by sufficient, valid data from rigorous, real-world studies. Absent such data, to promulgate or to continue a standard not only may be ineffective but may also be counterproductive to the interests of safety. Reliance solely on the votes of a majority, if untested, can simply reinforce and perpetuate erroneous assumptions. The rationale to adopt a consensual standard may seem plausible but may also be wrong -- as has been shown on a number of occasions.

Two noteworthy examples of topics that appear frequently in products liability litigation in the United States and that involve consensual standards are warnings and vehicle-operator education/training. These two topics have a striking and surprising thread of commonality: in each case, there is a common-sense litany regarding the efficacy of certain remedial steps -- including adherence to consensual standards -- yet in each case there have been well-designed and well-controlled research projects that have yielded counter-intuitive results.

Warnings. It is frequently asserted that warnings -- preceded by a "signal word," such as "danger" or "caution," and specifying the behavior to be avoided or used; properly worded, lettered, and colored; and including information on the consequences of noncompliance -- will induce persons to behave in a safe manner. Moreover, it appears true that, under certain circumstances, some warnings may change behavior in some persons (usually, where behavioral change is of relatively little "cost" to the viewer of the warning), at least for a relatively short period of time.

One such effect was seen after placing a sign above and behind a water fountain warning that its water was contaminated (Godfrey, Rothstein, and Laughery, 1985). The water fountain study tested two different warnings: an "unenhanced warning," and an "enhanced warning," and for each part of this study, observational data was collected for a 30-minute period. Based on their analysis of the data, the authors state that, unlike the unenhanced warning, the "enhanced warning caused a significant change in behavior."
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It may be noted that, in the study above, the behavior measured was that of persons who saw the sign (which implied significant negative consequences if they drank the water) under conditions where they had no basis or way to assess its credibility before making their decision. It is also noteworthy that, even with the enhanced warnings in place, and even with the threatening implications of their message, fully 1/3 of those who approached the fountain did drink from it.

The other side of this issue appears weightier. For example, a 1984 review of hundreds of studies constituting "all the literature published in English related to consumer product warning label effectiveness" led the authors to conclude that, "incredibly, to date, there appears to be no solid evidence that on-product warnings have measurably improved the safety of any product. There is, however, evidence to indicate that on-product warnings do not improve product safety." (McCarthy, Krumm-Scott, and Finnegan, 1984).

Research at NHTSA and elsewhere has also demonstrated quite clearly that a wide variety of approaches -- most of which included a warning of some type -- to induce vehicle occupants to use safety-belts were generally ineffective (Fleischer, 1971, 1972; National Analysts, 1972; Robertson, 1972; Kirschner Associates, 1978; Opinion Research Corp., 1980). The foregoing should not be interpreted to mean that this behavior is inherently intractable. Data gathered in the United States, as well as other countries, demonstrates quite clearly that the passage and enforcement of laws which make safety-belt usage mandatory is highly effective in obtaining high usage rates -- sometimes in excess of 90%.

Vehicle-operator education/training. Also, it seems natural to assume -- and it is routinely alleged in litigation -- that education and training of vehicle operators will cause them to adhere to safe practices and will thereby help diminish accident rates. Yet, well-controlled, large-scale research projects, such as those which were conducted in the Safe Performance Curriculum Demonstration Project (DeKalb County, Georgia) and in the Motorcycle Rider Education Evaluation Project (New York), have failed to show that significant reductions in accidents were associated with taking education/training courses which were designed to be exemplary.

How does one account for these counter-intuitive findings? It may be discovered, for example, that such behavioral influencers as peer pressure, purposeful risk-taking, showing-off, alcohol, or hormones -- alone or in some combination -- so far outweigh the influence of driver education that, whatever its safety effects may be, they are not discernible under real-world conditions. Alternatively, it may be that the basic, rational, and intuitive formulation -- that a safety treatment will favorably modify behavior so as to produce a diminished probability of accidents -- is invalid. Of course, there are other possible alternatives. Irrespective of the
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Explanation, however, the bottom line remains unchanged. Thus, most contentions that a particular accident would have been averted if the injured party had been given a training course are currently without scientifically acceptable real-world support and, as such, are baseless assertions which cannot properly be given any weight.

What are implications of such dramatic, puzzling failures to confirm common-sense assumptions in the areas of warnings and vehicle-operator education/training? Obviously, the most important is to recognize that the common sense, plausibility, and consensus -- even of highly credentialed persons -- must yield to real-world findings. Thus, if something is called a safety standard, it is expected to improve safety; if it does not actually do that, then the best options appear to be either to not label it a standard, or to delay its promulgation until its effectiveness in the real world can be demonstrated.

However, when confronted with the challenge that no solid evidence exists which shows that a particular consensual safety standard will (or would be expected to) produce overall safety benefits, advocates of those standards frequently voice the opinion: "Well, it couldn't hurt." But that is most often an incorrect view because such usage is connected with at least three serious problems.

First, the costs of compliance with such standards are usually not trivial. If these costs -- which include time, money, manpower, and materials -- are not compensated or offset by overall safety benefits, they are wasted resources, particularly egregious at a time when resources are highly limited.

Second, the creation and implementation, by a governmental or professional organization, of something called a "safety standard" removes or diminishes the incentive and support to seek and develop solutions to safety problems in the area of the standard, because the standard gives the appearance of having already solved those problems.

Last, but not least, something called a "safety standard" has a high likelihood of being misinterpreted, misrepresented, and misused -- especially in litigation. As noted previously, the term "standard" has probably come to mean, in the eyes of most laypersons, a requirement which, if not met, equates to a product which is deficient. Thus, a product which does not conform to a safety-related "standard" will most probably be judged as unsafe -- even if there is no sound, reliable data which demonstrates a significant correlation between conformance to the standard and a reduction of the number of injuries associated with that product. Again, the consequences of grave injustices are possible.
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It is noteworthy that, during litigation, the validity of such standards is often subjected to severe tests because the role of the lawyers on both sides of a case is to advocate the interests of their clients; and they ordinarily do so with great determination and skill. An interesting and potentially beneficial "spin-off" of such advocacy is that it may place a consensual safety standard's underlying assumptions and data under closer scrutiny than may have been present in the normal course of formulating that standard. To the extent that such scrutiny forces re-examination and clarification of assumptions and data, litigation can have a positive influence on scientific research and standards.

Nevertheless, absent some tangibly compelling reason to bypass the requirement, the issuance of a "safety standard" or its equivalent should occur only after the relationship of the standard’s requirements to real-world safety have been verified.

In connection with improving safety, it is also important to consider using alternate terms instead of the word: "standard" -- terms which do not have the same powerful and compelling equivalent meaning to a "requirement" -- until a relationship between its proposed specifications and its safety goals has been established. The terms, "recommended practice," "tentative recommendations," "suggested guidelines," as well as the modifiers "interim" and preliminary," are possible candidates as precursors to "standards," to be used in cases where no solid, reliable connection to real-world safety has been established.

But neither unbiased scientific inquiry nor legal advocacy can be expected, in the near-term, to cause the creation or rectification of real-world data bases for all possible issues that arise in litigation. Indeed, there probably will always be questions and issues which cannot be answered or resolved on the basis of immediately available, satisfactory real-world studies. As a consequence, it must be expected that pressures to create consensual standards will exist for some time, regardless of their shortcomings. This, in turn, demands at least a high level of alertness to recognize and identify such standards, as well as their limitations and their potential for misrepresentation and other forms of misuse. The prospective rewards for such vigilance include the creation of counter-forces which should act to improve the focus of research, both in the laboratory and the real world, as well as the rapidity with which demonstrably more effective safety levels can be achieved.

7. SUMMARY

Because much litigation seeks to determine the factors involved -- and the contribution of each -- in causing an accident, as well as the factors which could have averted an accident, it must rely on technically and scientifically sound data and
other information which is applicable and properly interpreted and applied. But
the state of such data and information is not such that it always can fully satisfy
this quest. One of the benefits of litigation is that, in the search for this
information, it often illuminates specific problem areas where improvements in that
information will not only benefit the interests of just and equitable resolutions of
legal disputes, but the cause of safety as well.

The four major topics discussed in this paper -- exposure indices, data- and
information-base limitations, surrogacy issues, and consensual standards -- were
all identified because of their frequency of appearance in litigation. Further, they
are linked by a central theme: the need to improve the applicability and utility of
data and other information to the real world, so that safety benefits can be realized
more rapidly and economically.

It was observed that genuine problems and deficiencies exist in these areas, and
some of them were briefly characterized. It was noted that, in certain areas, some
progress is evident; in other areas, however, it is badly needed. Examples of
possible forward steps were described. These included:

Increasing awareness and utilization of adequate exposure indices in
connection with accident data;

Disclosure of existing data- and information-base limitations, and
development of improved data- and information-bases;

More detailed consideration and disclosure of "surrogacy" factors
influencing the applicability of research results to real-world situations and
events; and

Recognizing the serious problems associated with "consensual standards,"
and restricting usage of the term "standard," when applied to a set of
safety-related specifications, to instances where there is a demonstrable
relationship between conformance to those specifications and an
improvement in overall safety in the real world.
IMPLICATIONS OF LITIGATION FOR SAFETY RESEARCH
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8. REFERENCES


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Impact of Litigation on the Federal Highway Administration’s Highway Safety Program

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U S A
THE IMPACT OF LITIGATION
ON THE
FEDERAL HIGHWAY ADMINISTRATION'S HIGHWAY SAFETY PROGRAM

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The Federal Highway Administration, as you may know, is a component of the United States Department of Transportation. The Federal-aid highway program, which is the centerpiece of our mission, provides money to the fifty States to construct and improve the urban, rural, and national interstate highway systems. The Federal Highway Administration sponsors research on all aspects of highway construction, modernization, development, design, maintenance, and traffic conditions in the United States and disseminates the results to the highway public for use.\textsuperscript{1}

During the last fiscal year (October 1, 1989 through September 30, 1990), the Federal Highway Administration obligated 14.3 billion dollars. Of that 14.3 billion dollars, 5.8 million dollars were obligated for highway safety research and development.

In 1989 more than 220,000 civil lawsuits were filed in the federal and State courts of the United States. Fifty-five thousand of these suits named the Federal government as a party.\textsuperscript{2}

\textsuperscript{1} 23 U.S.C. § 307(a) authorizes the FHWA (through delegation from the Secretary of the U.S. Department of Transportation) "to engage in research in all phases of highway construction, modernization, development, design, maintenance, safety, financing, and traffic conditions, including the effect thereon of State laws and is authorized to test, develop, or assist in the testing and developing of any material, invention, article or process. The Federal Highway Administration ... may publish the results of such research."

\textsuperscript{2} 23 U.S.C. § 403(b) authorizes the FHWA to carry out safety research with other Government and private agencies on (1) the relationship between the consumption and use of drugs and their effect upon highway safety and drivers of motor vehicles; and (2) driver behavior research, including the characteristics of driver performance, the relationships of mental and physical abilities or disabilities to the driving task, and the relationship of frequency of driver accident involvement in highway safety.

The United States as we know or read is a litigious society. And while the Federal Highway Administration's (FHWA) highway safety research program has not been directly impacted, it has felt the effects of a nation that is not afraid to go to court.

The Federal Highway Administration's exposure to liability arising from performing and applying roadway safety research is limited. This is primarily due to two factors. First, the Federal Tort Claims Act shields the United States Federal Government from liability for injuries resulting from discretionary acts, otherwise known as policy decisions. Second, and perhaps more significantly, roughly 95% of the roads in the United States are not owned or controlled by the Federal government but are rather owned and controlled by the fifty States. Consequently, the threat of litigation is largely a concern of States, contractors, and other non-Federal entities.

However, even though the Federal Highway Administration's exposure to monetary tort liability is limited, the threat of litigation affects our programs and influences the way we do business. Sometimes these effects are small. For instance, when we issue a report prepared by a research contractor for use by state highway officials or others in the highway public, we

3 The primary purpose of the Federal Tort Claims Act, 28 U.S.C. § 1346, § 2671, was to make the United States accountable for its torts in the same manner as private persons. The Act's discretionary function exception shields the government from liability if the action arises from a government decision grounded in social, political, or economic policy.

4 Federal Highway Administration, "Highway Statistics 1989."
include a disclaimer of liability. The disclaimer typically states that the report reflects the views of the author and the United States Government assumes no liability for its contents. Including a disclaimer on a report is a routine precautionary measure. It does not delay or add cost to the study.

The threat of litigation has a much greater impact on our research projects. For example, in the 1980's, the Federal Highway Administration selected the University of Tennessee to perform a study on "Innovative Railroad-Highway Active Warning Devices." The University’s task was to evaluate three types of active warning devices at railroad-highway grade crossings. It purchased the necessary railroad signal equipment, modified some of it (e.g., addition of skirts to gate arms) and obtained insurance to protect itself and the railroad company, on whose right-of-way the tests were to be performed. Difficulties arose

5 A typical research report Notice provides:

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6 The devices being evaluated were: (1) a four-quadrant gate system with skirts, (2) a four quadrant flashing light signal system with strobe lights, and (3) a highway traffic signal installation with a white bar strobe in all red lenses.
when the equipment suppliers insisted the University obtain insurance to protect the manufacturers from potential product liability suits. After much discussion, the suppliers got what they wanted. The Federal Highway Administration agreed to pay for insurance to protect them. Because of the time spent to resolve these liability concerns, the testing was delayed about 2 years and more funds had to be added to the project.

Unfortunately, on occasion, the fear of unknown financial exposure has also made States, utilities, and other entities hesitant to participate in Federal Highway Administration-sponsored demonstration projects. During the 1980's, the Federal Highway Administration wanted to test the safety attributes of breakaway electric utility poles located adjacent to highways. Two States, Kentucky and Massachusetts, expressed an interest in installing these poles. Kentucky had no trouble persuading its utility companies to install the poles. The State of Massachusetts, on the other hand, encountered stiff resistance from its utility companies because of their increased sensitivity to tort liability. The result was that the cost of insurance was added to the project.7 Ironically, there have been no claims filed with the insurance company. Although there have been four accidents involving the breakaway utility poles, only one person has complained of injury.

An FHWA project that is getting considerable attention

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7The U.S. Government is a self-insurer of its own property and activities, and while it cannot generally purchase insurance to cover itself, it can pay for insurance for its contractors. Decision of the Comptroller General, 59 Comp. Gen. 370 (1980).
these days is one I know you have all heard of -- the Intelligent Vehicle Highway Systems (IVHS) research program. The development and application of IVHS technology poses serious liability concerns for the Federal Highway Administration, States, and manufacturers of the technology.

The Federal Highway Administration recently faced an issue involving human participation in testing IVHS technology. Predicting the scope of Federal Highway Administration's liability for injuries related to the use of IVHS technology is difficult. In an effort to manage the liability risks associated with the development of this new technology, we require test subjects to sign consent forms. These consent forms advise the person of the risks involved in using the IVHS technology but do not waive the Federal Highway Administrations's responsibility for any injuries suffered as a result of testing.

But the liability concerns associated with the application of IVHS technology extend far beyond using human test subjects. As explained in an article by Professor Kent Syverud of the University of Michigan Law School, the use of IVHS technology on America's highways may shift the allocation of accident costs from the driver to manufacturers and highway owners.

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8 The Intelligent Vehicle Highway Systems program is designed to make significant improvements in highway transportation mobility, safety, efficiency, and productivity using advanced communications, computer and control technologies.

9 The consent forms do not contain any statement releasing the FHWA from liability for personal injury, wrongful death or property damage claims, since such a waiver would probably not be legally binding.

10 Syverud, Kent, Society of Automotive Engineers Technical Paper
According to Professor Syverud, in most automobile accidents today, the injured party brings suit against another driver. Rarely is the vehicle manufacturer or highway owner sued, usually only when there is no other driver involved. Manufacturers and highway owners are not sued because it is easier to prove to a jury that the other driver was negligent than it is to show that the car or the road caused the accident.

The introduction of IVHS technology, however, opens all kinds of doors for would-be plaintiffs. A plaintiff may now have an easier time convincing the jury that the new technology is at fault (hence reaching the manufacturer's deep pockets) than proving the negligence of another driver. As Professor Syverud put it, this result is "perverse" when you consider that the reason for developing this technology is to improve safety. But tort law in the United States, liability for negligence as well as products liability law, may allow this ironic result. Federal or State legislation may be able to give special protection by limiting liability such as that provided earlier in this century by the Warsaw convention and subsequent protocols to the fledgling airline industry. Whether this is possible practically or politically remains to be seen. I commend Professor Syverud's Technical Paper for the Society of Automotive Engineers for its extensive analysis of this subject.

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